15. Forest Communities and Climate Change

Lesson overview: In this activity, students assemble a graphic model of a forest community in the northwestern Sierra Nevada and then discuss species distributions in the context of climate change.

This activity includes some individual work by students to prepare for later classroom work. The individual work is treated here as homework, and thus the activity is divided into 2 days.

Subjects: Science, Mathematics, Reading, Speaking and Listening
Duration: 2 class periods
Group size: small groups, whole class
Setting: Classroom
FireWorks vocabulary: *aspect, climate/climate change, distribution, elevation, environmental conditions, gradient, migration/assisted migration/species migration, range/home range*

Lesson Goal: Increase students' understanding that forest communities develop under 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.
- Students can predict possible effects of changing climate conditions on the distribution of tree species.
- Students can express their thoughts and observations about one potential way to mitigate the effects of climate change - *assisted migration* - in a speaking and listening activity.

Standards:		9th	10th	11th	12th
CCSS	Reading: Literature	1,2,4,10		1,2,4,10	
	Reading: Informational Test	1,2,4,10		1,2,4,10	
	Speaking and Listening	1,2,6		1,2,6	
	Reading: Science and Technical Subjects	1,2,4,9,10		1,2,4,9,10	
NGSS	Interdependent Relationships in Ecosystems	LS2.A, LS2.C, LS4.C			
EEEGL	Strand 1	B,C,E,F,G			

Teacher background: Now that students know about several tree species in the Sierra Nevada, they can learn how species are interrelated in forest communities. They will need this information to understand how patterns of fire over time have shaped forest communities.

In this activity, students use a graphical model to learn about communities. Then they use the same model to make predictions about species distributions in response to climate change. Finally, they study the pros and cons of assisted migration to conserve species threatened by climate change; they express and discuss their opinions as part of the **Assessment**.

The table in **Handout H15-1: Modeling Forests of the Sierra Nevada** lists the 12 tree species of the Sierra Nevada that have been studied in previous activities. The table describes the most common conditions in which each species occurs. Note that these are common conditions – the heart of the species' environmental requirements - rather than strict limits to where the species can live.

Given the descriptions in the table, students show where each species is likely to occur in a graphical model of a mountainside. They also predict which species are likely to occur together to form a forest community. Then they predict how the best locations for a species might change if climate conditions change. If individual trees in the current locations can spread their seeds or otherwise reproduce in a "new" location for them – and then thrive and reproduce there - we say the species has *migrated* to the new location. If they cannot, the species may gradually die out.

As the world's climate changes, conditions that favored certain species in the past may no longer provide conditions in which they can survive and reproduce. There may be other locations where they could live, but if their seeds cannot reach those places, they may gradually die out. For this reason, some people propose deliberately introducing the species to locations that may prove more hospitable to them in the future. This is called *assisted migration.* After creating their graphical models, students will read an article that describes the potential for assisted migration of trees. The article provides a concise introduction about how species are adapted to specific combinations of environmental and climatic conditions, and what may happen as these conditions are altered with climate change. It describes the controversy over assisted migration, so it should get students thinking. The "Walk the Line" activity in the **Assessment** forces them to discuss this issue and take a stand on it.

If you want your students to read primary research on assisted migration, have them read: 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.

Note that this curriculum does not cover subalpine communities, but subalpine communities are very important in the Sierra Nevada. Trees that occur in subalpine communities include Sierra lodgepole pine, whitebark pine, western white pine, and mountain hemlock.

Materials/Preparation:

- Print 1 copy/student in color:
  - **Handout H15-1: Modeling Forests of the Sierra Nevada**
  - **Handout H15-2: Interpreting a Model and a Map**
- Map of United States or of the world that can be projected. Several U.S. maps are available at http://geology.com/world/the-united-states-of-america-satellite-image.shtml.
- Download ***H15 ForestCommunities.pptx***, which contains the graphics for the Sasquatch Peak Forest Model. You will project selected slides from this file during the lesson.
- Make sure each student has markers or colored pencils - 12 colors other than black.
- Decide whether to have students do the 7-page reading assignment for the assessment on-line (https://earlycareerecologists.wordpress.com/2013/01/16/trees-on-the-move-debating-assisted-migration-in-climate-change-mitigation/) or from paper copies of **H15_Reading-TreesOnTheMove.** Make copies if necessary.
- Make AGREE and DISAGREE signs for the "Walking the Line" activity (see **Assessment**).

Procedure:

1. **DAY 1 – Introduction and assignment**: Project a map of the United States or the world (U.S. maps are available at http://geology.com/world/the-united-states-of-america-satellite-image.shtml). 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 to the board and mark the places they would like to live. Ask why. What conditions would make a good place for them? Have a few students circle places where they don't think they could live. What would make those places so hard to live in?

2. Explain: Tree species grow best in certain *environmental conditions* and cannot grow at all in other conditions. The actual locations where a species currently occurs are its *distribution.* (With animals, we often call this the *range* or *home range.*)

3. Ask: What are some important environmental conditions that affect species distribution? Why do they matter?

   - **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.

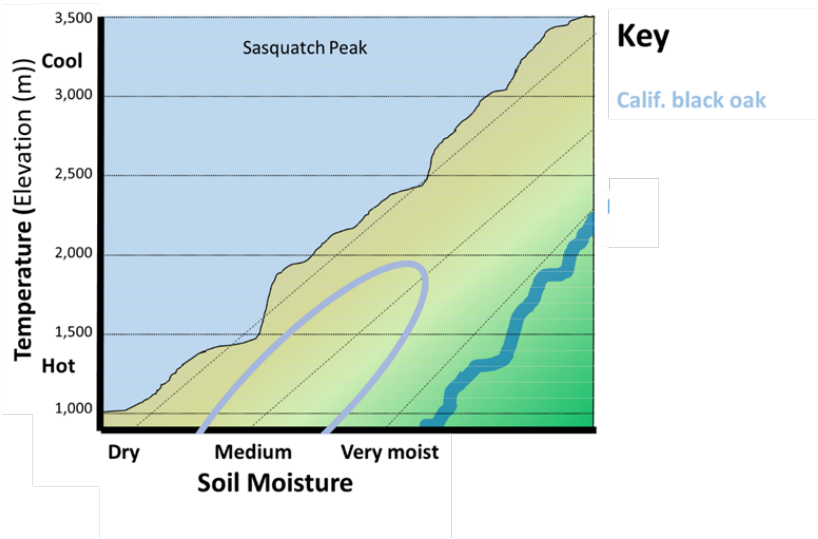
   - **Soil** matters because it influences the nutrients available to the plant, the air available to roots, and how well water is retained.

   - **Amount of moisture** matters because it influences how much water is available to plants and its seasonal availability.

4. We've talked about environmental conditions, but plants also need certain biological conditions to thrive. Can you think of any? Here are a few: abundant pollinators, fungi that help roots absorb moisture ("mycorrhizae"), sparseness of competing vegetation, limited numbers of animals feeding on plant parts, limited parasites and decay fungi.

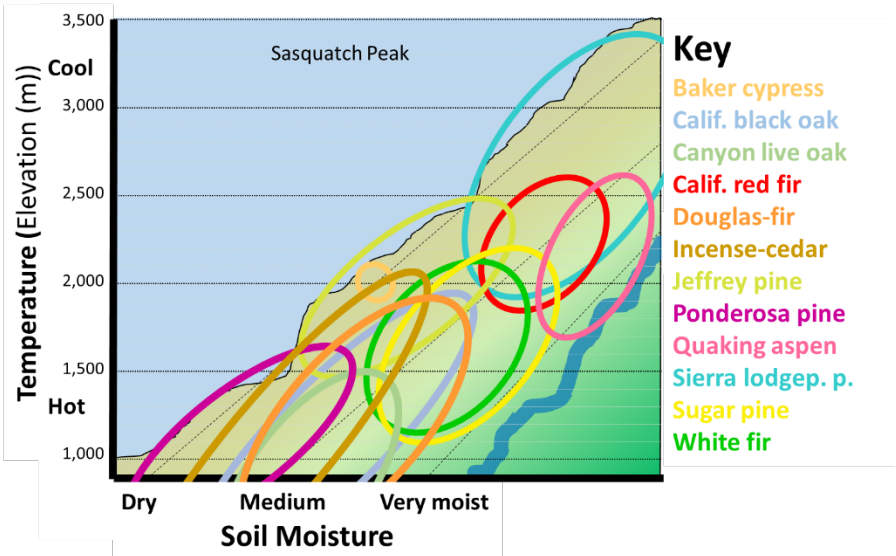
5. Explain: We are going to create a model that shows the typical forest communities in northwestern Sierra Nevada forests. The model is like a graph. It will show where tree species are most likely to live according to temperature conditions (represented by elevation) and soil moisture conditions (represented by distance from a stream). We will use a fictitious place called Sasquatch Peak to show the distribution of the 12 tree species that we've been studying and the communities where they commonly live.

6. Give each student a copy of **Handout H15-1: Modeling Forests of the Sierra Nevada**, and project **H15 Forest Communities.pptx, Slide 1** (at right). Go over the instructions. Use the example of California black oak (already graphed). Remind students that the data indicate where California black oak is common – that is, where it can best grow and thrive. The table does not show the limits of conditions that the species can tolerate.



7. Assign the rest of **Handout H15-1** for in-class work or homework.

8. **<u>DAY 2</u> – Interpreting and using the model.** Project **H15 Forest Communities.pptx, Slide 2,** an example of a completed forest model. Have students get together in small groups and compare their models with this one. Ask: Are your models similar? What might account for differences?



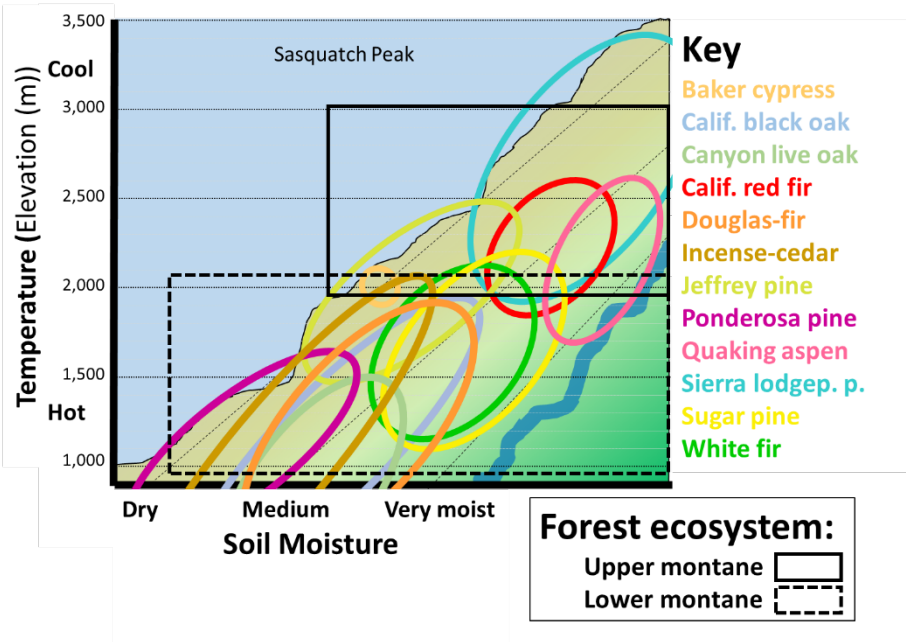
- Students may have misunderstood directions. If that happened, did they ask for help?
- Students may have created narrower or wider ellipses, which could reflect different interpretations of moisture conditions and would be valid, since the table does not offer much information on this.
- Students may have placed their ellipses at higher or lower elevations; very far off would be in error.
- Variation among models is expected, especially with regard to the width of ellipses. The example one is not perfect, partly because terms like "dry," "medium," and "very moist" are qualitative and can be interpreted somewhat differently.

9. Ask: What are some strengths and weaknesses of the model?

- The model describes where these species are common but not all of the places where they can occur, so it doesn't show limitations of the species. The model is useful because we can easily see which species are most likely to occur together, but many other species combinations can occur on the mountainsides of the northwestern Sierra Nevada. For example, the model suggests that sugar pine does not commonly occur with ponderosa pine – but it actually happens quite frequently. Can they think of other examples from their experience?
- This way of describing environmental conditions is simplistic. That means you can understand a species' needs and compare them to those of another species, but you can't explore the complexities of species distributions. For example, sites generally <u>do</u> get cooler as you go up in elevation, but not always. Other influences on temperature include aspect, presence of shade from other vegetation or mountains, presence of lakes or streams, wind patterns, and topography – such as narrow canyons vs open slopes. Sites generally <u>do</u> get moister as you get close to a creek or

lake, but that's not the only influence. Aspect, steepness, drainage patterns, soil properties, and presence of other vegetation are also important.

10. Project **H15 Forest Communities.pptx, Slide 3**. Explain: the black boxes represent the upper and lower montane plant communities on Sasquatch Peak. We'll use this distinction in future lessons, as we talk about the history and role of fire in montane communities.



11. Explain: We have used the model to **explore the relationships** among tree species and to **investigate** which species are likely neighbors. Now we'll use it to **make some predictions**.

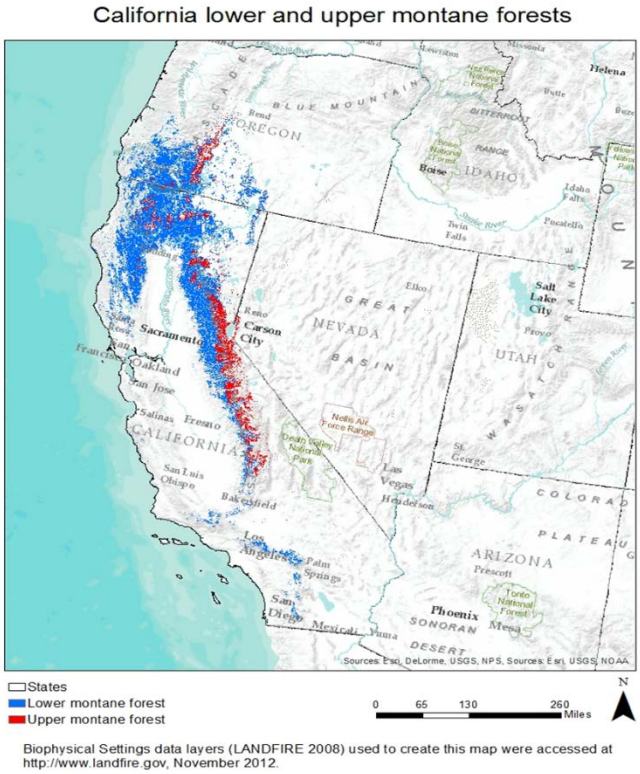
12. Explain: Over the past 100 years, the climate in our area has gotten warmer. In some places, it has gotten drier too. Ask: What is *climate* anyway? Average weather patterns over a long time, such as decades or centuries. "What you're wearing today shows the weather. What's in your closet shows the climate."

13. Explain: As climate changes, the environmental conditions for plant growth also change. We can use the model to predict how climate change might make a location more or less favorable for each tree species. Discuss this example: Suppose you were in a moist area around 1,100 m with a lot of sugar pine. Then the climate got much hotter and drier.

    - What tree species might become more common in your neighborhood? Ponderosa pine, Douglas-fir, incense-cedar, California black oak, canyon live oak

- Suppose some sugar pine seeds land in a medium-moist area at 2,500 m elevation. Would they have much of a chance to grow up? Why or why not? Their chances would probably be better than they are now because it will probably be warmer. Still, that habitat is quite a distance above the conditions where it currently thrives, so it might still be cooler than this species likes, so it might be hard for the trees to establish and grow. Furthermore, the odds of ANY tree seed growing up are pretty small.

  What if sugar pine seeds land in a dry area at 2,500 m? Their chances are not good unless the climate becomes moister.



14. Show **H15 ForestCommunities.pptx, Slide 4.** Explain: This map shows the places where lower and upper montane plant communities occur in California. Ask: What is the relationship between the Sasquatch Peak forest model that we've built and the map? The trees that compose the lower montane community on Sasquatch Peak would likely occur in the blue area on the map of California. The trees that compose the upper montane community on Sasquatch Peak would likely occur in red area on the map of California.

15. Give each student a copy of **Handout 15-2: Interpreting a Model and a Map**. Have the students answer the questions—in groups or individually. Review answers together to make sure the students understand how to interpret both graphics. Explain: There is a term for what happens when species move to new areas because conditions in their old homes have changed. It is called *species migration*. Now we'll consider whether we should help that process along in wildlands of the Sierra Nevada.

Assessment:

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 **H15_Reading-TreesOnTheMove**.
2. Explain: After you've read the article, you'll participate in a "Walking the Line" speaking and listening activity (below). Then you will write a final reflection on the activity. In

your reflection, discuss how the figures, reading, and "Walk the line" activity shaped your understanding of how forest communities develop and how they may change as climate conditions change.

Walking the Line activity:

- On opposing walls of the classroom, put signs that say AGREE and DISAGREE.
- Use classroom discussion to review what *species migration* and *assisted migration* mean.
- Explain: Because we are thinking about species moving 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" that shows their personal opinions and reactions to the reading. After students have moved in response to each question, invite discussion about it.

Questions:

1. This article surprised me. I had not heard about plant species naturally migrating before reading this article.
2. All of the tree species that we've studied will be able to "…keep pace with shifting climate and regenerate under suitable habitat conditions."
3. Tree species will be able to migrate approximately 10 kilometers per year.
4. If tree species cannot migrate fast enough, then they will become extinct.
5. Inaction (that is, NOT using assisted migration) will lead to extinction of some tree species.
6. Assisted migration will produce unintended, unpredictable consequences.
7. Assisted migration will preserve ecosystems and communities that are now in rapid decline.
8. Assisted migration will have detrimental effects on current communities at the transplant sites.
9. I agree with the use of assisted migration, at least on some occasions.
10. I understand why assisted migration "…is one of the most controversial, divisive debates within the ecological community."

Evaluation: See **Teacher Key for Handout 15-2: Interpreting a Model and a Map**.
Assess the written reflection as follows.

Credit for reflection piece	No Credit reflection piece
Student discussed how the figures, reading, and walk-the-line activity shaped his/her understanding of • how forest communities develop • how forest communities may change as climate conditions change	Students did not discuss the graphs, reading, and cross-the-line activity in their discussion. They also failed to explain their understanding of how forest communities develop and how they may change as climate conditions change.

Handout H15-1: Modeling Forests of the Sierra Nevada

Use the data in the table below to illustrate the environmental conditions in which each species can grow and thrive: Plot the data on the graphic on the next page. As an example, the environmental conditions for California black oak are already shown on the graph. Graph the conditions for the remaining 11 species like this:

1. Under "Key," use different-colored pencils or markers to write the names of all species in the table (except California black oak, since it is already done).
2. For each species:
   - On the model, figure out which moisture line to use for the species (dry, medium or very moist). If you think it should be in between, *lightly* sketch the line where it should go.
   - On the appropriate moisture line, use a dot to mark the lowest and highest elevations for the species. If the table lists an elevation below the range of Sasquatch Peak, estimate where the lowest mark should be.
   - About midway between these two dots, move to the left and right of the moisture line to mark the approximate driest and wettest conditions for the species.
   - Using the color that matches this species in your key, draw an oval shape connecting the 4 dots. This shows the environmental conditions in which the species can live and thrive.

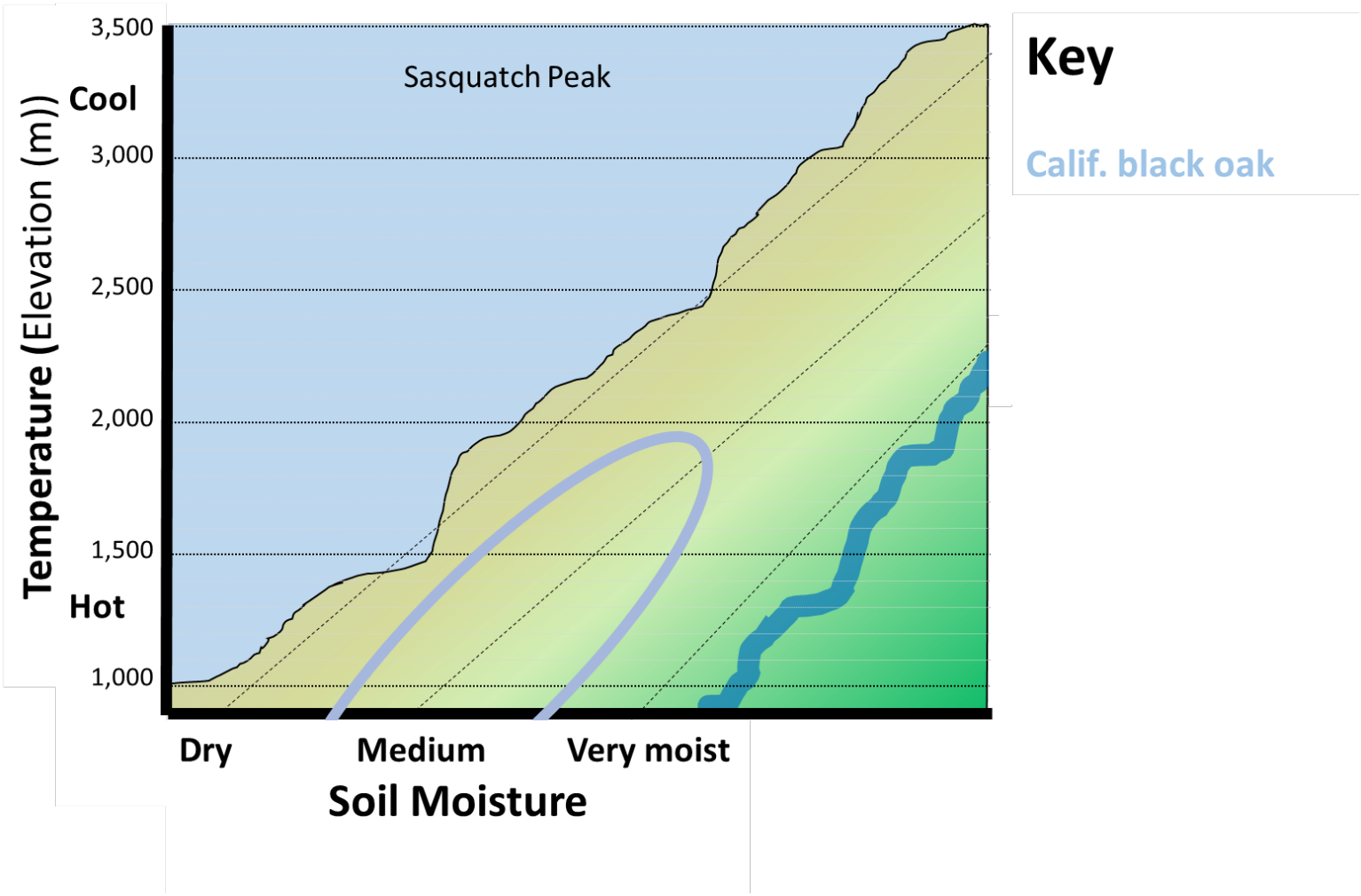
Ecological conditions for 12 tree species: Ecological conditions best for tree species on Sasquatch Peak**,** a fictitious mountain in the northwestern Sierra Nevada. The summit of the peak is at 3,500 m. The valley bottom is at 900 m elevation, but some species live and thrive at lower elevations than this.

Tree Species	Elevations where species is most common (m above sea level)*	Lives best in*
Baker cypress	1900-2100	Dry sites
Example: California black oak	500-1800	Medium sites
Canyon live oak	500-1300	Medium sites
California red fir	1900-2600	Medium sites
Douglas-fir	700-1700	Medium sites
Incense-cedar	700-2000	Dry to medium sites
Jeffrey pine	1500-2500	Dry to medium sites
Ponderosa pine	500-1700	Dry to medium sites
Quaking aspen	1600-2600	Very moist sites
Sierra lodgepole pine	1900-3400	Dry to moist sites
Sugar pine	1000-2100	Medium to moist sites
White fir	1200-2100	Medium sites

* Sources: Fire Effects Information System (https://feis-crs.org/feis/)
Burns, Russell M.; Honkala, Barbara H., tech. coords. 1990. *Silvics of North America. Volume 1. Conifers*. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service. 675 p.
Burns, Russell M.; Honkala, Barbara H., tech. coords. 1990. *Silvics of North America. Vol. 2*. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service. 877 p.

Sasquatch Peak Forest Model Name: _____

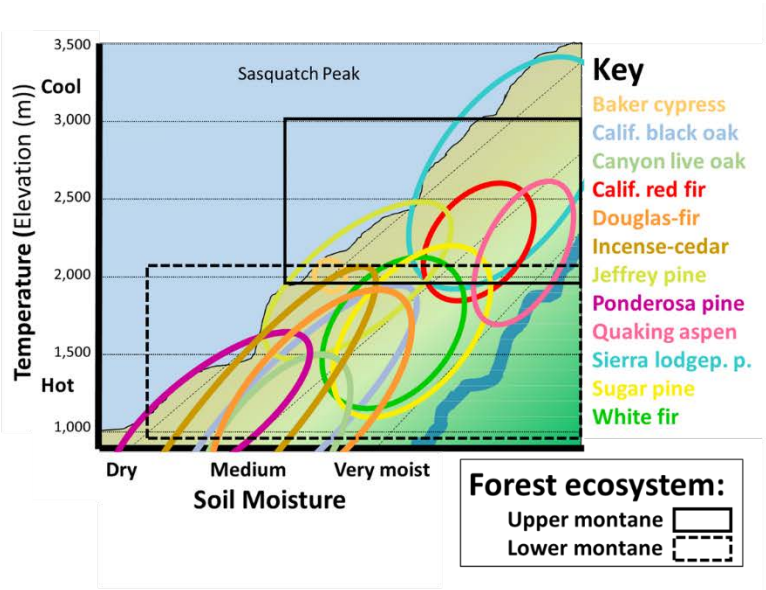
The vertical axis shows elevation, which is closely related to temperature. The horizontal axis and diagonal dashed lines show moisture on the site, from dry (very little moisture available) to very moist (lots of moisture available).

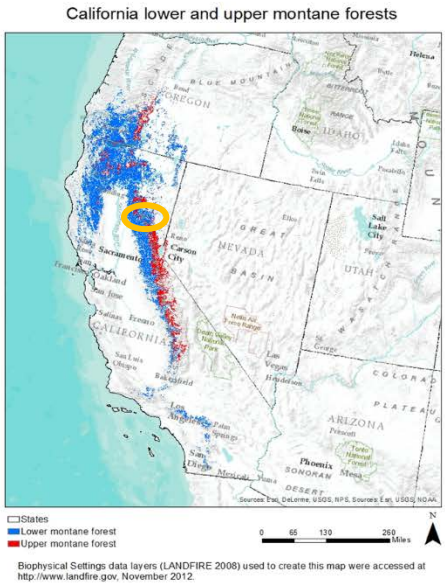


Handout H15-2: Interpreting a Model and a Map

Name: _____

Use the Sasquatch Peak Forest Model (left – or the one you made) and the map (right) to answer the questions below on a separate piece of paper.





1. What tree species commonly occur in lower montane forests? What tree species commonly occur in upper montane forests? What species commonly occur in both forest types?

2. Describe where on the map a red fir is most likely to live.

3. Describe where on the map you are NOT likely to find red fir.

4. Which species on Sasquatch Peak has the smallest distribution?

5. Suppose a California red fir lives at 1,900 m elevation and its habitat gets a lot warmer and drier. Are its seedlings likely to survive?

6. As you head north from Sasquatch Peak, would you expect Jeffrey pines to grow at lower or higher elevations than where they occur in your model? Explain why.

7. What biological factors would affect the ability of tree distribution to shift in response to climate change?

Teacher Key for Handout H15-2: Interpreting a Model and a Map

1. What tree species commonly occur in lower montane forests? What tree species commonly occur in upper montane forests? What species commonly occur in both forest types?
   There will be variation in these answers, depending on how students interpret "commonly occur." Here is one set of answers:
   - Lower montane forests: ponderosa pine, incense-cedar, California black oak, Douglas-fir, sugar pine, white fir, canyon live oak
   - Upper montane forests: Sierra lodgepole pine, California red fir
   - Species that commonly occur in both forest types: Jeffrey pine, quaking aspen, white fir, sugar pine

2. Describe where on the map a red fir is most likely to live.

   In the red-colored area

3. Describe where on the map you are NOT likely to find red fir.

   Anywhere other than in the red area.

4. Which species on Sasquatch Peak has the smallest distribution?

   Baker cypress

5. Suppose a California red fir lives at 1,800 m elevation and its habitat gets a lot warmer and drier. Are its seedlings likely to survive?

   It could have trouble. 1,600 m is already at the lower (hotter and dryer) end of its range. If it got even hotter and drier, it would be hard for seedlings to survive.

6. As you head north from Sasquatch Peak, would you expect Jeffrey pines to grow at lower or higher elevations than where they occur in your model? Explain why.

   Lower. As you head north, the climate typically gets cooler, so Jeffrey pines should be able to grow lower on the mountainsides.

7. What biological factors could make it easier or harder for a tree species' distribution to shift in response to climate change?

   There could be many answers. Here are a few:
   - competition with other trees, which stresses them
   - seed predation, so it can't regenerate even if environmental conditions are good
   - insects, fungi, or disease, so it can't produce seeds – or grow well in the new location
   - soil-related and land-use issues, such as use of herbicides and disturbance of soil
   - seed dispersal ability, so it can't deliver seeds far from the parent tree
   - variety in the species' traits and the rate of genetic change occurring, which could produce traits adaptive to environmental change