Lesson overview: In this activity, the class assembles a graphical model of forest communities in the northern Rocky Mountains and the North Cascades. They use feltboard materials to illustrate the optimal environmental conditions for each tree species and how individual species associate with each other in ecological communities. Then they use the graphical model to predict the effects of changing climate conditions on the distribution of species.

Goals:

1. To increase students’ understanding that forest communities develop under certain environmental conditions because species with similar or complementary needs are likely to occur together.

2. To increase students’ ability to interpret data displayed in a table or map and use the information to make predictions.

Objectives:

Given information on the environmental conditions in which various tree species live, students can:

- Describe a forest community in terms of tree species that are likely to occur together.
- Use information from maps to predict the effects of climate change.

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<th>7th</th>
<th>8th</th>
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<td>NGSS</td>
<td>From Molecules to Organisms: Structure and Processes</td>
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Subjects: Science, Mathematics, Reading, Speaking and Listening

Duration: one half-hour class session, possibly followed by a station activity

Group size: Whole class

Setting: Classroom

Vocabulary: aspect, climate change, community, continuum, elevation, environmental condition, gradient, habitat, moisture
Teacher background: Every species needs certain environmental conditions to survive, grow, and reproduce. Trees, for example, need a certain amount of sunlight and moisture and certain temperature conditions. They may also need a specific day length to begin growing, specific soils to provide nutrients, specific fungi to enhance their root function, and many other conditions. This activity focuses on their needs for specific moisture and temperature conditions.

Tree species with similar environmental needs are likely to occur together, forming unique forest communities. This version of FireWorks covers 10 tree species and focuses on the fire ecology of 3 forest communities: those dominated by ponderosa pine and Douglas-fir, those dominated by lodgepole pine and subalpine fir, and those dominated by whitebark pine and subalpine fir. Students learned about the ecology of the 10 tree species in Activity M11 (Who Lives Here? Adopting a Plant, Animal, or Fungus) and how to identify each species in Activity M13 (Tree Identification: Figure out the “Mystery Trees”).

The optimum habitat conditions for a species are fairly consistent throughout its range, but the locations where these conditions occur vary a lot from region to region. Ponderosa pine, for example, finds the conditions it needs at low elevations in Canada and near the mountain tops in the southwestern United States. To help students understand the forest communities in the northern Rocky Mountains and the North Cascades, we use a fictitious mountain called Sasquatch Peak. Its foothills are around 900 m elevation and its summit is at 3000 m. Summers are hot in the foothills but stay relatively cool in the high country. The table in Handout M14-1. Optimum habitat conditions shows the elevation range and moisture conditions where each tree species is most common, but individuals are likely to occur outside these conditions. Students use the information in the table to assemble a feltboard model that shows where each tree species is likely to occur on Sasquatch Peak.

Once students have assembled the model, you can help them recognize several patterns, including:

- Trees with similar habitat needs tend to occur together, thus forming forest communities – including the three featured in this curriculum (ponderosa pine/Douglas-fir at low elevations, lodgepole pine/subalpine fir at middle elevations, and whitebark pine/subalpine fir at high elevations).
- Communities often overlap, rather than having strict boundaries.
Students use the Sasquatch Peak model to understand the potential effects of climate change on forest communities. They apply information from 2 maps on climate change (Handout M14-2) to predict how current conditions, which are warmer and drier than most of the 20th century, might change the locations where a species can occur and influence the composition of forest communities.

This activity simplifies the factors that influence habitat for trees. It represents moisture conditions as depending on distance from a stream, while in reality, moisture availability is also influenced by soil properties, aspect, steepness, stand structure, and cover of litter and duff. North-facing hillsides, for example, tend to be shadier and thus more moist than south-facing ones (in the northern hemisphere); and sites with extensive forest cover and deep duff tend to be more moist than sites with a lot of bare ground.

Similarly, this activity represents low elevations as always hot and high elevations as always cold, while in reality, temperature is very seasonal and is also influenced by slope, aspect, and topography. For example, north-facing hillsides tend to be cooler than south-facing ones; and if frost pools in a valley bottom overnight, temperatures may go from cool at low elevation to warm at middle elevation and then to cool again at high elevation. (See Activity M09. Smoke from Wildland Fire: Just Hanging Around? to learn more about inversions.)

This activity also provides a simplified model of what may happen to tree distributions as climate conditions change. The only variables considered here are temperature and moisture. In reality, tree distributions respond to many other factors, including seed dispersal, species interactions, insects and diseases, connectivity of habitat, and changes in fire frequency, severity, and size.

**Materials/Preparation:**

1. Locate the following in the trunk:
   - Feltboard for the Ponderosa Pine forest community
   - Feltboard Kit (may be individual kit or stored in the Mystery Trees Box)
   - Straight pins

2. Make 5 copies of Handout M14-1. Optimum habitat conditions. Cut them in half so you’ll have 10 copies of the table. (You need one for each of the 10 tree species.)

3. Decide how you want to use the assessment tool, Handout M14-2. Trees in a Changing Environment. See the 3 options described below in Assessment:
   - completing the handout together as a class
   - completing it in teams at a station
   - completing it individually

   Make the number of copies needed.

4. Display the felt background for the Ponderosa Pine community – on a bulletin board, if possible, so you can use pins to secure the pieces.

5. Take out the pieces of the Feltboard Kit.
Attach the dark brown piece representing Sasquatch Peak to the feltboard.

Attach the elevation/temperature bar vertically along the right-hand edge of the feltboard.

Attach the moisture bar horizontally along the bottom.

Attach the two transparent labels that indicate moisture (see photo).

Secure the pieces with pins.

**Procedure**

1. Explain/ask: We’re studying fire in 3 forest **ecosystems** of the northern Rocky Mountains and North Cascades. The **living things** in an ecosystem (the things comprised of cells) are called the **community**. What are some of the living things in a forest ecosystem? **Trees, insects, mammals, fungi, plants**… What are some of the **nonliving things** in a forest ecosystem? **Air, water, mineral soil**… In this activity, we’ll focus on the tree species in forests on a steep mountainside.

2. Ask: What are some of the important tree species in communities of the northern Rocky Mountains and the North Cascades? Students could name any of the “mystery tree” species from **Activity M13**. They could mention other species as well.

3. Ask/discuss: What environmental conditions make a tree species thrive in some places and not others? What conditions help some species occur together and others occur in very different places? Why do these conditions matter so much? Draw out the following:

   - **Elevation** matters because it influences the temperature, length of summer vs. winter, exposure to wind, etc.

   - **Slope, aspect and steepness** matter because they control how much direct sunlight the plants receive (and thus temperature), how much wind they are exposed to, how rain and snow are deposited, and how moisture is retained in the soil.

   - **Soil** matters because it influences the nutrients available to the plant and how well water is retained.

   - **Amount of moisture** – precipitation and storage in the soil - matters because it influences how much water is available to plant roots.

   Note that this discussion addresses only **environmental** conditions that plants need. Every plant species also requires certain **biological** conditions, such as abundant pollinators or
fungi that help roots absorb moisture and sparseness of competing vegetation. This activity
doesn’t focus on biological requirements.

4. Explain: Let’s build a model that shows the “best”- or “optimal” – environmental conditions
for each of our mystery tree species – that is, the conditions where trees of each species are
most likely to grow and reproduce well. Then we will use the model to learn more about forest communities and how they might change as our climate changes.

5. Give each team a color-coded felt bar with a species name marked on it. You may want to
give the species to the team that described it in Activity M13. Your trunk may or may not
have small felt tree silhouettes with colors that match the bar colors. These tree silhouettes
are completely optional; they make the display more pictorial, but they may also clutter the feltboard unnecessarily.


7. Explain: We’re going to use information in the handout to place the felt bar for each species
on the felt background of a fictitious mountain named Sasquatch Peak. The handout shows
where each species’ habitat occurs on Sasquatch Peak, but this is just one example. The
same kind of habitat – the same combination of temperature and moisture conditions – is
likely to occur at different locations in other places.

The feltboard shows two kinds of environmental conditions:
• Along the right side is a continuum – also called a “gradient” – that goes from hot
conditions at low elevations to cold conditions at high elevations. This makes it look like
temperature depends only on elevation, but really there are many other influences.
What are some of these? Aspect, shade, drainage patterns – especially for cold air... see Teacher Background above.
• Along the bottom is another gradient that goes from dry conditions on an exposed ridge
to moist conditions along a streambed. This makes it look like moisture depends only on
how near you are to a creek, but many other things influence moisture availability to
plants. What are some of these? Aspect, soil properties, plant cover, litter/duff cover... see Teacher Background.

8. One at a time, have the student teams use Handout M14-1 to place their species’ colored
bar in the appropriate location on the feltboard.
• Start by finding the species’ maximum elevation on the vertical axis, then go across the
mountainside to a point that represents its optimum moisture conditions. Place one end
of the colored felt bar there.

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1 If your materials include a felt bar labeled GRAND FIR, turn it over and use a black marker to label it WESTERN REDCEDAR.
2 Sasquatch – or “Bigfoot” – is a common figure in the myths and legends of many Indian nations in the northwestern United States.
• Then go “downhill,” diagonally and to the left, and place the other end of the bar near the species’ minimum elevation in the correct moisture range. If the bar is too long, fold it under a little. If it’s too short, change the angle a little.
• Secure the felt bar.
• If you’re using the tree silhouettes, have the students place their silhouette somewhere along the bar for that species.

A little chaos and some criss-crossing of colored bars are no problem. When completed, the feltboard should look something like this photo, though perhaps less tidy and without the silhouettes.

9. Explain: This curriculum focuses mostly on the ecology of three communities: forests dominated by ponderosa pine with Douglas-fir, lodgepole pine with subalpine fir, and whitebark pine with subalpine fir. Where are those communities located in this model? Have students place the three felt labels for these forest communities on the feltboard.

10. Discuss: While we’ve named our 3 forest communities for the species most common there, you can see that other species are likely to occur.

What is one species that you might find in low-elevation ponderosa pine/Douglas-fir communities? Western larch is one example. Remind students to look at “low elevations” (near the bottom of the graph). Western larch is probably to the right of Douglas-fir, since it needs slightly more moisture. Quaking aspen and black cottonwood should be even further to the right.

What is one species that might show up on moist spots – perhaps next to creeks - in whitebark pine communities at high elevations – say, above 2000 m? Engelmann spruce. Show how to look to the right of whitebark pine and subalpine fir for more moist conditions.

11. Discuss: What happens to forest communities if the temperature and moisture conditions change? If you are in a moist area with a lot of subalpine fir, but the climate becomes hotter and drier, what species might become more common? Lodgepole pine, Douglas-fir, and even ponderosa pine. Show how to look at lower elevations for species that thrive in hotter conditions and how to look to the left for species that thrive in drier conditions.
12. Ask: Why does it matter if the higher-elevation species (whitebark pine and subalpine fir, for example) fail to thrive and species that currently live on dry sites at lower elevations (ponderosa pine and Douglas-fir, for example) replace them? Loss of the high-elevation species will reduce the diversity of tree species across the landscape. It will reduce food and other habitat features needed by birds, mammals, and insects that currently rely on high-elevation forest communities; these include Clark’s nutcrackers, red squirrels, and bears. With reduced habitat, the diversity of animal species may decline. Loss of the high-elevation species may lead to new combinations of species—new communities—in which there are fewer trees and more invasive (“weedy”) species.

13. Take a photo of the completed feltboard. That way, if you or students want to change the pieces around to show the effects of climate change or removal/addition of species, you can always restore it to the original arrangement. This will be especially helpful if students use the display as a station for completing Handout M14-2.

Assessment: You can use Handout M14-2. Trees in a Changing Environment in any of these ways:

A. Do part or all of the handout together, as a class; you can project the maps needed for Questions 1 and 2 from 2ClimateChangeMaps.

B. Set up the feltboard display as a station and have groups of students complete their handouts together, one or two teams at a time. If you use this option, students can touch and manipulate the felt pieces as they answer the handout questions—as long as they return the pieces to their original positions when they are done.

C. Turn the students loose with the handout and have them complete it on their own.

INSTRUCTIONS:

1. Give each student a copy of Handout M14-2. Trees in a Changing Environment. Explain: The first page of the handout contains data about how the climate throughout the United States has changed over the past 50 to 100 years. We are going to focus on the information about our regions, the northern Rocky Mountains and the North Cascades. The second page of the handout asks you to use information from the feltboard model to make predictions about how our forest communities might respond to climate change.

2. Have students complete the handout.

<table>
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<tr>
<td>• 1 point for circling region on map</td>
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<tr>
<td>• 1 point for correct verbal answer</td>
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<td>Questions 3-8: 1 point each</td>
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Handout M14-1. Optimum habitat conditions for 10 tree species on Sasquatch Peak, which is somewhere in the northern Rocky Mountains or the North Cascades. The valley bottom is at 900 m elevation. The summit of Sasquatch Peak is at 3000 m.

<table>
<thead>
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<th>Tree Species</th>
<th>Elevations (m) / temperature conditions where this species is most common</th>
<th>Moisture conditions where this species is most common</th>
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<td>Dry to medium</td>
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<td>Engelmann spruce</td>
<td>1300-2400</td>
<td>Medium to moist</td>
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<td>Lodgepole pine</td>
<td>1500-2300</td>
<td>Dry to medium</td>
</tr>
<tr>
<td>Quaking aspen</td>
<td>900-2000</td>
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<td>Ponderosa pine</td>
<td>900-1700</td>
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<td>Subalpine fir</td>
<td>1400-2500</td>
<td>Medium</td>
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<td>Western larch</td>
<td>900-2000</td>
<td>Medium</td>
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<tr>
<td>Western redcedar</td>
<td>900-1700</td>
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<tr>
<td>Whitebark pine</td>
<td>1800-2600</td>
<td>Dry</td>
</tr>
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Handout M14-2. Trees in a Changing Environment

Name: __________________

Figure 1. AVERAGE TEMPERATURE MAP.
Negative values indicate that the years 2011-2014 were cooler than the 20th century average. Positive values indicate that the years 2011-2014 were warmer than the 20th century average.

Source: https://www.ncdc.noaa.gov/cag/statewide/time-series/. This is an interactive web page with a huge amount of climatological information, both current and historical. The map shown here was obtained in February 2018. Consult the website to find information on more climate variables and on specific states or regions.

Figure 2. CHANGE IN ANNUAL PRECIPITATION, 1958 TO 2008.
While precipitation over the United States as a whole has increased, there have been important regional and seasonal differences. In the Northwest, decreases have occurred in all seasons except spring.

Use the maps on the previous page to answer these questions:

1. Figure 1 compares average temperatures in recent years with those of the 20th century. Circle the region that extends from the northern Rocky Mountains in the east across the North Cascades in the west. Does the map suggest that the climate in this region is getting hotter or colder? ______________

2. Figure 2 shows the trends in average precipitation over the past 50 years or so. Circle the area from the northern Rocky Mountains to the North Cascades. Does the map suggest that the climate in this region is getting wetter or drier? ______________

Use the half-page handout or the feltboard model of forest communities to answer these questions:

3. Suppose you are a western larch living at 1400 m elevation, and your home gets a lot drier. Name one tree species that will probably thrive in your community over the next 100 years: ____________________________

4. Suppose you are a whitebark pine living at 1900 m elevation and your home gets a lot hotter. Name one tree species that may become part of your community: ____________________________

5. Is whitebark pine likely to survive and reproduce better or worse in a hotter environment at 1900 m? Explain:
________________________________________________________________________
________________________________________________________________________

6. Suppose you are a subalpine fir living at 1500 m elevation, and your home gets drier and hotter. Name one tree species that will probably join your community – or will grow better, if it is already there.
________________________________________________________________________

7. Suppose you are an Engelmann spruce growing at 1600 m elevation, and your home gets both drier and hotter. Name one tree species that will probably be unable to persist in your community: ____________________________

8. Is Engelmann spruce likely to survive and reproduce better or worse in a drier, hotter environment at 1600 m? Explain:
________________________________________________________________________
________________________________________________________________________
Answer Key to Handout M14-2. Trees in a Changing Environment

Figure 1. AVERAGE TEMPERATURE MAP. Negative values indicate that the years 2011-2014 were cooler than the 20th century average. Positive values indicate that the years 2011-2014 were warmer than the 20th century average.

Source: https://www.ncdc.noaa.gov/cag/statewide/time-series/. This is an interactive web page with a huge amount of climatological information, both current and historical. The map shown here was obtained in February 2018. Consult the website to find information on more climate variables and on specific states or regions.

Figure 2. CHANGE IN ANNUAL PRECIPITATION, 1958 TO 2008. While precipitation over the United States as a whole has increased, there have been important regional and seasonal differences. In the Northwest, decreases have occurred in all seasons except spring.

Use the maps on the previous page to answer these questions:
1. Figure 1 compares average temperatures in recent years with those of the 20th century. Circle the region that extends from the northern Rocky Mountains in the east across the North Cascades in the west. Does the map suggest that the climate in this region is getting hotter or colder? **Hotter**

2. Figure 2 shows the trends in average precipitation over the past 50 years or so. Circle the area from the northern Rocky Mountains to the North Cascades. Does the map suggest that the climate in this region is getting wetter or drier? **Drier – although this is not uniform throughout the region, and the caption says that spring is NOT drier in this region.**

Use the feltboard model of forest communities to answer these questions:
3. Suppose you are a western larch living at 1400 m elevation, and your home gets a lot drier. Name one tree species that will probably thrive in your community over the next 100 years: **Ponderosa pine and Douglas-fir are both correct.**

4. Suppose you are a whitebark pine living at 1900 m elevation and your home gets a lot hotter. Name one tree species that may become part of your community: **Ponderosa pine**

5. Is whitebark pine likely to survive and reproduce better or worse in a hotter environment at 1900 m? Explain: **Whitebark pine will probably fare worse. 1900 m is near the low end of its current distribution. If the climate gets a lot hotter, the environment could become more like current conditions at 1600 m, where whitebark cannot grow. If ponderosa pines become established, they could use much of the water on the site, making conditions even worse for whitebark pines.**

6. Suppose you are a subalpine fir living at 1500 m elevation, and your home gets drier and hotter. Name one tree species that will probably join your community – or will grow better, if it is already there. **Douglas-fir, lodgepole pine, and ponderosa pine are all correct.**

7. Suppose you are an Engelmann spruce growing at 1600 m elevation, and your home gets both drier and hotter. Name one tree species that will probably be unable to persist in your community: **Western redcedar and quaking aspen are both correct.**

8. Is Engelmann spruce at 1600 m likely to survive and reproduce better or worse if the site gets drier and hotter? Explain: **Engelmann spruce is likely to fare worse in the new environment. There are many species at 1600 m and lower elevations that do better on dry sites than Engelmann spruce. These include western larch, Douglas-fir, and ponderosa pine. If these species become established, they are likely to use much of the water on the site, making conditions harder for Engelmann spruce.**