Lesson overview: In this activity, students assemble a graphical model of the forest communities on a mountainside in the northern Rocky Mountains/North Cascades region. They use the model to describe specific forest communities and to assess the potential for tree distributions to change in response to climate change. Then they read and take a stand on the use of assisted migration to conserve species.

Depending on how you choose to teach it, this activity may require independent work by students to prepare for the assessments. Depending on the need for independent work, the activity may require 2-3 class sessions.

Lesson Goal: Increase students’ understanding that species with similar needs may occur together, that forest communities occur in locations with specific environmental conditions, and that species distributions and community composition may change as climate conditions change.

Objectives:
- Students can list tree species that are likely to occur together and comprise unique forest communities.
- Students can predict some potential effects of climate change on the distributions of tree species.
- Students can express their observations and opinions about assisted migration, a method that could be used to mitigate the effects of climate change on species.

<table>
<thead>
<tr>
<th>Standards:</th>
<th>9th</th>
<th>10th</th>
<th>11th</th>
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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 associate with their roots, and many other conditions. Tree species with similar needs – or the potential to meet each other’s needs - are likely to occur together, forming unique forest communities. This version of FireWorks covers 10 tree species and ways in which they are associated in forest communities. It focuses especially on the 3 community types in the northern Rocky Mountains and the North Cascades:

- Northern Rocky Mountain Ponderosa Pine (dominated by ponderosa pine, often with a lot of Douglas-fir)
- Rocky Mountain Lodgepole Pine communities (dominated by lodgepole pine, sometimes with subalpine fir)
- Whitebark Pine (dominated by whitebark pine with, often with subalpine fir)

Students learned how to identify the 10 tree species in Activity 13, and they learned about the species’ ecology in Activity 14. Now they will use information about those species (provided in Handout H15-1) to create a graphical model that shows the distribution of each tree species based on its temperature and moisture requirements. (See Slide 3 in H15_ForestCommunitiesGradientModel.pptx for an example of a completed model.)

This activity has 2 assessments. In Assessment #1, students develop models that illustrate the species likely to occur in each forest community and then use their models to predict the consequences of a warmer, drier climate, since locations that favored certain tree species in the past may no longer provide conditions in which they can thrive and reproduce.

In Assessment #2, students read about assisted migration, a technique that could be used to mitigate the effects of climate change. While a species may not be able to persist in its current habitat, there may be other locations where it could thrive, but first its seeds must first reach those locations. For this reason, some people propose to deliberately introduce species to locations that may be more hospitable to them in the future. This is called assisted migration.

Assisted migration is controversial. In Assessment #2, students read an article about the controversy. Then they participate in a “Walk the Line” activity to express their own opinions. Finally, they write an essay in which they take a stand on the issue and explain their reasoning.

If you want your students to read primary research on assisted migration, we suggest: McKenney, Daniel W.; Pedlar, John H.; Lawrence, Kevin; Campbell, Kathy; Hutchinson, Michael F. 2007. Potential impacts of climate change on the distribution of North American trees. BioScience. 57(11): 939-948.
Materials/Preparation:

1. Download **H15_ForestCommunitiesIntroduction.pptx** and **H15_ForestCommunitiesGradientModel.pptx**.

2. Print 1 copy/student:
   - **Handout H15-1. Distributions of 10 tree species**
   - **Handout H15-3. Use a model to predict the future**

3. You may also want 1 copy/student of **Handout H15-2: Modeling forest communities.** Read the options in Step 6 below before you decide.

4. Make sure each student has markers or colored pencils - 10 colors in addition to black.

5. Decide whether to have students do the reading assignment for **Assessment #2** online ([https://earlycareerecologists.wordpress.com/2013/01/16/trees-on-the-move-debating-assisted-migration-in-climate-change-mitigation/](https://earlycareerecologists.wordpress.com/2013/01/16/trees-on-the-move-debating-assisted-migration-in-climate-change-mitigation/)) or from paper copies ([Reading_TreesOnTheMove.pdf](Reading_TreesOnTheMove.pdf)). Make copies if necessary.

Procedure:

**DAY 1 – Hook and developing the gradient model:**

1. **Introduction:** Go through **H15_ForestCommunitiesIntroduction.pptx**:

   
   ![](https://example.com/hook-image)

   Ask: Where do you think you could live happily?
   Think of some locations where you could flourish and some areas where you would probably flounder. Have a few students come up and point to the places where they would like to live.

   Review the distinction (covered in **Activity H01**) between **community** and **ecosystem**. (Community includes only living things in the environment; ecosystem includes both living and nonliving things.)

   Then ask more about the places where your students would like to live – their “preferences”:
   - What aspects of this ideal place are **living** – such as other people, parks, wildlands, animals?
   - What parts are **nonliving** – such as weather/climate, clean air, highways, museums, fast-food places, concert venues?

   Have a few students identify places where they don’t think they could live. What conditions would make those places hard for them to live in?
Explain: Tree species also have what we might call preferences: They grow best in certain *environmental conditions* and cannot grow at all in other conditions. The actual locations where a species occurs are called its *distribution* or its *range*. As an example, here is a map of ponderosa pine’s current distribution. What do you notice about the elevations where it lives? Ponderosa pine lives at high elevations in the southern part of its range and at lower elevations as you go north. Why might this be? Conditions at low elevations in the south are probably too hot for ponderosa pine; conditions at high elevations in the north are probably too cold.

We’ve been focusing on individual tree species and their needs, but species do not live in isolation; they have neighbors. Trees live in forest *communities*, and species that need similar environmental conditions - or create good conditions for others - tend to live together.

Fire does not interact with individual species in isolation either; it interacts with communities and ecosystems. So we’re going to assemble a model that shows how the tree species we’ve been studying form *forest communities* in the northern Rocky Mountains and the North Cascades, and how these communities are related to *environmental conditions*.

These communities are named for individual tree species, but only because those species tend to predominate there. Many other plants – trees, shrubs, and herbs - occur in each of these communities. And the “named” tree species (ponderosa, lodgepole, and whitebark pine) can occur in other places, but they don’t predominate there.

For example, ponderosa pines can be found from the Canadian border all the way into southern California, but this map shows where you could find the specific mix of ponderosa pine, Douglas-fir, and particular shrubs and herbs that characterizes northern Rocky Mountain ponderosa pine communities.

2. Ask: What are some important conditions that affect species distribution? Why do they matter? Try to draw out the following. Note that some relate to nonliving conditions and some to living things in the ecosystem.
   - **Elevation** matters because it influences the temperature, length of summer vs. winter, amount of snow vs. rain, 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, and how rain and snow are deposited and melted/absorbed/evaporated.
   - **Soil** matters because it influences the nutrients available to the plant, the air available to roots, and how well water is retained. Soil cover (litter and duff) also influences these conditions.
   - **Amount of moisture** matters because it influences how much water is available to plants and its seasonal availability.
   - **Other important conditions** may include abundance of pollinators, availability of fungi that help roots absorb moisture (“mycorrhizae”), density and vigor of competing vegetation, presence of animals that feed on plants, presence of parasites and pathogens, and nearness of seed sources for the species.
   - **History of the site – including the pattern of fire type, size, and severity** - influence the species present and many of the conditions listed above.

3. Explain: We’re going to focus on just 2 environmental conditions: elevation (which represents temperature – hot at low elevations and cold at high elevations) and moisture.

4. Give each student a copy of Handout H15-1. **Distributions of 10 tree species.** Explain: We will use this handout to create a model that shows how our 10 tree species are associated with each other in forest communities. Then we will zero in on 3 specific forest communities: forests historically dominated by ponderosa pine and Douglas-fir, those
dominated by lodgepole pine and subalpine fir, and those dominated by whitebark pine and subalpine fir.

5. Using the information given in Handout 15-1 and the directions in Handout 15-2, complete a gradient model with the class. Use 1 of these options, depending on how intensively you want to guide the students. Use slides from H15_ForestCommunitiesGradientModel.pptx, as needed.

A. **Fully guided:** Project or trace the template for the gradient model (Slide 1 in H15_ForestCommunitiesGradientModel.pptx, shown below) onto butcher paper or a whiteboard. Then use markers to develop the model together as a class; the result should resemble Slide 3. Have each student copy this model onto Handout H15-2 so he/she has a copy for answering questions on Handout 15-3.

B. **Sort-of guided:** Introduce the template for the gradient model using Slides 1 and 2 in H15_ForestCommunitiesGradientModel.pptx. Have students use Handout H15-2 to create their own gradient models.

C. **Least guided:** Have students develop their own graphical models of where the species occur in relation to moisture & temperature gradients; these could be drawings, graphs, or other media.

H15_ForestCommunitiesGradientModel.pptx:

In reality, elevation may not always follow this temperature gradient. Any idea how it might vary? If a mountainside is exposed to frequent inversions, as studied in Activity H11, it may be cooler at the bottom than in the middle. The same thing can happen if frost “pools” in a basin at the bottom of the mountain and cannot flow downhill. In reality, moisture is influenced by many things in addition to distance from a stream. Can you think of some? Soil texture and organic content influence moisture. So does the aspect of a slope. (North-facing slopes tend to be moister than south-facing slopes because they have less direct exposure to sunlight.) Patterns of wind, deposition of snow, and snow-melt all matter.
Here’s the template with 1 species described, as shown in Handout H15-2. Modeling forest communities.

Here’s an example of a completed gradient model using the template. Your class’s model should resemble this one, but don’t worry about the details.

This model shows some of the environmental conditions needed by the 3 “focus” forest communities: Northern Rocky Mountain Ponderosa Pine communities (dominated by ponderosa pine and sometimes Douglas-fir), Rocky Mountain Lodgepole Pine communities (dominated by Rocky Mountain lodgepole pine, sometimes with a lot of subalpine fir), and Whitebark Pine communities (which can also have a lot of subalpine fir). It also shows species that have similar needs, so they may also occur in the focus communities.

6. Regardless of which option you used for developing the graphical models, either:
   a) have students mark on their graphs where these 3 forest communities are likely to occur: ponderosa pine/Douglas-fir, lodgepole pine/subalpine fir, and whitebark pine/subalpine fir....
   b) or use Slide 4 to show the environmental conditions where these communities occur.

**DAY 2 – Interpreting and using the model(s)**

1. Have students get together in small groups. If you used Option B or C in Step 5 above, have students compare and discuss their models. Are the models fairly similar? What might account for differences? Check with each group to make sure the models are all fairly accurate; if they’re way off, the students can’t complete Handout H15-3 successfully.

2. Ask each group to list 2 strengths of this approach to modeling (use of elevation and moisture, also the graphical techniques) and 2 weaknesses, then share these with the class. Possibilities:
   - The models are useful because we can easily see which species are most likely to occur together
• With the models, you can compare one species’ needs to those of another species.

• Substituting elevation for temperature... and distance from a stream for moisture... oversimplifies the species’ real needs.

• Other species combinations might occur – or these species might be absent - based on other environmental conditions – for example, presence of animals that graze on seedlings, insects that eat the trees’ leaves or cambium, parasites and pathogenic fungi, mycorrhizal fungi that enhance roots’ ability to absorb moisture...

• You can’t use these models to explore the complexities of topography (what about shade in narrow canyons?) or history (what about a site’s history of logging? fire? insect epidemics?).

• The models can’t help us account for species whose seeds just never got to a certain place – whether the environmental conditions are a good fit or not.

Assessment #1 – Using a model for predictions: With the whole class or in groups or as homework, have students complete Handout H15-3. Use a model to predict the future. Before proceeding with the second assessment, discuss answers in class.

Assessment #2 – Should we use assisted migration?

1. Hand out or provide electronic access to “Trees on the Move? Debating Assisted Migration in Climate Change Mitigation.” It is available online at https://earlycareerecologists.wordpress.com/2013/01/16/trees-on-the-move-debating-assisted-migration-in-climate-change-mitigation/ or you can print it from Reading_TreesOnTheMove.pdf.

2. Explain: In this reading, you’ll find out what “assisted migration” is and why it’s controversial. In the next class, after you’ve read the article, you’ll express your opinions about assisted migration. Then you will write a short essay explaining your opinions.

3. DAY 3 - Walking the Line activity:
   • On opposing walls of the classroom, write or put signs that say AGREE and DISAGREE.

   • Review what species migration and assisted migration mean.

   • Explain: Because we are thinking about moving species around, you are actually going to move around in this activity.

   • Have all students stand. Read the following statements. For each one, have students move to a place on the gradient between “agree” and “disagree” to show their personal opinions and reactions to the statement. After students have moved in response to each question, invite discussion about it.
Questions for “Walking the Line”:

a. This article surprised me. I had not heard about plant species naturally migrating before reading this article.

b. All of the tree species that we’ve studied will be able to “...keep pace with shifting climate and regenerate under suitable habitat conditions,” as the article puts it. In other words, they’ll be OK.

c. All of our 10 tree species will be able to migrate approximately 10 kilometers per year.

d. If our tree species cannot migrate fast enough, then they will become extinct.

e. Inaction (that is, NOT using assisted migration) will lead to extinction of some tree species.

f. Assisted migration will produce unintended, unpredictable consequences.

g. Assisted migration will preserve tree species that are now in rapid decline.

h. Assisted migration will preserve forest communities that are now in rapid decline.

i. Assisted migration will negatively affect plant communities that currently live on the transplant sites.

j. I agree with the use of assisted migration, at least on some occasions.

k. I understand why assisted migration “…is one of the most controversial, divisive debates within the ecological community.”

4. Write an essay stating your opinion about the use of assisted migration to mitigate the effects of climate change. Back up your opinion with examples from the graphical model that you developed and quotations from the article. You may use other sources as well.
Evaluation:

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<th>Excellent</th>
<th>Good</th>
<th>Poor</th>
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</thead>
<tbody>
<tr>
<td>Assessment #1. Handout H15-3. Use a model to predict the future. See Teacher Key below.</td>
<td>Correctly answered 8-10 questions.</td>
<td>Correctly answered 5-7 questions.</td>
</tr>
</tbody>
</table>

Assessment #2. Reflection on assisted migration

- Student’s reflection is clear and well written.
- Student expressed a clear opinion on assisted migration.
- Student backed up opinion with more than 1 example from the graphical model.
- Student backed up opinion with more than 1 quotation from or reference to the article on assisted migration.
- Student supplemented arguments for/against assisted migration with thoughts from “Walk the Line” activity or other sources.
- Student’s reflection contains some confusion or writing problems.
- Student expressed a clear opinion on assisted migration.
- Student backed up opinion with at least 1 example from the graphical model.
- Student backed up opinion with at least 1 quotation from or reference to the article on assisted migration.
- Student’s reflection is confusing and/or poorly written.
- Student did not express a clear opinion on assisted migration.
- Student did not back up opinion with examples from the graphical model.
- Student did not back up opinion with quotation or other reference to the article on assisted migration.
Here are moisture conditions and elevations where 10 tree species occur in a particular mountain range. The summit of these mountains is at 3,000 m elevation. The valley at the base of the mountains is at 900 m. The lowest elevation in the region, and thus the lowest elevation where any species can occur, is around 500 m.

<table>
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<tr>
<th>Tree Species</th>
<th>Moisture conditions where this species is most common</th>
<th>Elevations (m)/temperature conditions where this species is most common</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black cottonwood</td>
<td>Very moist</td>
<td>500-1400</td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>Dry to medium</td>
<td>500-2000</td>
</tr>
<tr>
<td>Engelmann spruce</td>
<td>Medium to very moist</td>
<td>1300-2400</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td>Dry to medium</td>
<td>1500-2300</td>
</tr>
<tr>
<td>Quaking aspen</td>
<td>Medium to very moist</td>
<td>500-2000</td>
</tr>
<tr>
<td>Ponderosa pine</td>
<td>Dry</td>
<td>500-1700</td>
</tr>
<tr>
<td>Subalpine fir</td>
<td>Medium</td>
<td>1400-2500</td>
</tr>
<tr>
<td>Western larch</td>
<td>Medium</td>
<td>800-2000</td>
</tr>
<tr>
<td>Western redcedar</td>
<td>Very moist</td>
<td>500-1700</td>
</tr>
<tr>
<td>Whitebark pine</td>
<td>Dry</td>
<td>1800-2600</td>
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</table>

Sources:

Fire Effects Information System [http://feis-crs.org/feis/].


Handout H15-2: Modeling forest communities

Use this diagram to show the distributions of tree species based on the information in Handout H15-1. The x axis shows a gradient of moisture conditions, from dry along the ridge to very moist next to the stream. The y axis shows a gradient of temperature conditions based on elevation, from hot at low elevations to cool at high elevations. For each species:

1. Under “Key,” use a unique color to write the species name (except black cottonwood, which is already done).

2. Figure out where the species fits best in regard to moisture. Is it centered on a dashed line (for dry, medium, or very moist), or is it between lines?

3. Find the highest elevation where the species occurs. In the appropriate area for moisture at that elevation, place a small dot.

4. Find the lowest elevation where the species occurs. In the appropriate area for moisture at that elevation, place another dot. If the table lists an elevation below 900 m, estimate where the lowest mark should be below the graph.

5. Connect your 2 dots with a light pencil line. Midway down this line, move to the right and left and use dots to mark the approximate driest and wettest conditions for the species.

6. Using the color that matches this species in your key, draw an oval connecting your 4 dots. This shows the approximate distribution of the species.

Name: ____________________
Handout H15-3. Use a model to predict the future

Name: ____________________________________

1. Describe the environmental conditions where **ponderosa pine/Douglas-fir forest communities** live:

2. Name 1 species that might occur with ponderosa pine and Douglas-fir if a site is not too dry:

3. What species might be found in places where there’s a little more moisture (like in a gully or along a river bed)?

4. Describe the environmental conditions in **lodgepole pine/subalpine fir communities**:

5. What additional species could occur there?

6. What will happen to lodgepole pine/subalpine fir communities if the climate gets warmer and drier?

7. Describe the environmental conditions in **whitebark pine/subalpine fir communities**:

8. What is likely to happen to whitebark pine/subalpine fir communities if the climate becomes warmer and drier?

9. What tree species are likely to show up on these sites if the climate becomes warmer and drier?

10. Could whitebark pine “just move north” so it would have a better environment?
Teachers’ Key to Handout H15-3.

Use a model to predict the future

1. Describe the environmental conditions where **ponderosa pine/Douglas-fir forest communities live**: Low elevations. Hot and dry.

2. Name 1 species that might occur with ponderosa pine and Douglas-fir if a site is not too dry? Western larch.

3. What species might be found in places where there’s a little more moisture (like in a gully or along a river bed)? Quaking aspen... also possibly black cottonwood and western redcedar.

4. Describe the environmental conditions in **lodgepole pine/subalpine fir communities**: Higher and cooler than at the base of the mountain. Occurs at middle elevations. Fairly dry.

5. What additional species could occur there? Whitebark pine in cold, dry places... western larch with a little extra warmth and moisture... Douglas-fir unless it’s too cold... spruce and aspen on small areas (“microsites”) where moisture permits.

6. What will happen to lodgepole pine/subalpine fir communities if the climate gets warmer and drier? Whitebark pine, spruces and aspen are less likely to be present. Subalpine fir may not do as well. Ponderosa pine may become more plentiful.

7. Describe the environmental conditions in **whitebark pine/subalpine fir communities**: High elevations. Cool to cold. Dry.

8. What is likely to happen to whitebark pine/subalpine fir communities if the climate becomes warmer and drier? The current sites where whitebark pine lives may get too hot. Whitebark pine may fail to reproduce. Subalpine fir may do poorly if conditions get drier.

9. What tree species are likely to show up on these sites if the climate becomes warmer and drier? Lodgepole pine and Douglas-fir, possibly even ponderosa pine. Species that require more moisture, such as western larch, are not likely to do very well because conditions will continue to be dry.

10. Could whitebark pine “just move north” so it would have a better environment? Whitebark can only move north if its seeds are carried there. Clark’s nutcrackers can deliver seeds many kilometers, but that probably won’t be far enough to get them into a substantially cooler environment. If conditions on north-facing aspects get dry enough, whitebark pine could thrive there.