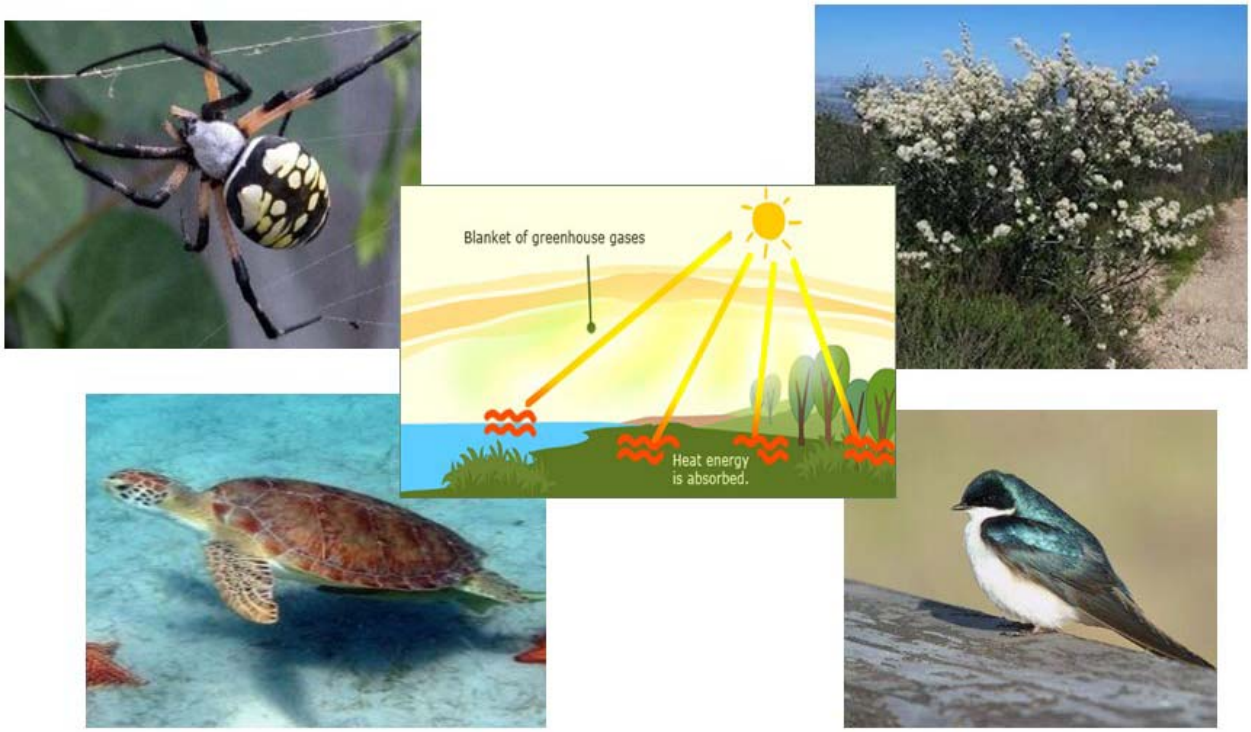
Climate Change in San Diego's Local Environment: Lessons in Schoolyards and on Field Trips



Lessons aligned with Next Generation Science Standards

Written for Middle School teachers and students in the San Diego region

November 2, 2016

SD Children & Nature

San Diego County Office of Education

CREEC Network
California Regional Environmental Education Community

Tijuana River National Estuarine Research Reserve

Living Coast Discovery Center
San Diego Bay at Chula Vista

Climate Science Alliance

Climate Change in San Diego's Environment: Lessons in Schoolyards and on Field Trips

These lessons follow the communication model of providing explanations for the science of climate change that make sense to the average citizen. Students develop explanatory chains using the metaphor of increased carbon dioxide creating a "heat-trapping blanket." Students start in their schoolyard (Part 1) by measuring temperatures in different microclimates, and then explore predicted effects of climate change in the San Diego region. Field visit (Part 2) emphasizes how climate change may impact local natural areas and wildlife. After the field visit (Part 3), students learn and communicate about a local plant or animal adaptation to climate change, in the Climate Change Challenge Project.

Contents

Please send suggestions on content, teaching approach, and format to annemarie.tipton@parks.ca.gov and afege@sdchildrenandnature.org .

Learning Outcomes

By the end of this unit, students will be able to answer these questions:

1. What will happen in San Diego, when the climate changes?
2. What will be some of the effects on plants and animals? How can they adapt?

At the conclusion of these lessons, students will be able to:

1. Measure and compare temperatures in various microclimates.
2. Develop an explanatory chain for the "heat-trapping blanket" metaphor on climate change impacts on plants and animals in San Diego.
3. Provide evidence for and communicate the predicted effects of climate change on local animals and plants.

Next Generation Science Standards (NGSS)

This lesson is based on the following NGSS Performance Expectations:

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Disciplinary Core Ideas

MS-ESS2.D: Weather and Climate

MS-ESS3.D: Global Climate Change

MS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Crosscutting Concepts

Cause and Effect. Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Stability and Change. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. (MS-ESS3-5)

Science and Engineering Practices

Constructing Explanations and Designing Solutions.

Common Core State Standards for Literacy

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Vocabulary

Adaptation: adjustment of natural or human systems to a new or changing environment

Drought: less rainfall than is expected over several months or years

Explanatory chain: a series of clear causal descriptions of the processes that connect factors to outcomes

Heat-trapping blanket: the effect of carbon dioxide trapping heat in the atmosphere, resulting in climate warming and other impacts (another name for "greenhouse effect")

Microclimate: an area where the temperature and other atmospheric factors consistently differs from the surrounding area

Mitigation: activities that reduce the human impacts on the environment

Urban heat islands: areas in cities that are warmer because of the built environment

Other definitions for climate change terms are provided in http://www3.epa.gov/climatechange/glossary.html

Teacher Preparation

These lessons follow the communication model of providing explanations that make sense to the average citizen. Students will develop explanatory chains using the metaphor of increased carbon dioxide creating a "heat-trapping blanket."

Climate change education includes the sources of greenhouse gases, evidence for changes, mitigation and adaptation strategies, student actions, and more. These lessons only provide part of this broad education - they feature changes and impacts in the natural environment and get students outdoors (in their schoolyard and field trip or nearby park).

Scientists around the world have made detailed observations of the impacts that climate change has already made on ecosystems. It is difficult to make future projections based on these observations because of the complexities involved in human/nature interactions (e.g., land use change). Nevertheless, the observed changes are compelling examples of how rising temperatures can affect the natural world and raise questions of how vulnerable species will adapt to direct and indirect effects associated with climate change. [Background from https://downloads.globalchange.gov/toolkit/Teacher_Guide_6_9_09.pdf]

Students will start in their schoolyard (Part 1) by measuring temperatures in different microclimates, then explore predicted effects of climate change in the San Diego region. Field visit (Part 2) emphasizes how climate change may impact local natural areas and wildlife. After the field visit (Part 3), students learn and communicate about a local plant or animal adaptation to climate change, in the Climate Change Challenge Project.

Logic for Heat-trapping Blanket Metaphor

Students will create explanatory chains, which are clear causal descriptions (statements) of the processes that connect determinants (factors) to outcomes.

Burning fossil fuels like coal, oil, or gas has created a heat-trapping blanket around our planet. This “blanket” is causing climate change. This is another name for the “Greenhouse effect” of climate change.

A general explanatory chain is:

When we burn fossil fuels like coal, oil and gas for energy, we pump more carbon dioxide ($CO_{2)}$ into the atmosphere.

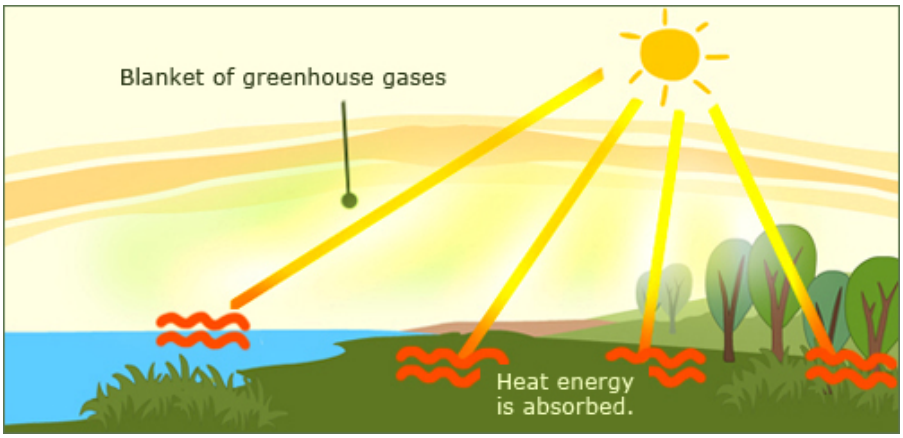
The carbon dioxide in the atmosphere acts like a blanket, trapping in heat.

In the atmosphere, this CO_2 acts like a heat-trapping blanket, trapping in some of the earth’s heat that would otherwise escape to space.

As we burn more fossil fuels and trap more heat, our planet is warming.

Seasonal temperatures determine when insect-eating birds like Cliff Swallows lay their eggs. As the warmer weather starts earlier in the spring, the swallows’ egg laying has advanced by up to two weeks.

Swallow chicks rely on insects for food, and there may be no insects when the chicks need to feed. Therefore the swallow chicks may not survive to adulthood.



Draft prepared by Climate Change Lessons team led by Anne Marie Tipton - California State Parks. Also Crystal Howe - San Diego Unified School District and California Regional Environmental Education Community (CREEC), Crystal De Soto - Local Point of View Tours, Amanda Grant - Living Coast Discovery Center, Lorena Warner-Lara and Marya Ahmad - California State Parks, and Leta Bender, Judie Lincer, Anne Fege and Su Scott - San Diego Children and Nature.

Comments are welcome on content, teaching approach, and format. Send to annemarie.tipton@parks.ca.gov and afege@sdchildrenandnature.org .

Part 1. Climate in the Schoolyard

Students will measure temperatures in different microclimates, develop explanatory chains relating to the heat blanket effect, and then explore predicted effects of climate change in the San Diego region.

Learning objectives

At the conclusion of these lessons, students will be able to:

Measure and compare temperatures in various microclimates

Develop an explanatory chain for the “heat-trapping blanket” metaphor on climate change impacts on plants and animals in San Diego.

Engage: Feeling the heat

Time: Two blocks of 45-minutes each

Materials

A sunny, warm day

Infrared thermometers (IR thermometers) or digital pocket thermometers - one for each group of 3 to 4 students

Maps of schoolyard

Stopwatches

Data collection table in student journals (either copy for students to glue in or have students copy into their journals directly)

Making a diagram

Discuss what students notice about temperatures in different places in the schoolyard, at different times of the day. It is much hotter in an asphalt parking lot, than under the trees in the schoolyard or in a nearby park. In groups of 2 to 4, students make a diagram of the energy and heat flow to illustrate this. This is the students’ model of how and why temperature varies in the built environment.

Ask students to predict which areas of the schoolyard are the warmest and which are the coolest, on a sunny day. Mark these areas on a schoolyard map.

Science methods

Show students how to use the thermometers and remind them that each measurement is taken the same distance from the ground. (It's important that all groups collect data from several exact heights above the ground so that data can be compared.)

If using IR thermometers, remind students to point the thermometer directly at the ground surface they wish to measure (i.e., concrete, asphalt, grass, dirt, etc.)

If using digital thermometers, remind students to keep it in place for at least two minutes and to shade the thermometer from direct sunlight while taking a measurement.

Infrared thermometers (IR thermometers) are recommended for this activity. IR thermometers measure temperature by assessing the amount of energy emitted from an object. When sunlight hits the Earth surface, some of that energy is absorbed and some is reflected. The energy that is absorbed heats and is radiated from the surface. Students can alternatively use digital thermometers as long as they measure to tenths of degrees, but it might be more difficult for them to see the patterns emerge, especially if there is any wind. [from http://www.windows2universe.org/teacher_resources/teach_heat.html]

Science observations

Students record the following in their science journals:

Prediction of areas that are warm:

Prediction of areas that are cool:

Go outside into your schoolyard on a sunny, warm day.

Ask students to look around and make predictions about which areas of the schoolyard are the warmest and which are the coolest.

Choose areas of the schoolyard that students have identified. Students will collect temperature data in these areas. Make sure that there is a mix of sunny and shaded areas as well as a mix of paved and grass/natural areas. Provide school maps to each team to mark where they will collect data.

Provide each student group with the listed materials and assign them one of the chosen areas of the schoolyard.

Data acquisition and analysis

Groups walk to their locations, and record descriptive information about each location on their data collection chart. Use thermometers to record the temperature, following the agreed-upon protocols of amount of time (one minute) and distance from the ground (about 1 meter).

Students record data in their science notebooks, using table similar to this:

Duration of thermometer reading:

Distance from the ground:

Sample #	Location	Temperature reading (degrees)	Surface material	Shaded or sunny (full or partial shade)
1				
2				
3				
4				

In the classroom, create a chart of the locations, or project a large school map to show locations of data collection.

Student groups fill in data on a chart about their location including average temperature, sun/shade, and ground cover/habitat.

Class discussion

Are the results what students predicted?

Introduce the concept of microclimates. A microclimates in an area where the temperature and other atmospheric factors consistently differs from the surrounding area

Ask students what aspects of the environment affect temperature in these areas. (The most likely result is that areas in the sunshine were warmer than those in the shade, and areas that had a paved surface were warmer than grass or natural areas.)

Ask students, based on these results, which they think would be warmer: urban areas or rural areas. (In urban areas where surfaces like asphalt and concrete are abundant, temperature will be higher.)

Introduce the concept of urban heat islands (see Student Reading)

Students look at the diagrams they drew of the energy and heat flow in their schoolyard. Then each group redraws their diagram, based on the evidence they collected about temperatures in different microclimates.

Based on their temperature data, ask students why one organism would do well in one area and not in another?

Where might we find more organisms?

What areas in the schoolyard are most comfortable for humans (middle school students)?

What would happen if the cooler areas continued to warm? (Students may bring up speed of adapting, ability to find available new habitats, and ways to help prevent urban heat islands.)

What are the effects of continued warming (heat waves) on human health? What people are most affected? (older, young, asthma)

Extension: Demonstrating the "heat-trapping blanket"

Demonstrate how a "heat-trapping blanket" increases the temperatures inside a plastic bottle.

Set up activity to measure temperature differences between painted bottle (clouded sky), unpainted bottle, and white and black sand. Cut top off some bottles to allow air flow.

Students can predict what will happen to the temperature in the greenhouse (bottles) when the lamp is turned on? What conditions will result in the highest temperatures? Why?

[Lesson posted at http://trnerr.org/wp-content/uploads/2016/10/Birch_Greenhouse_Activity.pdff]

Explain: What causes climates to change?

Time: 45-minutes (including assignment of the reading for San Diego 2050 report, next lesson)

As recommended by the National Network for Ocean and Climate Change Interpreters (www.climateinterpreter.org), we are swapping the metaphor of **Greenhouse Effect** with the metaphor of a **heat-trapping blanket** because people can better relate to the idea of living under too many blankets.

Show the 3-minute video Climate Science in a Nutshell: Too Much Carbon Dioxide (http://planetnutshell.com/portfolio/too-much-carbon-dioxide/) to summarize the role of carbon dioxide in the atmosphere and how the rise of carbon dioxide is adding "too many blankets" on the Earth.

> Ask students to diagram in their science notebooks how the atmosphere becomes a heat-trapping blanket based on what they saw in the video.

Based on their diagrams, use a class discussion to create an explanatory chain for climate change using the heat-trapping blanket metaphor. After the class comes up with the explanatory chain, students should add this to their notebooks.

> Example: The sun's rays enter the earth's atmosphere → some of the rays are reflected back out into space, some are absorbed by earth, some are trapped in the atmosphere → more CO2 enters the atmosphere from human actions →the atmospheric blanket thickens → more heat from the sun is trapped → the climate changes

Questions to ask:

> Isn't the atmosphere already a blanket? Are we making the blanket thicker?
>
> When air temperatures are increased, what effects does that have on the weather? Water cycle? Soil?
>
> What happens when ocean temperatures are increased? (melted glaciers and ice sheets, increased water temperatures, increased water volume at the warmer temperatures, increased acidity)

Extension: The chemistry of greenhouse gases

When sunlight reaches Earth's surface, it can either be reflected back into space or absorbed by Earth. Once absorbed, the planet releases some of the energy back into the atmosphere as heat (also called infrared radiation). Greenhouse gases (GHGs) like water vapor (H2O), carbon dioxide (CO2), and methane (CH4) absorb energy, slowing or preventing the loss of heat to space. In this way, GHGs act like a blanket, making Earth warmer than it would otherwise be. This process is commonly known as the "greenhouse effect". More chemistry at https://www.epa.gov/climatechange/.

Activity that uses construction paper, ribbon, and all students in the classroom to illustrate the carbon cycle and how atoms combine and recombine, https://downloads.globalchange.gov/toolkit/Carbon_Cycle_A1%20_6.9.09.pdf

Explore and Explain: What could happen in San Diego?

Time: 45-minutes

Students refer to their notebook for the explanatory chain.

Students are asked to write predictions of how they think climate change might affect their community or neighborhood.

Explore how San Diego will be impacted by climate change. The Sea level rise simulator (https://coast.noaa.gov/digitalcoast/tools/slr) is an interactive tool that allows students to see how San Diego and the world will be impacted by sea level rise. Use the simulator to highlight your neighborhood, local areas most impacted, and national or international areas with big impacts. If appropriate, allow students to use the simulator. San Diego is expected to have a rise of 12-18 inches by 2050.

Divide class into teams. Each team will receive one of the four parts of the San Diego 2050 report. Students will use their assigned reading section to add to the explanatory chain for climate change that was created as a class for the impact of climate change in their topic.

This exercise will help students explain how climate change will affect the local animals in their research project. Each wildlife challenge will be linked to at least one of the changes predicted for San Diego.

Pass out pages 8-15 of the report to student groups, “San Diego, 2050 is Calling. How will we answer?” (http://www.sandiego.edu/2050/)

Discuss how regional changes in temperature and rainfall fuel drought, coastal flooding, wildfires, threats to wildlife and even public health.

Four likely impacts, to weave into the explanatory chains.

Drought: Warming, compounded by less frequent precipitation, will worsen droughts and threaten our imported and local water sources. (10-11)

Increased temperatures: We expect to experience hotter and more humid heat waves and less frequent but more intense rainfall. (8-9)

Flooding: Extreme high tides and winter storms magnified by sea level rise will result in more frequent and widespread coastal flooding. (pgs. 12-13)

Wildfires: Wildfire seasons may be longer and more extreme, with warming temperatures, drier soils and vegetation and less frequent rains. (pgs. 14-15)

Teams will write the San Diego Climate Challenge on large sheets of paper to post around the room. This should illustrate the local explanatory chains for climate change using the blanket metaphor.

Part 2. Go on a field trip!

Field visit emphasizes how climate change may impact local natural areas and wildlife. Self-guided field trips may also provide the opportunity for students to measure and compare temperatures in natural settings, at the field trip site, with those in their schoolyard.

Additional preparation for the field trip

Students gather additional information about the field site.

What is the local climate? How has the local climate changed in the past?

Identify the common plants in that natural area. What are the common animals?

What plants and animals are threatened or endangered?

Students can bring thermometers and measure the difference between various microclimates (for example, just above bare soil and grass, under and over shrubs, in shade of tree, south and north-facing slopes).

Students make a list of questions to ask the rangers, land managers, and naturalists who lead the field trip.

What climate changes do they expect at this location?

What effects will those have on two or three local plants and animals?

What solutions could mitigate or reduce those effects? (also ask students)

What are the other human threats of climate change to local plants and animals?

Field trip opportunities

Field trip provider	Field trip focus
Tijuana River National Estuarine Research Reserve	Grades 6-12. Field trips to the Tijuana Estuary.
Field trip destinations at SDCaN_FieldTripList	

Field trip may be a walk to nearby park or nature area.

Take temperature measurements in the shade and full sun, under trees and on the grass.

Invite local gardener landscape architect or other professional to show students 4-5 different planting beds, and why those plants grow well in those microclimates.

Invite local park ranger to meet the class there, and ask questions about local climate, plants and animals, and the City's programs for climate change effects and adaptations.

Part 3. Local impacts of climate change

After the field trip or visit to nearby park, students learn and communicate about a local plant or animal adaptation to climate change, in the Climate Change Challenge Project.

Evaluate: Compare field and schoolyard temperatures

Time: 15 minutes

In a class discussion, compare outdoor temperatures in various locations in the schoolyard with those in the natural areas.

What are the differences?

What evidence does this provide for the Urban Heat Island effect?

What did you learn from the field trip hosts?

What climate changes do they expect?

What effects will those have on local plants and animals?

What are they doing to mitigate those effects?

What did they tell you about their jobs and careers?

Elaborate: What will happen to local animals and plants?

Time: Two 45-minute class periods

Teacher preparation

Review the San Diego 2050 Report

Review the 3-page NOAA Communicate Climate Change Activity

Identify a timeline for the student research project and presentation.

In teams, students will research how local populations of plants and animals may be impacted by climate change. Students may choose a species from the Wildlife Climate Challenge Species List (student handout) or identify another local plant or animal.

What habitat(s) does your plant or animal rely on for survival? Some animals rely on multiple habitats.

What are the biggest climate challenges for your animal? Be as specific as possible (drought, coastal flooding, wildfires). Revisit the San Diego Climate Challenges as needed.

Are there any other environmental challenges that your animal is dealing with? (habitat loss, over fishing, pollution, etc.) If the species is federally listed as sensitive, threatened, or endangered it currently facing big environmental challenges.

Complete an explanatory chain about how the local population of your animal will likely respond to climate change. Based on your research, will the species **adapt**, **migrate** to new habitats or become **extinct**?

Student teams develop a solution to help keep this plant or animal in its current habitat and alive for generations to come.

What impacts would there be on similar animals in other parts of the world? What about those areas with Mediterranean climates?

Evaluate: Communicate local impacts on wildlife

Time: Two 45-minute periods

In teams, work to develop a presentation on the potential impacts of climate change on a local plant or animal. Students present their findings to the class (create a PSA, poster, give a talk, video) using the explanatory chain framework for guidance.

Review how others are communicating climate change, at http://oceanservice.noaa.gov/education/discoverclimate/NOAA_Activity%209_Communicate.pdf .

Sample Wildlife Message

"The gray jay is a montane boreal (mountain tree) specialist that could be particularly sensitive to climate change because it catches food using frozen spit." David King, U.S. Forest Service

Why is the gray jay sensitive to climate change?

When we burn fossil fuels like coal and petroleum for energy, we pump more carbon dioxide into the atmosphere. The carbon dioxide builds up in the atmosphere and acts like a blanket, trapping in heat. This heat increases average temperatures in the mountains. Gray jays live in mountain trees where the average temperature is at freezing or below. Gray jays use frozen spit to catch their food, so they will move to higher elevations to hunt as temperatures warm. If mountain temperatures continue to warm, gray jays will most likely run out of suitable hunting habitat and become extinct.

References on Climate Change Impacts

Climate change

Science and climate change, www.climate.gov

Science and climate change, https://www3.epa.gov/climatechange/

Facts and other "vital signs" of the planet, http://climate.nasa.gov/

"Climate Kids" activities for weather and climate, plants and animals, http://climatekids.nasa.gov/

Glossary for Climate change, wildlife and wildlands, http://downloads.globalchange.gov/toolkit/Glossary_Entire_wout_Citations_6_9_09.pdf

Frequently-asked questions about climate change, http://downloads.globalchange.gov/toolkit/Climate_Basics_8pager_508_v4.pdf

Communicating about climate change

Creating messages about climate change, http://oceanservice.noaa.gov/education/discoverclimate/NOAA_Activity%209_Communicate.pdf

The value of explanatory chains in reframing climate change, http://www.frameworksinstitute.org/assets/files/occ_values.pdf

Climate literacy: The essential principles of climate sciences. Sun is the primary energy. Climate is complex. Life affects climate—and climate affects life. Climate is variable. Scientists study climate. Humans affect climate. Climate change has consequences. 17-page report. https://www.climate.gov/teaching/essential-principles-climate-literacy/essential-principles-climate-literacy (also Spanish)

Curriculum and lessons

Wildlife and Wildlands Educators' Toolkit for middle school students, http://www.globalchange.gov/browse/educators/wildlife-wildlands-toolkit. Separate documents for impacts of climate change on birds and fish.

Two-week middle school lesson plan about climate change, "Facing the Future, Climate Change: Connections and Solutions, Grades 6-8" 128 p., .pdf download at https://www.facingthefuture.org/collections/all

Global Climate Change curriculum for middle school, 18 units, https://pangea.stanford.edu/programs/outreach/climatechange/curriculum/middle-school

Links to NGSS components, https://www.climate.gov/teaching/national-climate-assessment-and-next-generation-science-standards

Climate Change Education website, http://www.climatechangeeducation.org/

Mobile apps about climate change, http://climate.nasa.gov/earth-apps/

How we know what we know about our changing climate: Scientists and kids explore global warming (book), L. Cherry and G. Braasch, 2008, 66 p. Excerpts

from Teachers' guide at http://youngvoicesonclimatechange.com/pdf/Anya-Citizen-Science_curriculum.pdf

Urban heat island

Lessons about urban heat island, http://www.windows2universe.org/teacher_resources/teach_heat.html

Resources on Heat Island Effects, http://www.epa.gov/heatisld/index.htm

Wildlife and climate change

Video about wildlife and climate change, 13 minutes, http://www.globalchange.gov/browse/educators/wildlife-wildlands-toolkit/video

Effects on birds, mammals, amphibians, and reptiles, http://www.fs.usda.gov/ccrc/topics/wildlife

Wildlife in a warming world, National Wildlife Federation, x p., http://www.nwf.org/pdf/Reports/NWF_Wildlife-Warming-World_Report_web.pdf

EPA website with impacts on ecosystems, including seasons, ranges, food webs, pathogens and pests, and extinction, https://www3.epa.gov/climatechange/impacts/ecosystems.html

Regional impacts of climate change

San Diego, 2050 is Calling, How will we answer? http://www.sandiego.edu/2050/

Climate change impacts in the southwest U.S., https://www3.epa.gov/climatechange/impacts/southwest.html

Teaching about climate change in the southwest, https://www.climate.gov/teaching/southwest-region

Local plants and animals

Illustrated guides and checklists of San Diego's mammals, reptiles and amphibians, and arthropods (insects), http://www.sdnhm.org/science/field-guide/

Plants native to San Diego, http://www.cnpssd.org/plantlistlinked.html

Plants and their growing conditions, http://plants.usda.gov/about_plants.html .

Birds and their habitats, http://allaboutbirds.org/guide/search/

Student Reading on Climate Change Impacts

What are microclimates?

The term microclimate can be used to describe differences between small areas of just a few square meters or much larger areas a few kilometers apart. Relatively small differences in the schoolyard reflect different microclimates. The areas on the coast and in the inland valleys in San Diego have different microclimates.

What is the "urban heat island" effect?

An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surroundings. Many cities have air temperatures up to 10°F (5.6°C) warmer than the surrounding natural land cover. This temperature difference usually is larger at night than during the day and larger in winter than in summer, and is most apparent when winds are weak.

Heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb - rather than reflect - the sun's heat, causing surface temperatures and overall ambient temperatures to rise. Temperatures decrease at night, after the sun sets, and cities don't cool as much because there is heat stored in the roads, buildings and other structures.

Trees and other vegetation shade the ground, preventing radiation from the sun from being absorbed. Without them, the ground surface heats up. The evaporation of water from soil and leaves (evapotranspiration) cools the air. Tall buildings and narrow streets can heat air trapped between them and reduce air flow. Waste heat from vehicles, factories, and air conditioners may add warmth to their surroundings. In addition, the haze of air pollution that hangs over many cities can act as a miniature greenhouse layer, preventing outgoing thermal radiation (heat) from escaping from urban areas. [Adapted from http://www.windows2universe.org/earth/climate/urban_heat_islands.html]

How will climate change affect animals?

For many years plants and animals of all types have interacted with each other in well-established patterns that depend on specific signals in the climate (cues), such as temperature ranges and precipitation levels. However, as climate change occurs, these reliable climate cues will shift, prompting new and different responses in the organisms that rely on these cues and on each other for survival.

The separation of ecological relationships is perhaps the largest climate change impact facing animals. As temperatures increase, models predict that some species, both plant and animal, will begin to migrate toward the poles and to higher elevations in search of cooler temperatures. Plants will change their seasonal pollination and seed dispersal events in response to changing climate cues. Extreme weather events may eliminate habitat or cause population mortality. [Adapted from http://downloads.globalchange.gov/toolkit/Birds_6_9_09.pdf]

What are some ways that ecosystems are disrupted by climate change?

Climate is an important environmental influence on ecosystems. The physical environment and the plants and animals are affected by the average and extreme temperatures and precipitation, and by extreme weather events such as storms and droughts.

For many species, the climate where they live or spend part of the year influences key stages of their annual life cycle, such as migration, blooming, and mating. As the climate has warmed in recent decades, the timing of these events has changed in some parts of the country.

As temperatures increase, the habitat ranges of many North American species are moving northward in latitude and upward in elevation. While this means a range expansion for some species, for others it means a range reduction or a movement into less hospitable habitat or increased competition. Some species have nowhere to go because they are already at the northern or upper limit of their habitat.

Climate change and shifts in ecological conditions could support the spread of pathogens, parasites, and diseases, with potentially serious effects on human health, agriculture, and fisheries.

In some cases, ecosystem change occurs rapidly and irreversibly because a threshold, or "tipping point," is passed.

[Adapted from https://www3.epa.gov/climatechange/impacts/ecosystems.html]

Where can additional information be found?

Science and climate change, www.climate.gov

Science and climate change, http://www.epa.gov/climatechange/

San Diego, 2050 is Calling, How will we answer? http://www.sandiego.edu/2050/

Climate change impacts in the southwest U.S., https://www3.epa.gov/climatechange/impacts/southwest.html

Climate Change Education website, http://www.climatechangeeducation.org/

Illustrated guides and checklists of San Diego's mammals, reptiles and amphibians, and arthropods (insects), http://www.sdnhm.org/science/field-guide/

Plants native to San Diego, http://www.cnpssd.org/plantlistlinked.html

Plants and their growing conditions, http://plants.usda.gov/about_plants.html .

Birds and their habitats, http://allaboutbirds.org/guide/search/

Effects on birds, mammals, amphibians, and reptiles, http://www.fs.usda.gov/ccrc/topics/wildlife

Wildlife in a warming world, National Wildlife Federation, 48 p., http://www.nwf.org/pdf/Reports/NWF_Wildlife-Warming-World_Report_web.pdf

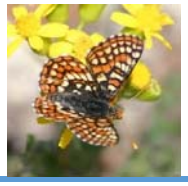
Handout: Wildlife Climate Challenge Species List

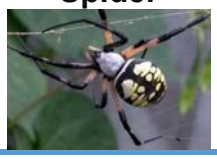
Choose a local animal to study. Use the information below and your own research to answer the following:

> What habitat(s) does your animal or plant rely on for survival? Some animals rely on multiple habitats.
>
> What are the biggest climate challenges for your animal? Be as specific as possible (drought, coastal flooding, wildfires). Revisit the San Diego Climate Challenges as needed.
>
> Are there any other environmental challenges that your animal is dealing with? (habitat loss, over fishing, pollution, etc.) If the species is federally listed as sensitive, threatened, or endangered it currently facing big environmental challenges.

Complete an explanatory change about how the local population of your animal will likely respond to climate change. Based on your research, will the species **adapt**, **migrate** to new habitats or become **extinct**?

Identify a solution to help keep your organism in its current habitat and alive for generations to come.

Green Sea Turtle 	Sand temperature affects the sex of hatchlings in some turtle species. Hotter sand results in more female turtles. Green sea turtles live in San Diego Bay, and their nesting sites are in Baja California. .
Edith's Checkerspot 	Wildfires in 2003 and 2007 in San Diego burned large areas of the host plants for these butterflies.
Ridgway's Rail 	Ridgway's Rails (formerly known as Clapper Rails) live in coastal estuaries. Houses are built at the edges of estuaries in San Diego, so the estuaries are now small and limited.
Cliff Swallow 	Cliff swallows lay eggs based on the seasonal temperatures. Cliff swallows across North America have advanced egg-laying by as many as nine days from 1959 to 1991. They feed their chicks insects, which are only available during certain times of the year.

Southwestern Pond Turtle 	Southwestern pond turtles are aquatic animals. They move to dry upland areas for egg laying. In the warmer months the pond turtle will bask on rocks and logs near slow-moving streams. More extreme weather causes winter flooding for some rivers and streams.
Golden Orb Weaver Spider 	This orb-weaving spider has started weaving its webs earlier in the spring and later in the fall.
American Kestrel 	This is a raptor, a bird that hunts for insects, birds and small mammals from the sky or a perch. It nests in cavities in trees and other structures that provide a cavity.
Jeffrey Pine 	Drought makes plants more susceptible to insects. With more frequent drought years in the past decade, the trees are less resistant to bark beetle attacks.
Pacific Black Brandt 	The Pacific Black Brandt depends highly upon eelgrass, which has very specific habitat requirements and grows only in some coastal estuaries.
Buckwheat 	Drought increases the likelihood of fires in Chaparral areas. Native plants such as buckwheat take a long time to grow from seed following a fire. This increases the chance of non-native species growing in their place.
Ceanothus 	These are common local shrubs that are grow on sunny slopes in the chaparral ecosystem. They re-sprout or reseed after wildfires, as long as there have been 15-20 years since the most recent fire.
Pickleweed 	This plant grows in salt marshes and estuaries. It uses saltwater as the primary source of water, and concentrates the salt in segments growing at the tip of each branch. When the brine concentration gets high enough, the segment turns red and falls off.