Environmental Science Institute
THE UNIVERSITY OF TEXAS AT AUSTIN

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CLIMATE CHANGE AFFECTS ECOSYSTEMS AND THE DISTRIBUTION OF ORGANISMS

Lesson plans for grades 4-8
From KQED: Public Media for Northern California, Education Network: Clue into Climate.
http://www.kqed.org/education/educators/clue-into-climate/ecosystems.jsp

SAMPLES OF POTENTIAL TEKS ADDRESSED THROUGH THESE LESSONS:

§112.15. Science, Grade 4, Beginning with 2010-2011: 2A, 2B, 2C, 2D, 2F, 3A, 3C, 3D, 4A, 7C, 9B, 10A
§112.16. Science, Grade 5, Beginning with 2010-2011: 2A, 2B, 2C, 2D, 2F, 2G, 3A, 3C, 3D, 4A, 7C, 8A, 9A, 9B, 9C
§112.18. Science, Grade 6, Beginning with 2010-2011: 2A, 2C, 2D, 2E, 3A, 3B, 3C, 3D, 4A, 12E, 12F
§112.19. Science, Grade 7, Beginning with 2010-2011: 2A, 2B, 2C, 2D, 2E, 3A, 3B, 3C, 3D, 4A, 10A, 10B, 11B
§112.20. Science, Grade 8, Beginning with 2010-2011: 2A, 2D, 2C, 2D, 2F, 3A, 3B, 3C, 3D, 4A, 11A, 11B, 11C

CONCEPTS:

When faced with ecosystem change, species must either adapt to the changes or move to more suitable habitats, or else they may face extinction. At the end of this unit, students will be able to describe how climate is currently changing and discuss examples of how these changes are altering life for both plants and animals. There are four lessons in this unit, and each one can also stand alone. Lesson descriptions are provided below, as well as links to the teacher and student workbooks (the PDF documents can also be found on our website as attachments to this lesson).

MATERIALS:

The following documents are included in this lesson as PDF files:

a) Clue Into Climate Student Workbook – for student engagement and reflection.
b) Educator Guide – contains the entire content strand so that it can be taught as a unit or as individual lessons.
c) Background Information.
d) Lesson A: The Changing Arctic Ecosystem – The effects of climate change on ecosystems and the distribution of organisms within them are already evident in the Arctic. In this lesson, students will learn about the challenges that climate change presents for four specific Arctic predators. They will explore how such changes ripple throughout ecosystems, habitats, and food webs. *Video on the Web: Jean-Michel Cousteau Ocean Adventures: A Warmer World for Arctic Animals*.
e) Lesson B: Adapting to Climate Change – Plants and animals are adapted to live in habitats with specific environmental conditions; these adaptations might be physiological or behavioral or both. Climate change can cause conditions in a given area to change. In this lesson, students will become familiar with some adaptations and learn that plants and animals must be able to adapt or move in order to survive significant environmental changes. *Video on the Web: Forecasting Suitable Habitat for Redwoods from the Present to 2100.*
f) Lesson C: Animals on the Move – Species distribution is closely correlated with climate. Over the past 100 years, the natural ranges of many animals have shifted higher in elevation or northward to areas

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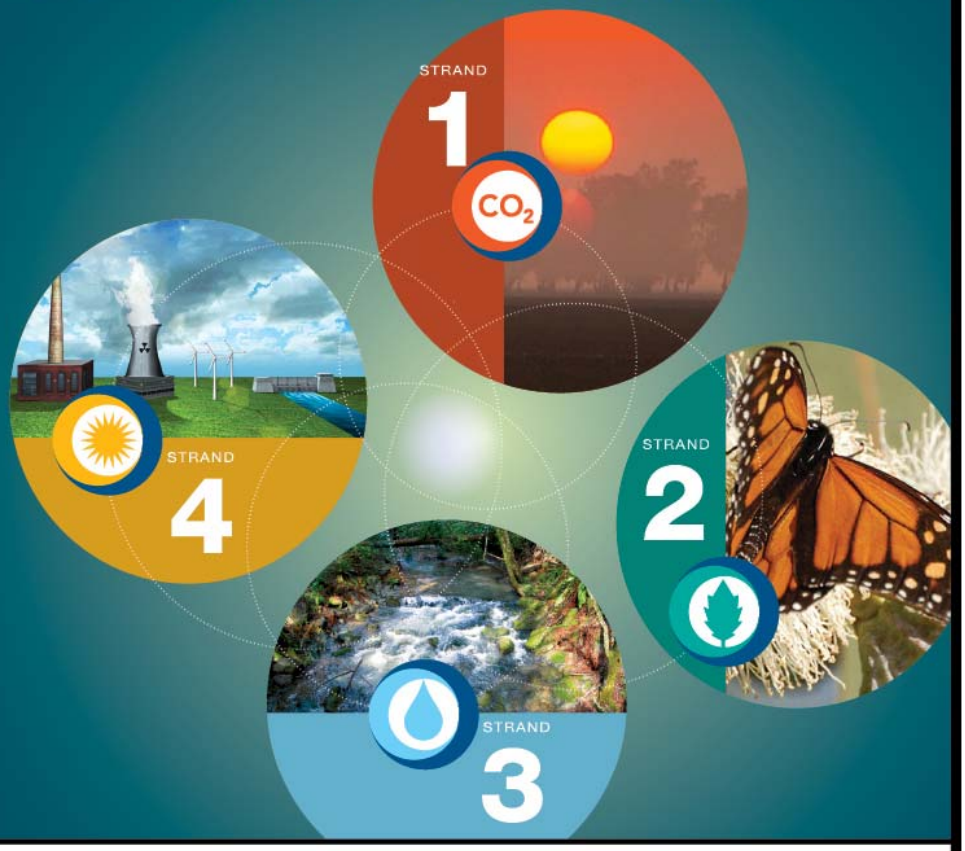
that provide preferred climate conditions. In this lesson, students will learn that scientific surveys are providing evidence that animal populations in Yosemite and along the California coast have shifted over time in response to rising temperatures. *Videos on the Web: Resurveying California's Wildlife and The Intertidal Zone and Sea Level Rise.*

g) Lesson D: Plants in Peril – Like animals, plants can respond to climate change by moving to cooler areas, whether northward or to a higher elevation. However, unlike animals, plants can move only over the course of multiple generations. The pace of climate change may be too fast for plants to shift their ranges. In this lesson, students will learn about the particular challenges that plants face in responding to global warming and will exercise their critical thinking skills after a hands-on investigation. *Video on the Web: Disappearing Plants.*

CLUE into CLIMATE



Student Workbook

Name

Class

School

Date

www.kqed.org/**ClueintoClimate**

KQED
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Science
ready to EXPLORE

VOCABULARY

climate change
a change in long-term average weather patterns; can be natural or the result of human activities

climate model
a mathematical model based on data from global cycles that drive Earth's climate system that helps scientists predict changes in our planet's climate over time

ecosystem
a system made up of a community of living things interacting with their environment

global warming
an average increase in Earth's temperature, which in turn causes changes in climate

CLIMATE OVERVIEW

Fill in the blanks using the words provided

Climate Change

_____ describes the average patterns of weather for an area over a long period of time. _____ describes the temperature, wind, and precipitation in an area at a particular time. Over the past century, the climate has changed on Earth. Temperatures have gone up 1.2 to 1.4 degrees Fahrenheit and are expected to continue to rise. You probably won't notice this warming on any particular day. Over long periods of time, however, it causes many changes around the world.

The Greenhouse Effect

There are many factors that influence how climate changes. One factor is the amount of _____ in Earth's atmosphere. These gases trap the heat from the sun, causing the greenhouse effect and warming Earth. Without these gases, Earth would be too cold to support life. These gases include _____ and _____.

Greenhouse Gases

People have been producing a much greater amount of these gases in the past 100 years. We produce greenhouse gases whenever we burn gas in our cars and burn coal to make electricity. With more greenhouse gases in the atmosphere, the _____ is stronger. This makes temperatures on Earth go up.

Ecosystems

Climate change affects _____, or the living and nonliving parts of a particular environment. When the climate changes, animals and plants may change as well. Sometimes they have _____ that allow them to survive in the new conditions. Sometimes they will move, or migrate, to another ecosystem. And sometimes, animals and plants will not be able to survive in the new climate, and they may become _____.

Word bank:

adaptations	carbon dioxide	climate
ecosystems	extinct	greenhouse effect
greenhouse gases	methane	weather

VOCABULARY

greenhouse effect
Energy (radiation) from the sun passes through the atmosphere, where most of it is absorbed by Earth. Some infrared radiation (heat) is reflected back into space. Greenhouse gases act like a blanket, trapping some of this infrared radiation and warming Earth and its atmosphere, a process called the greenhouse effect.

hydrologic cycle
the continuous process by which water is circulated throughout Earth and its atmosphere; another term for the water cycle

suitable habitat
an area where a given species can live because the area's temperature and precipitation levels meet the survival needs of the species

CLIMATE OVERVIEW CONTINUED

Fill in the blanks using the words provided

The Water Cycle

Climate change affects the water cycle in many ways. First, when the temperatures are warmer, _____, or water entering the atmosphere, happens more quickly. In some places, this can cause the land to dry out and can cause a _____. Warmer air contains more _____. In some places, this leads to more _____, or rain or snow falling. When this happens, storms can be bigger than normal, and flooding may occur.

Warmer temperatures also affect how water gets stored in its frozen form in _____ or _____. When more snow and ice melt, sea levels can rise, and _____ may occur. In addition, many people rely on melting snowpack to provide their _____ during summer months. If climate change alters how much snow falls and when the snowpack melts, the amount of water that gets stored in _____ will change too.

Word bank:		
drought	evaporation	flooding
fresh water	glaciers	precipitation
reservoirs	snowpack	water vapor

Energy

Nonrenewable energy comes from **fossil fuels** like _____, _____, and _____ and from uranium, which is used in _____. Fossil fuels are created over millions of years. When these are burned to release energy, they also emit carbon dioxide into the atmosphere. This adds to the greenhouse effect, which makes Earth warmer.

Renewable energy is energy created from resources that people cannot use up. The most common renewable resources are:

- _____ = comes from the sun
- _____ = turns turbines to make electricity
- _____ = comes from moving water
- _____ = comes from _____, or plant and animals parts
- _____= comes from Earth's heat

Word bank:			
bioenergy	biomass	coal	
geothermal energy	hydropower	oil	
natural gas	nuclear power	solar power	wind

PEER REVIEW

Once an experiment is done, the work of science isn't over. Other scientists look at what has been done, a process called **peer review.** They check to make sure that the experiment was well designed and that the data were analyzed correctly. For the **findings** to be accepted, other scientists need to get the same results when they do the experiment. In other words, they need to **replicate** the results.

Review one of your classmate's experiments. Do you think their experiment and findings make sense? Why or why not?

STEM LITERACY

Selected Parts of the Scientific Process:

- Scientists develop a **question** about how the world works.
- Scientists make a **hypothesis**—an educated guess or proposed explanation—about how something works.
- Scientists design an **experiment** to test their hypothesis.
- Scientists collect **data** from their experiment.
- Scientists analyze the **results** from their experiment and **revise** their experiment if necessary.
- Scientists draw **conclusions** from their experiment and **communicate** their results.

Design Your Own Experiment

Question:

_____

Hypothesis:

_____

_____

Data and Observations:

_____

_____

Results:

_____

_____

Conclusions:

_____

_____

_____

Notes

SCIENCE MEDIA

Make a list of types of science media.

MEDIA LITERACY

How reliable are your sources about science? Pick an article, radio story, video, or website to analyze below:

Media:

_____

Who made this?

_____

Why did they make it?

_____

What information or perspective is not included?

_____

_____

_____

Who benefits from this piece? Who could be harmed?

_____

_____

_____

Notes

TAKING ACTION

Here are some examples of ways to reduce your impact on climate change:

- Travel by foot, bike, or skateboard instead of car.
- Replace your old lightbulbs with compact fluorescent lights (CFLs) that use less energy.
- Recycle your paper, metal, and plastic.
- Bring your own bags to the grocery store.

CLIMATE CAREERS

I'm a science journalist. I write about climate change.

I'm a paleoclimatologist. I study ice cores in the Arctic to find out about what Earth's climate was like long ago.

I'm a botanist. I study how different plants move when the climate changes.

I'm a meteorologist. I study hurricanes.

I'm an oceanographer. I study how climate change affects ocean ecosystems.

I'm an atmospheric chemist. I study how gases interact in the atmosphere.

I'm a computer scientist. I create climate models.

I'm a geologist. I look for sources of geothermal energy.

I'm a biologist. I study climate change and the rain forest.

I'm an astronomer. I study the sun's effects on climate.

I'm an agricultural scientist. I study how climate affects the growth of crops.

I'm an economist. I predict how climate change affects trade and economic development.

Here are some examples of climate careers. Which of these careers is most interesting to you? Why?

TAKING ACTION

Here are some other examples of ways to reduce your impact on climate change:

- Plant trees in your yard.
- Use a power strip for your TV and chargers, and turn it off when you don't need it.
- Use public transport-tation or carpool.
- Teach others what you've learned, so they can make informed choices.

GLOBAL IMPACT

How will climate change affect different parts of the world? Use this space to record notes about changes around the globe.

_____

_____

_____

_____

_____

_____

Notes

CLIMATE PLEDGE

Pick three things you plan to do to reduce your impact on climate change. How will you help?

In order to reduce my impact on climate change, I pledge to:

1._____

2._____

3._____

_____
Your Signature

CLUE into CLIMATE

KQED education network

Science ready to EXPLORE

Strand 2 Educator Guide – Climate Change Affects Ecosystems and the Distribution of Organisms

SUBJECT

Life Science

GRADE LEVELS

4–8

OVERVIEW

In this strand, students learn how changes in climate affect the distribution of organisms in ecosystems around the world. By the conclusion of these lessons, students will be able to describe how climate is currently changing and to provide examples of how these changes are altering life for both plants and animals. They will appreciate that when faced with ecosystem change, species must either adapt to the changes or move to more suitable habitats, or else they may face extinction. Through examples ranging from the ice pack of the Arctic to the mountains of California to tide pools along the coast, students will understand that if climate change occurs as predicted, it will have a profound influence on the distribution and survival of species on Earth. In order to complete this unit, students should already understand food chains and how organisms interact within an ecosystem.

STRAND UNIT PLAN

Week	Monday	Tuesday	Wednesday	Thursday	Friday
1	Lesson 2a: Activity 1	Lesson 2a: Activity 2, Global Impact Discussion	**Explore Your Earth: Walk in Schoolyard or Local Park**	Lesson 2b: Activity 1	Lesson 2b: Activity 2, STEM Literacy Discussion
2	**What Can We Do at School? Planning the Native Plant Garden**	Lesson 2c: Activity 1	Lesson 2c: Activity 2, Media Literacy Discussion	**Field Trip: Visit Zoo, Botanical Garden, or Aquarium**	Lesson 2d: Activity 1, Climate Careers Discussion
3	**What Can We Do at School? Installing the Native Plant Garden**	Lesson 2d: Activity 2 (Note: continue experiment for six weeks)	Begin Alternative Assessment or Review for Traditional Assessment	Complete and Share Alternative Assessment or Give Traditional Assessment	

EXPLORE YOUR EARTH

Take a walk around your schoolyard. Do you think the plants there will be affected by climate change? Why or why not? If the kinds of plants that survive there change, how will this affect animals in your schoolyard ecosystems?

Visit a local park. Record animal and plant observations. How might the food webs at your local park be affected by changing temperatures? Can you find any evidence of changes already taking place?

STRAND ESSENTIAL QUESTIONS

1. How does climate change affect ecosystems?
2. How does climate change affect the survival and distribution of organisms?

LITERACY CONNECTIONS

Lesson	Media Literacy	STEM Literacy	Global Impact	Climate Careers
Lesson 2a: The Changing Arctic Ecosystem			**X**	
Lesson 2b: Adapting to Climate Change		**X**		
Lesson 2c: Animals on the Move	**X**			
Lesson 2d: Plants in Peril				**X**

STRAND ASSESSMENT IDEAS

1. **Strand 2 Traditional Assessment (attached)**
   This test uses multiple choice and short-answer questions to assess student learning for the entire strand.
2. **Strand 2 Alternative Assessment: Zoo/Botanical Garden Information Panel**
   Zoos and botanical gardens educate the public about issues regarding the species in their care. How will these species fare if our climate continues to warm? In this assessment, students select an animal or plant species to research, then design an informational panel that might be displayed in front of their species' exhibit at a zoo or botanical garden. Students examine the species' habitat, role in the food chain, and potential fate in the face of climate change, then design an information panel to teach the public about how climate change might affect the chosen species.

   Students should examine the following topics in their research:
   a) Habitat: Where does your plant or animal live? How large is its range? What is the climate of the habitat?
   b) Ecosystem: What is your species' role in the ecosystem? What does it eat and/or what eats it?
   c) Climate change: How will climate change affect the plant's/animal's habitat? How will changes affect the species' food web? Do members of this species have adaptations that will allow them to survive or thrive in the new climate? Can this organism move to other suitable habitats? What is this species' likely fate in the face of climate change?

SCIENCE STANDARDS

Lesson	California State Science Content Standards, Grades 4–8	California's Environ-mental Principles and Concepts	National Science Education Standards for Middle School	Earth Science Literacy Principles	The Essential Principles of Climate Literacy
Lesson 2a: The Changing Arctic Ecosystem	Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (3.b.) Grade 6: Ecology (Life Sciences) 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (5.e.)	People Influence Natural Systems (Concept a) There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing between Systems (Concepts b, c)	Life Science: Populations and ecosystems	Big Idea 3: Earth is a complex system of interacting rock, water, air, and life. (3.5, 3.6, 3.7, 3.8)	Principle #3: Life on Earth depends on, is shaped by, and affects climate. (C) Principle #7: Climate change will have consequences for the Earth system and human lives. (E)
Lesson 2b: Adapting to Climate Change	Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (3.b.) Grade 6: Ecology (Life Sciences) 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (5.e.) Grade 7: Evolution. 3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. (3.e.)	People Influence Natural Systems (Concept a) There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing between Systems (Concepts b, c)	Life Science: Diversity and adaptations of organisms Unifying Concepts and Processes: Evidence, models and explanation	Big Idea #3: Earth is a complex system of interacting rock, water, air, and life. (3.6, 3.7, 3.8) Big Idea #9: Humans significantly alter the Earth. (9.3)	Principle #3: Life on Earth depends on, is shaped by, and affects climate. (A, C) Principle #5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling. (A, B, C) Principle #7: Climate change will have consequences for the Earth system and human lives. (E)

Lesson	California State Science Content Standards, Grades 4–8	California's Environ-mental Principles and Concepts	National Science Education Standards for Middle School	Earth Science Literacy Principles	The Essential Principles of Climate Literacy
Lesson 2c: Animals on the Move	Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (3.b.) Grade 6: Ecology (Life Sciences) 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (5.e.) Grade 7: Evolution. 3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. (3.e.)	People Influence Natural Systems (Concept a) There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing between Systems (Concepts b, c)	Life Science: Diversity and adaptations of organisms	Big Idea #3: Earth is a complex system of interacting rock, water, air, and life. (3.6, 3.7, 3.8) Big Idea #9: Humans significantly alter the Earth. (9.3)	Principle #3: Life on Earth depends on, is shaped by, and affects climate. (A, C) Principle #7: Climate change will have consequences for the Earth system and human lives. (E)
Lesson 2d: Plants in Peril	Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (3.b.) Grade 6: Ecology (Life Sciences) 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (5.e.) Grade 7: Evolution. 3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. (3.e.)	People Influence Natural Systems (Concept a) There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing between Systems (Concepts b, c) Decisions Affecting Resources and Natural Systems are Complex and Involve Many Factors (Concept a)	Life Science: Diversity and adaptations of organisms	Big Idea #3: Earth is a complex system of interacting rock, water, air, and life. (3.6, 3.7, 3.8) Big Idea #9: Humans significantly alter the Earth. (9.3)	Principle #3: Life on Earth depends on, is shaped by, and affects climate. (A, C) Principle #7: Climate change will have consequences for the Earth system and human lives. (E)

WHAT CAN WE DO AT SCHOOL?

As native plants lose precious habitat due to climate change and human activities, they may be at risk of extinction in your state. Plant a native plant or install a native plant garden at your school, researching which plants are native to your state and will survive best in your climate. Will your garden serve as habitat for animals as well? Consider how to support species, such as butterflies or birds, that rely on native plants for survival.

INTERDISCIPLINARY CONNECTIONS (CA CONTENT STANDARDS)

Lesson	English Language Arts	Visual and Performing Arts
Lesson 2a: The Changing Arctic Ecosystem	Grade 4:1.0. Listening and Speaking Strategies; Comprehension (1.1, 1.2) Grade 6: 1.0. Writing Strategies Research and Technology (1.4)	Grade 4: 5.0. Connecting and applying what is learned in the visual arts to other art forms and subject areas and to careers (5.3. Visual Literacy)
Lesson 2b: Adapting to Climate Change	Grade 6: 2.0 Writing Applications (Genres and Their Characteristics); Expository Compositions (2.2)	
Lesson 2c: Animals on the Move	Grade 6: 2.0 Writing Applications (Genres and Their Characteristics); Narratives (2.1)	Grade 4: 5.0. Connecting and applying what is learned in the visual arts to other art forms and subject areas and to careers (5.3. Visual Literacy)
Lesson 2d: Plants in Peril	Grade 4:1.0. Listening and Speaking Strategies; Comprehension (1.1, 1.2)	

ABOUT THE AUTHOR

Laura Hodder is an education writer based in San Francisco. She has worked as an author for the California Education and the Environment Initiative and is a former middle school math and science teacher.

KQED Education Network engages with community and educational organizations to broaden and deepen the impact of KQED media to effect positive change.

www.kqed.org/education

SUPPORT

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STRAND 2 ASSESSMENT ANSWER KEY

1. C
2. C
3. B
4. A
5. C
6. B
7. A
8. D
9. C
10. A
11. Answers will vary. Sample answer: In the Arctic, the Arctic fox is a predator that eats lemmings. In warmer temperatures, the population of lemmings goes down, which reduces the amount of food available for Arctic foxes. In addition, warmer temperatures have caused the range of the red fox to increase, and it now competes with the Arctic fox for food.
12. Answers will vary. Sample answer: The cactus has several adaptations to help it survive in a dry climate. It has a thick waxy coating that prevents evaporation of water, and it has long taproots to reach deeper sources of water during the driest months.
13. Answers will vary. Sample answer: An animal that has more time to gather food before winter will be more likely to survive through winter. As temperatures warm, the food-collecting season gets longer. Scientists have found that some mosquitoes have evolved the adaptation of going dormant later, which allows them to take advantage of the longer summer to gather food.

ADDITIONAL RESOURCES (SPECIFIC TO THE BAY AREA)

- The San Francisco Zoo and the Oakland Zoo offer collections of animals from around the world. Take a field trip to see a variety of species and explore how different animals may respond to climate in their unique habitats. www.sfzoo.org, www.oaklandzoo.org

- How do different plants survive in a particular climate? Compare the plants from Mediterranean climates around the world at the San Francisco Botanical Garden at Strybing Arboretum. www.sfbotanicalgarden.org

- Participate in the Expanding Oceans classroom program at San Francisco's Aquarium of the Bay, in which students participate in hands-on experiments exploring how rising sea levels will affect ecosystems in the San Francisco Bay. www.aquariumofthebay.org

STRAND 2 ASSESSMENT

Multiple Choice (1 point each)

1. How have habitats changed in response to climate change over the past few decades?
a. On average, temperatures are decreasing and habitats are getting wetter.
b. On average, temperatures are decreasing and habitats are getting drier.
c. On average, temperatures are increasing. Some habitats are getting wetter and some are getting drier.

2. How has climate change affected the Arctic ice pack?
a. The ice pack has increased, mainly due to cooler temperatures.
b. The ice pack has increased, mainly due to increased amounts of snow.
c. The ice pack has decreased, mainly due to warmer temperatures.
d. The ice pack has remained relatively constant.

3. Which of these will cause an animal population to increase?
a. The population of the animal's prey decreases.
b. The population of predators that feed on this animal decreases.
c. The animal's season for hunting food gets shorter.

4. Which animals are *least* likely to be able to survive climate change?
a. Animals that have a small suitable habitat
b. Animals that can move to new habitats easily
c. Animals that can survive at a variety of temperatures
d. Animals that can eat a variety of different foods

5. What is likely to happen to wolverines if climate change continues at its current pace?
a. They will adapt to the new conditions and become a new species.
b. They will easily move to habitats with cooler climates.
c. They will not be able to survive in many of their former habitats.
d. They will thrive in the warmer climate.

6. In the early 1900s, Joseph Grinnell visited land in Yosemite to study the wildlife there. When scientists returned recently, what changes did they find?
a. Glaciers in Yosemite had increased in size.
b. Several species of small mammals that used to live at a variety of elevations are no longer found at lower elevations.
c. The range of small mammals had increased.
d. Most small mammal species developed adaptations to the warmer temperatures.

7. How has an increase in average temperatures affected animals and plants that live on the coast?
a. Some animals and plants are moving north to new habitats.
b. Tide pool ecosystems are getting bigger.
c. The sea level is dropping, increasing the size of marshes.
d. Most animals and plants that live in tide pools have already become extinct.

8. What happens when an animal moves to a new habitat?
a. It may become a competitor with animals that already live there.
b. It may become a predator for animals that already live there.
c. It may become prey for predators that already live there.
d. All of the above.

9. What do climate models predict will happen to native plant species in California?
a. Plants will move to lower elevations.
b. Plants will move to the south.
c. About two-thirds of native plants may lose much of their habitat.

10. What is the main difference between the way plants and animals respond to climate change?
a. Although both animals and plants can move their range, animals can do it within a single generation. Plants move over multiple generations.
b. Animals evolve faster than plants, so they can develop adaptations to changing climate more rapidly.
c. Plants are more dependent on seasonal changes than animals, so changes in seasons affect them more.

Short Answer (2 points each)

11. Pick an ecosystem. Identify one predator and its food source that live in this ecosystem. How might climate change affect these species?

12. Pick a species. What adaptations help that species survive in its suitable habitat?

13. Give an example of an adaptation in either a plant or an animal that could result from increasing temperatures.

Strand 2 Background Article
Climate Change Affects Ecosystems and the Distribution of Organisms

SECTION TOPICS

- What an ecosystem is (interconnected nature of species)
- How climate change affects ecosystems and the organisms within them
  - Changes in temperature
  - Changes to seasonal events (when to mate, migrate, hibernate) and growing seasons (when to bloom, shed seeds)
  - Changes to one species affects other organisms within an ecosystem

CLIMATE CHANGE AND ECOSYSTEMS

In the past 100 years, Earth's surface temperature has increased an average of 1.2 to 1.4 degrees Fahrenheit, and climate models suggest that without changes to human activities, global surface temperatures will rise an estimated 3 to 7 degrees Fahrenheit by the end of the century. This warming of the atmosphere and oceans will alter climate patterns for diverse ecosystems around the world and affect the survival of millions of species.

Ecosystems are communities of living organisms interacting with the environment in which they live. When scientists discuss ecosystems, they emphasize the interconnected nature of the abiotic factors (nonliving variables such as soil composition, water, and temperature) and the biotic factors (living components such as plants, animals, and microbes) within these systems. For example, an increase in average temperature in an ecosystem may alter precipitation and wind patterns. This could lead to water levels rising or soil chemistry changing. As the abiotic conditions of a habitat change, so do the chances of survival of the species that live there. Some may thrive and others may struggle, but either kind of change to one population inevitably affects others, as organisms are linked through the food web and the various services, such as pollination or shelter, that they provide to one another. Ecosystems are complicated, and any change to one part will affect many others.

To understand how climate change may affect an ecosystem, consider an estuary. Warmer temperatures are expected to bring both increased precipitation (in some places) and rising sea levels. Increased precipitation causes increased river flow volume, allowing for more freshwater to enter an estuary at its head. Higher sea levels push more salt water into the mouth of the estuary. As a result, the zone of transition from riverine freshwater to oceanic saltwater could be "squeezed" on both ends—the estuary shrinks. This could have a wide range of effects on the animals and plants within the estuarine ecosystem.

Changes in climate can affect species throughout an ecosystem. Some respond directly to temperature increases. For example, mussels cannot survive in water that gets too warm, and polar bears have no place to rest between hunting trips when sea ice melts. Changing temperatures can lead to new precipitation patterns, such as drought in the Sahel in Africa, which has killed many plants and threatened the survival of humans and other animals that depend on the plants for nourishment. Many species rely on temperature cues to direct seasonal activity, such as migration, mating, and hibernation in animals and when to flower and produce seeds in plants. Of course, since species are so interdependent in ecosystems, the changing of a seasonal pattern for one species may alter the life of another. For example, if a flower blooms before insects have come out of dormancy, pollination cannot happen. If a bird migrates before plants have produced food for them to eat, they risk starvation.

SECTION TOPICS

- Death/extinction
- Moving (including the reaction of native ecosystems to invasive species)
- Adapting
  - Changes to migration patterns
  - Species with long life cycles and low reproductive rates less likely to adapt

RESPONSES TO CLIMATE CHANGE

In the face of climate change, species face several possibilities: they may die off, they may be forced to move to a more suitable habitat, or they may adapt to their changing environment. Species such as the lemuroid ringtail possum in Australia are already at risk of climate-induced extinction. This kind of mammal is unable to withstand long periods of high temperatures, and a 2005 heat wave in Australia killed almost the entire population. In Central and South America, harlequin frogs are also at risk of extinction due to climate change. Warmer temperatures have produced more clouds over their rain forest habitats. During the day, the clouds prevent the sun from warming up the frogs, and at night, they act as an insulating blanket, preventing temperatures from dropping. In previous decades, the hot daytime sun and cold nighttime temperatures held the population of a deadly disease-causing fungus in check, but changes in cloud cover have led to a proliferation of the fungus. As a result, about two-thirds of the known 110 harlequin frog species are now extinct.

As global temperatures increase, some species move to more suitable habitats. For example, many North Atlantic fish populations have been shifting northward over the last four decades in conjunction with changing ocean temperatures. As the fish move, food webs of their former waters and new habitats change. Removing prey species leaves predators without a food source. Small fish such as herring and menhaden support top predator species like large fish, ocean mammals, and sea birds. If they leave an ecosystem, all the organisms that once fed on them will need to find new sources of food or move to follow the prey. Removal of top predators changes the food web in favor of smaller prey. As cod populations in the Atlantic have decreased, mostly due to over-fishing, scientists have seen the populations of smaller fish and invertebrates rise. In turn, zooplankton and algae have been consumed faster, as more small species exist to dine on the microorganisms. Seals have also benefited from the decreases in cod because they no longer compete with the cod for food. These kinds of food web changes will also occur in the face of climate change as organisms move to habitats at their preferred temperature. As the species composition of an ecosystem changes, some organisms will thrive in their new niche in the food web, and some will suffer. Overall, as climate change continues, ocean species distribution and survival will look very different than it does today.

Another climate-affected species is the pika, a mammal with extremely thick fur that thrives in cold, alpine climates. As mountain temperatures have increased, the pika has moved to increasingly higher elevations to escape the heat. Eventually, if temperatures continue to increase, the pika will not be able to climb any higher and will be at risk of extinction.

As climate changes, the characteristics of species' populations change. Some species adapt to the changes in their ecosystem. Scientists have already seen evidence of climate-induced adaptations. For example, as warm springtime temperatures arrive earlier in the year, Canadian squirrels are evolving to breed earlier so they can have more time to collect food before winter. One North American mosquito species has adapted to longer summers by going dormant later, giving them more time to gather resources. A population of the European bird called the blackcap has evolved a new migration strategy: it winters in now-warmer England rather than in Spain or Portugal, giving its members a shorter journey home and thus the first opportunity for territory and mates during breeding season. All of these adaptations—in breeding, dormancy, and migration—allow individuals to take advantage of the changes to their ecosystems, and those best able to survive these changes are most likely to pass on the adaptive traits.

Predicting how climate will change in the future is a highly debated topic. Scientists predict that if current trends continue, many species will become extinct. Others will move, altering not only the food webs they leave behind, but also the new ecosystems they enter, as they compete with native organisms that already live there. Some species will adapt to climate changes, evolving characteristics that promote their survival amid the new dynamics of their ecosystem. Those species with long life spans, low reproductive rates, and small populations will be least likely to adapt and will have a greater risk of extinction.

SUPPORT

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ABOUT THE AUTHOR

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Science ready to EXPLORE

Lesson 2a: The Changing Arctic Ecosystem

SUBJECT

Life Science

GRADE LEVELS

4–8

CA SCIENCE STANDARDS

Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (b)

Grade 6: Ecology (Life Sciences). 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (e)

EARTH SCIENCE LITERACY PRINCIPLES

#3: Earth is a complex system of interacting rock, water, air, and life.
(3.5, 3.6, 3.7, 3.8)

OVERVIEW

The effects of climate change on ecosystems and the distribution of organisms within them are already evident in the Arctic. In this lesson, students will learn about the challenges that climate change presents for four specific Arctic predators. They will explore how such changes ripple throughout ecosystems, habitats, and food webs.

ESSENTIAL QUESTIONS

1. How is climate change affecting the Arctic ice pack? *(Warmer temperatures are causing the ice pack to shrink and to retreat earlier in the year.)*
2. How do changes in the Arctic ice pack affect specific predators? *(Many predators rely on the ice pack to hunt and rest; as the ice pack shrinks, they have to swim greater distances to find food.)*
3. How does climate change affect ecosystems? *(Climate change affects many animals and plants within an ecosystem—changes in one part of an ecosystem affect every other part of the ecosystem.)*

MEDIA RESOURCE

***Jean-Michel Cousteau Ocean Adventures* video: "A Warmer World for Arctic Animals"**
Video length: 3 minutes, 1 second
Link: http://www.kqed.org/education/educators/clue-into-climate/distribution-organisms.jsp
Through watching this video, students will learn:

- How global warming affects four different animals in the Arctic—polar bears, walruses, arctic foxes, and beluga whales
- Different ways in which global warming affects Arctic ecosystems

VOCABULARY

abiotic factors
nonliving parts of an ecosystem, such as soil and water

Arctic
the region around the North Pole; the Arctic Ocean and the lands in it and next to it

biotic factors
living parts of an ecosystem, such as animals and plants

climate change
a change in long-term average weather patterns; can be natural or the result of human activities

ecosystem
a system made up of a community of living things interacting with their environment

ACTIVITY 1: COMPARING ECOSYSTEMS

Time: 30 minutes, plus time for research and 15 minutes for follow-up
Materials:

- Access to a library or the Internet
- Paper
- Pens
- Colored pencils

Procedure:

1. Define the words *"*ecosystem*"* and *"*habitat*"* and distinguish between the two.
2. Brainstorm a list of habitat types (such as marine, wetland, oak woodland, redwood forest, and desert). Discuss characteristics that differentiate these habitats, such as climate (precipitation, wind, and temperature), amount of water, soil type, type of vegetation, and diversity of animals. If students have trouble coming up with different habitats, start with a local habitat, identify its characteristics, and then change them one by one to come up with examples of other habitats and how they differ.
3. Ask students to describe some of the interactions that might occur between living things and the environment in which they live (their *habitat*). Guide students to a discussion of food chains and webs and predator/prey relationships within ecosystems.
4. Optional extension: Students take on the role of organisms within a specific ecosystem (predators, prey, plants, etc.) with different identified survival needs (provided by the teacher). For example, every round, plants need one unit of water and/or soil nutrients, herbivores need to eat one of a certain kind of plant, predators need to eat one of their prey, and so on. Each round, adjust the availability of water units, soil nutrients, and so on, and students will observe the effect on the different populations. From this simulation, students can identify and define the various relationships within food webs and ecosystems.
5. Ask students to select an ecosystem. Have them research their ecosystem and create a profile that describes the ecosystem's typical climate, soil type, and characteristic plants and animals. Have them diagram a food chain or web associated with the ecosystem.
6. Post the ecosystem profiles in a classroom "gallery" and have students draw comparisons among different ecosystems. For example, have students pick one organism from their own ecosystem. Next they should determine in which of the other ecosystems their organism could and could not survive and why.

ACTIVITY 2: CHANGES IN THE ARCTIC ECOSYSTEM

Time: 30-45 minutes
Materials:

- Computer with Internet connection
- Projector and speakers
- Handout: Changes in the Arctic Ecosystem chart

Procedure:

1. Ask students to describe an Arctic ecosystem. If necessary, review what students know about ecosystems and the abiotic and biotic factors within them. Record ideas on the board. Explain that Arctic ecosystems are changing.
2. Hand out the Changes in the Arctic Ecosystem chart. Watch "A Warmer World for Arctic Animals" twice. While students watch, have them complete the chart (pause as necessary).

VOCABULARY

global warming
an average increase in Earth's temperature, which in turn causes changes in climate

habitat
the place or environment in which a plant or animal normally lives

ice pack
a large area of ice that forms in the polar (Arctic and Antarctic) oceans; pack ice, or sea ice, floats on the surface of the ocean

species
a biological classification consisting of individual organisms capable of interbreeding

territory
the area defended by an animal against other animals of the same species

ACTIVITY 2 CONTINUED

3. On the back of their chart, students should construct a food chain/web based on the video.
4. Revisit students' original ideas about Arctic ecosystems. What did they learn from the video?
5. As a class, list at least five things that influence where a plant or animal lives (such as amount of precipitation, amount of sunlight, type of food available, type of soil, temperature, fire, availability of shelter, adequate space/territory). Circle and discuss those that might be affected by rising global temperatures.
6. Have students write hypothetical new descriptions of the Arctic ecosystem if climate change continues its current trajectory.

GLOBAL IMPACT

Discussion Questions

- This video presents information about changes taking place in the Arctic. Locate the Arctic on a map or globe. Also locate the Antarctic.
- Wildlife in the Arctic face challenges due to rising temperatures in their habitat. Melting polar ice caps add water to the world's oceans and cause sea levels to rise. How will this affect human communities? Where might the impacts be most keenly felt?
- Who is responsible for managing and trying to prevent the effects of climate change in the Arctic?

ABOUT THE AUTHOR

Lori Mann is an environmental education consultant with 30 years experience at the local, state, and national levels. She has worked extensively with curriculum development and has taught many environmental education courses and workshops. She served for 15 years as education director at Coyote Point Museum for Environmental Education in San Mateo, Calif.

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ASSESSMENT IDEAS

- Students complete Changes in the Arctic Ecosystem charts.
- Students create three questions about interactions within their ecosystem for other students to answer.

WHAT CAN WE DO?

Many organizations are working to protect the Arctic ecosystem from the effects of global warming. Research the goals and programs of some of these organizations. Conduct a fund-raiser on campus and contribute funds to help one of these organizations with their efforts to bring about change.

ADDITIONAL RESOURCES

All About Sea Ice, National Snow and Ice Data Center
http://nsidc.org/seaice/index.html
This website provides information on sea ice and its influence on climate, wildlife, and people who live in the Arctic.

Climate Change, Teachers' Domain: Digital Media for the Classroom and Professional Development
http://www.teachersdomain.org/special/climchg/climchg.clim.all/
This website provides background information, videos, PDF documents, lesson plans, and links to further resources on all aspects of climate change, including some specific to Arctic ecosystems.

Climate Kids: NASA's Eyes on the Earth, NASA Global Climate Change
http://climate.nasa.gov/kids/index.cfm
This National Aeronautics and Space Administration interactive website offers student-friendly information, videos, and reports on scientific studies related to climate change. Educator resources are included.

Polar Bears and Climate Change, Teachers' Domain
http://www.teachersdomain.org/resource/lsps07.sci.life.eco.polarbear/
This three-minute video describes studies of polar bears and the Arctic ecosystem relative to climate change. The site includes background information and links to additional resources and lesson plans.

STUDENT WORKSHEET

Changes in the Arctic Ecosystem Chart

Directions: Complete this chart as you watch the video. Give at least one example in each empty box.

Arctic animal	How is the animal's environment being changed because of climate change?	How is that environmental change affecting the animal?	Name other animals/plants in the ecosystem that could be affected by any change in population of this animal.
Polar bear	Example: Sea ice is shrinking.	Example: Resting area is limited and bears may become exhausted and die looking for a place to rest.	
Walrus			
Arctic fox			
Beluga whale			

Changes in the Arctic Ecosystem Answer Key
(Sample answers provided—student answers may vary.)

Arctic animal	How is the animal's environment being changed because of climate change?	How is that environmental change affecting the animal?	Name other animals/plants in the ecosystem that could be affected by any change in population of this animal.
Polar bear	Example: Sea ice is shrinking.	Example: Resting area is limited and bears may become exhausted and die looking for a place to rest.	Example: Changes in polar bear populations could affect seal populations.
Walrus	Example: Pack ice has retreated from the walrus's shallow feeding area.	Example: Walruses have to swim longer distances for food and may exhaust themselves.	Example: Changes in the walrus population could affect the clams that they eat.
Arctic fox	Example: Warmer temperatures have increased the suitable habitat of the red fox.	Example: The Arctic fox has to compete with the red fox for resources.	Example: Changes in the Arctic fox population could affect the population of the red fox.
Beluga whale	Example: Sea ice is shrinking.	Example: Accessibility of Arctic water to humans may leave beluga whales exposed to increased shipping traffic.	Example: Changes in the beluga population could affect the populations of the fish that they eat.

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Lesson 2b: Adapting to Climate Change

SUBJECTS

Life Science

GRADE LEVELS

4–8

CA SCIENCE STANDARDS

Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (b)

Grade 6: Ecology (Life Sciences). 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (e)

Grade 7: Evolution. 3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. (e)

ESSENTIAL PRINCIPLES OF CLIMATE LITERACY

#5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling. (A, B, C)

OVERVIEW

Plants and animals are adapted to live in habitats with specific environmental conditions; these adaptations might be physiological or behavioral or both. Climate change can cause conditions in a given area to change. In this lesson, students will become familiar with some adaptations and learn that plants and animals must be able to adapt or move in order to survive significant environmental changes.

ESSENTIAL QUESTIONS

1. Why is the ability to adapt or move important to plants and animals? *(otherwise they may become extinct)*
2. How are climate change and plant and animal adaptations related? *(Animals and plants may need to adapt to changing climate conditions.)*
3. What is likely to happen to wolverines and coast redwoods if climate change continues at its current pace? *(Their suitable habitat will likely both shift and shrink.)*

MEDIA RESOURCES

- **Diagram: Forecasting Suitable Habitat for Wolverines for the Next 100 Years**
- **Video slideshow: "Forecasting Suitable Habitat for Redwoods over the Next 100 Years"**
  Slideshow length: 3 minutes, 2 seconds

Link: http://www.kqed.org/education/educators/clue-into-climate/distribution-organisms.jsp
Through watching the video slideshow about coastal redwoods and viewing the diagram about wolverines, students will learn that:

- Global climate change will likely change the suitable habitat of certain animals and plants
- Scientists use models of future emissions scenarios to predict what might happen to wildlife as the planet warms

VOCABULARY

adaptation
behavioral or physiological change by which an organism becomes better suited to a particular environment over time; the process of making that change

climate change
a change in long-term average weather patterns; can be natural or the result of human activities

climate envelope
the area containing temperature and precipitation levels that a species can live within; used interchangeably with "suitable habitat"

extinct
no longer existing

global warming
an average increase in Earth's temperature, which in turn causes changes in climate

greenhouse gas
gases such as carbon dioxide that trap heat in the atmosphere; greenhouse gases can be emitted to the atmosphere through natural processes or human activities

suitable habitat
see *climate envelope*

ACTIVITY 1: ADAPTING TO CHANGING CONDITIONS

Time: 60+ minutes
Materials:

- Variety of crafts supplies, such as toilet paper tubes, pipe cleaners, construction paper, card stock, yarn, toothpicks, and plastic bags
- Scissors
- Glue
- Markers or crayons

Procedure:

1. Explain that plants and animals have certain features and behaviors that help them survive in specific kinds of habitats. These are called adaptations, and they are the result of change over long periods of time. If students are already familiar with adaptations, instead encourage them to review and share what they know about adaptations.
    - Ask students what kinds of plants survive well in a desert environment. *(cactus)* Use probing questions to help students identify features that enable different kinds of cacti to survive in the hot, dry climate. *(spines to protect from animals, provide shade on the stem, and collect moisture; few leaves or small leaves, which prevents water loss through evaporation; thick, succulent leaves and trunks to store water; long tap roots to find underground water; dormancy during dry periods; rapid growth when water is available; waxy coating on stems to seal in moisture)* Ask whether a cactus plant would be well suited to live in a wetland or rain forest habitat where there is a lot of moisture. *(No. It would hold too much moisture and likely rot.)*
    - Ask students to picture an owl in a forest. What are some of the features of the owl that help it to succeed in this habitat? *(large, light-sensitive eyes for good night vision; fringed feathers that muffle flight sounds so they fly nearly silently; talons for grasping prey; acute hearing; camouflage coloring to hide during the day; facial discs to collect sounds and direct them to inner ears; hooked bill for tearing flesh)*
    - Point out that humans also have many adaptations to help us survive. Ask students to name some human adaptations. *(walking upright; forward-facing eyes for depth perception; different kinds of teeth to enable omnivorous diet)* Explain that having an opposable thumb is one adaptation of humans that is not shared by many other animals. In pairs, have students brainstorm advantages of having an opposable thumb. Share some ideas aloud.
2. Ask students to select a spot in the schoolyard as a "micro habitat" (if this is not possible, teachers can select a real habitat, such as a forest). Using any of the available craft supplies, have students invent an animal that has physical adaptations that would help it survive in that habitat. Encourage students to think about the animal's habits, such as what it might eat, and what kind of protection it needs.
3. Ask students to write one paragraph describing the physical adaptations and one behavioral adaptation they have given their animals. The paragraph should explain how each adaptation benefits the animal and helps it survive. (If necessary, review the difference between physical and behavioral adaptation.)
4. A few students should share their animals and explain the adaptations they have created. If time allows, create a "safari" by placing the animals and paragraphs in their habitats and having students walk around to see and read about their classmates' animals.

WHAT CAN WE DO?

Create posters or brochures that encourage people to conserve energy and reduce greenhouse gas emissions in order to save habitats. Display the materials in a public library or other venue.

ACTIVITY 1 CONTINUED

5. Next, randomly change the environment (remove a food source, remove shade, etc.) and have students discuss which of their hypothetical animals would be in the best shape to survive the change. If only those animals survived, how would the safari look in several generations? What would happen to the animals that did not have traits that helped them survive the change?

ACTIVITY 2: REDWOODS AND WOLVERINES

Time: 30 minutes
Materials:

- Computer with Internet access
- Projector

Procedure:

1. Review what students know about how climate change is affecting ecosystems and organisms. Introduce the term “climate envelope” (also known as “suitable habitat”) and explain that plants and animals have preferred conditions in which they normally live. If conditions in a given area change due to climate change, the suitable habitat of some plants and animals may no longer be present in that area.
2. Ask students to write down what they know about wolverines and redwood trees (consider: habitat, food source, adaptations, appearance, life span). You can find detailed information about the wolverine at http://www.fs.fed.us/r6/sfpnw/issssp/documents/planning-docs/sfs-vert-ma-Gulo-gulo-luteus-2007-09-27.doc and about redwoods at http://www.savetheredwoods.org/education/coastredwood.shtml. Make a list of facts on the board. Please note that redwoods and wolverines are included in this lesson because they both represent important species whose suitable habitats may be affected by climate change, not because their habitats are necessarily connected.
3. Read aloud the description of the California Academy of Science’s project (below). Answer student questions as necessary. Be sure to highlight the difference between an organism’s suitable habitat, or climate envelope, and its actual distribution.
4. In partners (or as a class), students view the diagram Forecasting Suitable Habitat for Wolverines for the Next 100 Years and the video slideshow “Forecasting Suitable Habitat for Redwoods over the Next 100 Years.” Students should identify which states and which part of the continent *(California/Oregon and western North America)* are shown in the maps based on topographical features/state abbreviations or boundaries. Assist students as necessary with this.
5. Discuss as a class what the models predict will happen to the suitable habitats of wolverines and redwood trees. Do the suitable habitats increase in size or decrease in size? *(decrease)* What do you think will happen to the redwood trees or wolverines that are outside their suitable habitat? *(Answers may vary.)* What are their options? *(move or adapt)* Why are certain animals and plants more likely to survive environmental changes? *(They already possess traits that are more favorable for the changing conditions or they are able to adapt to changes at a faster rate.)* What might happen to wolverine and coast redwood populations if global climate change causes changes to their habitat? *(Their numbers may decrease.)*

ASSESSMENT IDEAS

- Students write a paragraph explaining why the suitable habitats of animals and plants may shift due to global climate change.
- Students create posters or brochures that encourage people to conserve energy and reduce greenhouse gas emissions in order to save habitats. Display the materials in a public library or other venue.

ACTIVITY 2 CONTINUED

6. Optional extension: Students create a poster detailing redwood trees or wolverines with information about their habitats, their adaptations, and what might happen to them in the future.

California Academy of Sciences Project Description
Researchers around the world use physics and math to predict the future climate of Earth (the different global climate models). The California Academy of Sciences (the Academy) project looks at our planet's future climate in response to different levels of greenhouse gas emissions (the different greenhouse gas emissions scenarios). Due to the greenhouse effect, increased greenhouse gases warm Earth and cause the climate to change.

If we continue to emit a lot of greenhouse gases, the models predict the planet will be really warm by the end of the century (2100). This is the pessimistic scenario. If we reduce our greenhouse gas emissions by around 2050, the models predict less warming. This is called the optimistic scenario. Why is the warmer scenario pessimistic (meaning gloomy or hopeless)? And why is the scenario that involves less warming optimistic (meaning hopeful or having a favorable view)? Warmer temperatures mean things will be really different on our planet. Glaciers may melt, sea levels may rise, and there may be more drought and severe weather.

And a changing climate means the conditions where certain animals and plants can live might also change. All plants and animals have a specific "climate envelope," which is an area with the right temperature and right amount of moisture for them to survive. This is their suitable habitat. It is important to note the difference between their suitable habitat and where species of animals and plants actually live. For example, wolverines could live in the Sierra Nevada in California, but they are actually rarely seen in California. However, as our climate changes, the conditions where plants and animals could live may become more important. You'll understand why in a moment.

Back to the Academy's project: Researchers have selected key (important) species that play an important role in their ecosystem, such as the wolverine and the redwood tree, to study. It would be impossible to model the future habitat of every species! Researchers take the records of where wolverines are actually seen and use them in their models to determine where they may be able to survive in the future.

As the planet warms, the areas where wolverines will be able to survive are predicted to shrink. This is because a warming world will cause the snowpack—which wolverines rely on—to shrink. However, animals and plants can adapt to changes in their environment, and this is why knowing their predicted suitable habitat is important.

If conservation managers know that a certain area (for example a national park) will remain a good place for wolverines to live (called a "climate refuge"), they can work now to protect that area and plan for climate change. Think about it this way: If a place where wolverines actually live today will no longer be habitable for them in 2100, wolverines could move to the protected area—if it is protected now and there is a way for them to get there! But if no areas are protected for wolverines and their suitable habitat shrinks as much as the pessimistic scenario predicts, wolverines, along with many other animals and plants, may become extinct. That's why this research is important!

ABOUT THE AUTHORS

Lori Mann is an environmental education consultant with 30 years experience at the local, state, and national levels. She has worked extensively with curriculum development and has taught many environmental education courses and workshops. She served for 15 years as education director at Coyote Point Museum for Environmental Education in San Mateo, Calif.

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STEM LITERACY

Discussion Questions/Activities

- What is the difference between distribution and forecasted suitable habitat? *(Distribution is where species have actually been recorded; forecasted suitable habitat is based on global climate models.)*
- What is the difference between the optimistic and the pessimistic climate scenarios? *(The optimistic model is based on a reduction in greenhouse gas emissions by 2050; the pessimistic model is based on continued rising greenhouse gas emissions.)* Do you think these scenarios are optimistic and pessimistic for every plant and animal that lives within the changing habitats? *(No. Some animals and plants may thrive in the changing habitats.)*
- Why are scientists interested in predicting the future suitable habitat of animals and plants? *(to help plan for climate change and ensure species and ecosystems will survive into the future)*
- Do scientists know exactly what is going to happen in the future? Brainstorm a list of limitations to this type of research.

ADDITIONAL RESOURCES

Adaptations, Exploring Nature Educational Resource
http://www.exploringnature.org/db/detail_index.php?dbID=5&dbType=2t
This website provides student-friendly background information and examples of interesting adaptations in plants and animals.

Climate Change: Health and Environmental Effects—Adaptation, U.S. Environmental Protection Agency
http://www.epa.gov/climatechange/effects/adaptation.html
Read about the need for adapting to or coping with climate change in certain regions and for certain socioeconomic and environmental systems. The site includes examples of possible adaptation measures in different sectors.

"Deciding When to Move Plants and Animals to Save Them from Global Warming," Cassandra Brooks, Stanford University News
http://news.stanford.edu/news/2009/june10/butterfly-061009.html
This short article introduces a paper from the *Proceedings of the National Academy of Sciences* about managed relocation of species that are likely to find themselves in unsuitable habitat due to climate change.

Indicators of Climate Change in California, April 2009
http://oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicatorsApril2009.pdf
Read a report that presents a compilation of environmental indicators that collectively describe changes to California's climate, the drivers of these changes, and the impacts of such changes on the state.

Using the Very, Very Simple Climate Model in the Classroom, Windows to the Universe, University Corporation for Atmospheric Research
http://www.windows.ucar.edu/tour/link=/teacher_resources/teach_climatemodel.html
This lesson uses a simplified, interactive online model to help students learn about the relationship between average global temperature and carbon dioxide emissions while predicting temperature change over the course of the 21st century. The site also provides student-friendly explanations of climate change, climate models, and global warming.

CLUE into CLIMATE

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Science ready to EXPLORE

Lesson 2c: Animals on the Move

SUBJECT

Life Science

GRADE LEVELS

4–8

CA SCIENCE STANDARDS

Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (b)

Grade 6: Ecology (Life Sciences). 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (e)

Grade 7: Evolution. 3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. (e)

EARTH SCIENCE LITERACY PRINCIPLES

#3: Earth is a complex system of interacting rock, water, air, and life. (3.6, 3.7, 3.8)

#9: Humans significantly alter Earth. (9.3)

OVERVIEW

Species distribution is closely correlated with climate. Over the past 100 years, the natural ranges of many animals have shifted higher in elevation or northward to areas that provide preferred climate conditions. In this lesson, students will learn that scientific surveys are providing evidence that animal populations in Yosemite and along the California coast have shifted over time in response to rising temperatures.

ESSENTIAL QUESTIONS

1. Why are Joseph Grinnell's surveys from the early 1900s important to scientists today? *(Scientists can compare current data with data from 100 years ago to determine whether species' ranges have changed.)*
2. What can happen to animal populations over time in response to an increase in average temperature? *(Populations may shift higher in elevation or move northward.)*
3. Why is the distribution of animal species changing? *(Rising temperatures are changing the location of their preferred climate conditions/suitable habitat.)*

MEDIA RESOURCES

***QUEST* video: "Resurveying California's Wildlife"**
Video length: 7 minutes, 42 seconds
Link: http://www.kqed.org/education/educators/clue-into-climate/distribution-organisms.jsp
Through watching this video, students will learn that:

- Scientists can compare current data with data from 100 years ago to determine whether species' ranges have changed
- The ranges of many animal populations have moved higher in elevation over the last 100 years and this ascent correlates to a rise in temperature
- Scientists have been concerned for many years about the effects of human activities on natural environments

***QUEST/Climate Watch* video: "California at the Tipping Point: The Intertidal Zone and Sea Level Rise"**
Video length: 5 minutes, 40 seconds
Link: http://www.kqed.org/education/educators/clue-into-climate/distribution-organisms.jsp
Through watching this video, students will learn that:

- Ranges of tide pool species along the Pacific coast are changing in response to warming temperatures
- Interactions between tide pool species are altered by the changing distribution of species
- Rising sea levels due to global warming affect coastal habitats

VOCABULARY

bellwether
an indicator or predictor of trends

elevation
height above sea level

genetic diversity
genetic variation within a population

naturalist
an expert in or a student of natural history; a person who studies plants and animals as they exist in nature

retract
to pull away

species
a biological classification consisting of individual organisms capable of interbreeding

suitable habitat
an area where a given species can live because the area's temperature and precipitation levels meet the survival needs of the species

survey
to examine and record the features of an area of land

ACTIVITY 1: JOSEPH GRINNELL'S JOURNAL

Time: 30-45 minutes
Materials:

- Computer with Internet connection
- Projector and speakers
- Handout: Student Worksheet

Procedure:

1. Make copies of and hand out the Student Worksheet (attached). Watch "Resurveying California's Wildlife." Ask students to fill in the worksheet with the names of the animals mentioned, where they were originally found, and where they are found now. Pause the video as necessary to allow students to complete their worksheets.
2. After students write their own responses to the following question, debrief as a class: What do the results of this resurvey tell us about climate change?
3. Have students imagine themselves as Joseph Grinnell joining a current survey in Yosemite. Have each student write a journal entry comparing Grinnell's original survey results with what he would observe today.

ACTIVITY 2: CLIMATE CHANGE FROM COAST TO MOUNTAIN

Time: 30 minutes
Materials:

- Computer with Internet connection
- Projector and speakers
- Chart paper
- Markers
- Handout: Student Worksheet

Procedure:

1. Make copies of and hand out the Student Worksheet (attached). Watch "The Intertidal Zone and Sea Level Rise." Ask students to take notes about the effect of climate change on specific tide pool animals. Play the video a second time if necessary.
2. Have students create Venn diagrams comparing the effects climate change is having in Yosemite (Activity 1) with its effects along the California coast.
3. In groups of three or four, have students use their Venn diagrams to help them create futures wheels around this central question: What might happen to animals along the coast if global warming continues at its present rate? (Similar to a concept map, a futures wheel poses a "what if" question in a central circle, then, in radiating circles, identifies potential ramifications of successive changes.) Have groups create their wheels on chart paper and post them when completed. For an online template of a futures wheel that can be constructed and saved, go to: http://www.exploratree.org.uk/app/?document_id=977&permission_id=template.
4. Ask students to individually review all of the futures wheels and write down three conclusions about the effects of global warming. As a class, identify the most common conclusions, see if any of them conflict, and discuss the conflicts, if any.
5. Optional extension: Have students discuss or debate the opinion expressed in these statements: "People should not get involved in managing nature. We should let plants and animals respond naturally to global warming."

WHAT CAN WE DO?

Make others aware of this relatively unreported climate change effect. Tell your brothers and sisters about how animals are moving to higher elevations due to climate change.

MEDIA LITERACY

Discussion Questions/Activities

- Different people believe different things about climate change and whether it is a serious problem. How might this affect the information presented in media about climate change? Ask students to consider what a person's views on climate change might be, based on his or her public role.
- Sometimes, people choose particular words to present information about climate change in order to influence what the viewer/listener will believe. Can you find any words in "The Intertidal Zone and Sea Level Rise" that might affect people's opinions?
- How can statistics be biased?
- When you watch or listen to media on climate science, what questions should you ask yourself in order to figure out if the material is accurate?

ASSESSMENT IDEAS

- Students write journal entries that reflect the influence of climate change on species distribution.
- Students write paragraphs explaining why species may not be able to shift their ranges endlessly.

ABOUT THE AUTHOR

Lori Mann is an environmental education consultant with 30 years experience at the local, state, and national levels. She has worked extensively with curriculum development and has taught many environmental education courses and workshops. She served for 15 years as education director at Coyote Point Museum for Environmental Education in San Mateo, Calif.

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SUPPORT

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ADDITIONAL RESOURCES

Bird Adaptation and Survival, Ocean News, Bamfield Marine Sciences Center
http://oceanlink.island.net/ONews/ONews7/sea_birds_lp.html
In this lesson, students examine bird characteristics and make predictions about which birds are best suited to a changing climate.

Early Warning Signs of Global Warming: Plan and Animal Range Shifts, Union of Concerned Scientists
http://www.ucsusa.org/global_warming/science_and_impacts/impacts/early-warning-signs-of-global-7.html
Read about what global biome models suggest about animal and plant distribution and how it may change in response to global warming.

Observed Impacts of Climate Change in the United States, Pew Center on Global Climate Change
http://www.pewclimate.org/global-warming-in-depth/all_reports/observedimpacts
Download a 67-page report that reviews the broad range of ecological changes that have occurred in response to human-induced changes in the global and U.S. climate.

Photos: Ten U.S. Species Feeling Global Warming's Heat, National Geographic News
http://news.preview.nationalgeographic.com/news/2009/12/photogalleries/091211-ten-threatened-species-animals-global-warming-pictures/index.html
See photos and read brief statements about ten endangered species under added threat from global warming.

Terry L. Root, Ph.D.
http://terryroot.stanford.edu/
Watch a 30-minute interview with Dr. Terry Root, Senior Fellow for Woods Institute of the Environment, Stanford University, during which she discusses the effect of climate change and global warming. The site also includes informative articles and Dr. Root's presentation at the Fifth Annual California Climate Change Conference in 2008.

STUDENT WORKSHEET

"Resurveying California's Wildlife" Viewing Chart

Directions: Complete this chart as you watch the video.

Animal	Where it was originally found by Grinnell	Where it is found today	Any interesting information about the animal

What do the results of this resurvey tell us about climate change?

STUDENT WORKSHEET

"The Intertidal Zone and Sea Level Rise" Viewing Chart

Directions: Complete this chart as you watch the video.

Animal	How is climate change affecting this animal?

CLUE into CLIMATE

KQED education network

Science ready to EXPLORE

Lesson 2d: Plants in Peril

SUBJECT

Life Science

GRADE LEVELS

4–8

CA SCIENCE STANDARDS

Grade 4: Life Sciences. 3. Living organisms depend on one another and on their environment for survival. (b)

Grade 6: Ecology (Life Sciences). 5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. (e)

Grade 7: Evolution. 3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. (e)

ESSENTIAL PRINCIPLES OF CLIMATE LITERACY

#3: Life on Earth depends on, is shaped by, and affects climate. (A, C)

#7: Climate change will have consequences for the Earth system and human lives. (E)

OVERVIEW

Like animals, plants can respond to climate change by moving to cooler areas, whether northward or to a higher elevation. However, unlike animals, plants can move only over the course of multiple generations. The pace of climate change may be too fast for plants to shift their ranges. In this lesson, students will learn about the particular challenges that plants face in responding to global warming.

ESSENTIAL QUESTIONS

1. What do climate models tell us about the future of plant life in California? *(that most of California's native plants will be gone by the end of the century; two-thirds of native plants in California face a loss of 80 percent of their habitat)*
2. What happens to plant populations over time in response to an increase in average temperature? *(They move to a higher elevation or migrate north.)*
3. What is the primary difference between plants and animals in their ability to respond to climate change? *(Plants can move only over the course of multiple generations; the pace of climate change may be too fast for plants to survive.)*

MEDIA RESOURCE

***QUEST* video slideshow: "Disappearing Plants"**
Slideshow length: 5 minutes, 12 seconds
Link: http://www.kqed.org/education/educators/clue-into-climate/distribution-organisms.jsp
Through watching this video, students will learn that:

- A change of less than one degree in average temperature in an area can result in completely different vegetation patterns in that area
- Climate models project widespread loss of habitat for about two-thirds of California's plants
- Plants' ability to withstand a rise in average temperatures is limited by the rate at which they are able to migrate to cooler climates

VOCABULARY

climate model
a mathematical model based on data from global cycles that drive Earth's climate system that helps scientists predict changes in our planet's climate over time

endemic
native or restricted to a particular area

migrate
move from one region or habitat to another

native
a plant or animal that occurs naturally in a particular place

ACTIVITY 1: THE TIME FACTOR

Time: 30 minutes
Materials:

- Computer with Internet access
- Projector and speakers

Procedure:

1. Ask students the following question: Animals may be able to move in response to warming temperatures, but can plants? Discuss as a class.
2. Watch "Disappearing Plants." Have students take notes about the effects of rising global temperatures on the distribution of plants in California.
3. As a class or in small groups, discuss the following questions:
   - What do climate models tell us about the future of plant life in California?
   - What might happen to the natural ranges of native plants in response to global warming?
   - What is the most significant difference in the ability of plants and animals to adapt to climate change?
4. The video raises the question of managing for climate change by moving endangered plant systems north in advance of rising temperatures. Debate or chart the pros and cons of this management technique.

ACTIVITY 2 WHAT A DIFFERENCE A DEGREE MAKES

Time: 50 minutes plus time to monitor
Materials:

- Two identical terrariums
- Twelve plant starts (or radish seeds that can be germinated in class)
- Two grow lights
- Thermometers
- Black plastic sheeting
- Soil

Procedure:

1. If possible, visit a natural area similar to the Jasper Ridge site mentioned in the "Disappearing Plants" video. Survey the area and compare the vegetation on two sides of a ridge or canyon that have different average temperatures due to the angle of the sun.
2. Design and conduct an experiment to test the effects of temperature on plant growth. Encourage students to come up with experimental design conditions based on previously discussed environmental differences and identify expected outcomes for comparison with actual results. Following is an example of an experimental design:
   a. Set up two identical terrariums with six plants each.
   b. Cover the terrariums in black plastic and insert a grow light to create a constant light level.
   c. Place the terrariums in locations with two different temperatures (such as near a heat vent and in a cool closet).
   d. Water both terrariums equally.
   e. Monitor the temperature of each terrarium.
   f. Monitor and chart plant growth over time.
   g. After six weeks, draw conclusions about the effect of temperature on plant growth.
3. Optional extensions: Conduct the same experiment except vary moisture or sunlight.
4. Discuss the results of the experiment and what they suggest about global climate change.

WHAT CAN WE DO?

Plant trees. Use paper with a high percentage of post-consumer recycled fibers. Purchase paper manufactured from sustainably harvested forests. Use paper made of wood-free fibers, such as kenaf.

CLIMATE CAREERS

Discussion Questions/Activities

- This video slideshow features several people working in jobs related to climate science. What are some of the jobs these people have?
- If Joseph Grinnell, a naturalist who studied California around 1900, were to participate in an ecosystem survey today, what new skills might he have to learn and/or what technologies would he have at his disposal to inform him?
- Scientists need to be involved in making decisions about managing wildlife as the climate changes. Who else might be involved in these decisions? What kinds of careers might they have?
- Invite a speaker from the National Park Service, the U.S. Geological Survey, or a park near you to discuss the effects of climate change in your area.

ASSESSMENT IDEA

- Have students write a story from the perspective of a plant facing a warming climate. The story should describe the potential effects of temperature change and how the plant might respond.

ABOUT THE AUTHOR

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ADDITIONAL RESOURCES

Climate Change Action Projects, Facing the Future
http://www.facingthefuture.org/ServiceLearning/ClimateChangeActionProjects/tabid/350/Default.aspx
Follow links to a variety of climate change action projects in the United States and worldwide that are appropriate for student involvement.

Climate Change: Connections and Solutions, Facing the Future
http://www.facingthefuture.org/Home/CurriculumDetails/tabid/131/Default.aspx?ItemID=CCMS
This downloadable 128-page middle school curriculum includes hands-on activities, readings, and handouts that encourage students to think critically about climate change and to collaborate to devise solutions. Students examine interconnections among environmental, social, and economic issues.

Climate Change Kids Site, U.S. Environmental Protection Agency
http://epa.gov/climatechange/kids/index.html
This student-friendly site explains global warming and its potential effects on plants, animals, and human societies. It includes games and links to additional information as well as ideas and resources for teachers.

Effects of Global Warming Already Being Felt on Plants and Animals Worldwide, Stanford News Service
http://news.stanford.edu/pr/03/root18.html
This news release describes a study published in the journal *Nature* that identifies effects of global warming already in evidence in plant and animal populations.

Global Warming—Tracking the Effects of Climate Change on Plants, by Niall Dunne, Brooklyn Botanic Garden
http://www.bbg.org/gar2/topics/sustainable/2003fa_globalwarming.html
Read an article that describes the effects of climate change on garden plants and in natural ecosystems. The articles introduces shifts in timing, density, and range of plant populations in response to warming temperatures and discusses the disruptions caused by the differential nature of such responses (species responding individually rather than as a unified whole).