Wildlife, Plants, & Habitats Seminar

# Interconnected: Relationships between a Mountain, People, Plants, & Fire

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**Context & Rationale**

Our School Community

My students are a part of the ponderosa pine ecosystem at the base of Dook'o'oosłííd (San Francisco Peaks), a mountain of sacred significance to Diné and the highest point in Arizona. On a Sunday morning in June 2022, everyone in Flagstaff watched as incredibly high winds whipped a pinpoint campfire into a mountain-wrapping, raging wildfire. The Tunnel fire burned quickly, skipping across areas that had been scorched only a couple months before in another wildfire. It expanded into areas of forest where there had been no fire for many years, feeding off accumulated organic material on the forest floor. Plumes of orange flame were visible from town as trees exploded and billows of smoke rose high into the air. Within a day, the wildfire became the number one priority for fire resources in the country, and hot shot crews, air support, and tank trucks poured into town. Just outside of town to the northeast, a lightning-ignited fire took hold, eventually fusing with the Tunnel fire and demanding further resources and (Golightly, 2022). The experience of having their town and homes threatened by wildfire was not new for my high school students. Our fire-prone community is starting to learn this tale by heart as large-scale fires inevitably work their way up our mountains and through our canyons. Most of my students know what it is like to see embers simmering in the distance in the dark of the night. My hope in writing this unit is that my students will know and understand the ecological communities that range from the top of Dook'o'oosłííd to the lower Sonoran Desert and be able to describe ways to measure these communities, interpret the interconnectedness of their plant species, and make predictions about how these communities might respond to stressors, including wildfire and climate change.

There is evidence from built structures to indicate that trees and plants from the ponderosa pine forests around Flagstaff have been utilized by the Indigenous peoples of this region for more than 1,100 years. There is also evidence that Indigenous peoples held an active role in the fire regime and alteration of the forests in the Southwest for the last four centuries (Alcoze, 2003). One hundred and seventy-four years ago, the area of present-day Flagstaff was annexed from Mexico by the US government through the Treaty of Guadalupe Hidalgo (U.S. National Archives, 2022). The city of Flagstaff was established 140 years ago along with development of the transcontinental railroad, which allowed for the transport of livestock and lumber (Discover Flagstaff, n.d.). Flagstaff has a current population of about 78,000 people and has grown steadily since 1950 (World Population Review, 2022). Flagstaff is a border town of the sovereign Navajo Nation, which is 25 miles away. It is also a gateway town to the Grand Canyon, bringing many visitors to Flagstaff on their way to this landmark. Because of the moderate weather and forest access, people in Flagstaff tend to spend a lot of time outdoors. Flagstaff is home to many science institutions such as Lowell Observatory, the United States Geological Survey, US Forest Service Research Station, and Northern Arizona University (NAU). Both the School of Forestry and the Ecological Restoration Institute (ERI) at NAU have served as resources in the creation of this unit.

Our school district, Flagstaff Unified School District (FUSD), serves approximately 9,100 students at fifteen different schools (Flagstaff Unified School District, n.d.). Every student in FUSD has a school-issued iPad that was distributed in 2019 based on bond funding voted for by the community. Our district offered online-only classes from March 2020 to March 2021 due to the COVID-19 pandemic. The option to attend classes online ended in May 2021 and since then all classes have been in-person.

This year will mark the 100th anniversary of Flagstaff High School (FHS). The mission of the FHS community is "to graduate all students academically prepared to harness post-secondary success." Our school motto is "Once an Eagle, Always an Eagle." FHS has a total population of 1,570 students. They range from very low income and homeless to upper middle class. Our racial diversity is as follows: 48.5% white, 25% Native American, 20.6% Hispanic, 0.9% Asian, 0.7% Black or African American, with 3.8% identifying in multiple categories (AZ School Report Cards, 2021). According to the school

registrar, 14% of our students have Individual Education Plans (special education accommodations or modifications) and 23% of our student population qualifies for Free & Reduced Lunch. FHS has received a B grade from the state of Arizona over the last five years; however, in 2021 and 2022 school letter grades were not calculated due to the pandemic (AZ School Report Cards, 2021). FHS serves students from Flagstaff and the nearby communities of Dilkon, Tolani Lake, Cameron (which are on the Navajo Nation), Doney Park, Bellemont, Parks, Baderville, Kachina Village/Mountainaire, Munds Park, and Lake Mary. Some students may travel by bus from as far away as 90 miles, which means they start out for school early in the morning and arrive home late in the afternoon.

FHS is honored to serve a population of Native American students who live in the Kinłani Bordertown Dormitory one mile north of the school. Originally built in 1958 by the Bureau of Indian Affairs (BIA), the dormitory initially housed students from kindergarten through high school. By the 1980s, the last student to have lived in the dorm for K-12th grades graduated (Flagstaff Bordertown Dormitory, 2021). The dorm now houses only high school students, having undergone a major renovation in 2008. College-style dorm rooms provide living quarters and the building also has a cafeteria, gym, computer labs, and common areas. Students from the dorm walk back and forth to FHS and have dorm faculty who support them in academics, recreation, and residential life. This school year the dorm has been unable to hire enough staff, and as a result, students must travel home every weekend. As a teacher at FHS, I acknowledge the assimilatory history and colonial aims of boarding schools and their impacts on generations of Indigenous People in our community. I have a responsibility to work against the harms passed down from this system and to honor the cultures of my students and their families who have made the decision to live at the Kinłani dorm and attend our school.

This unit is designed for my Advanced Placement Biology students. They are juniors and seniors, 16-18 years old who have purposely signed up for a rigorous class. To enroll in AP Biology, students must already have a biology and chemistry credit. Many students take multiple advanced classes at the same time, such as AP English Literature, AP Statistics, AP Calculus, and AP US History. Last year, 23% of students at Flagstaff High were enrolled in one or more AP classes. My students also tend to be committed to their school and local communities through student council, athletics, band, theater, campus clubs, dual enrollment classes, and internships. Many students have jobs outside of school, and it is not uncommon for seniors in AP Biology to have no seventh hour so they can leave early and go to work. Each year I have one or two students who graduate early and leave at the end of the first semester. While taking the AP test is not a requirement of the class, a majority of students take it each year.

I teach two sections of AP Biology with about 25 students in each section. We meet every day for 50 minutes with a shorter day on Wednesday. The AP test is held in May and there are eight content units of the class, as required by the College Board. This unit best aligns with Unit 8, Ecology, which takes place at the end of the year, most likely starting in late April.

I grew up in the community of Flagstaff and I graduated from FHS. I have a long line of educators in my family--my paternal grandparents moved to Flagstaff from Michigan to teach at NAU and my parents both worked in the Flagstaff school district, one as an English teacher and the other as a speech therapist. This is my ninth-year teaching at FHS and my second year participating in the Diné Teacher Institute. From my porch I have watched my children grow into their childhood and I have watched wildfires burn in the distance. I have spent some of the most significant times of my life in this ecosystem, connecting my memories to the landscape, and look forward to teaching my students about the fire ecology of their home.

*"In the twenty-first century, climate change will require human communities to adapt and reimagine interdependent relationships with and responsibilities to the natural world and each other."*

*- Dr. Megan Bang (Bang et al., 2018)*

My science teacher education classes stressed the definition of science as a **product** (facts and laws), a **process** (scientific methods), and a **way of knowing** (based on empirical evidence). While this definition clearly delineates what is science and what is not, it does not leave space to value traditional ways of knowing and being that my students may have. Along with being testable, measurable, and repeatable, we are also taught that science is objective and free of bias. However, Western science is not infallible and was built upon a history of colonialism and racism. Research from Bang, Marin, and Medin (2018) claims that this myth of "value-free" Western science inhibits underrepresented students from engaging and therefore achieving in science. This unit acknowledges Traditional Ecological Knowledge as a way of knowing that can bring greater understanding of an ecosystem. Humans are discussed as only one of the critical species in our habitat. AP Biology is one of the last classes my students take before going into a science-related field after high school and I hope to send them with an appreciation for the interconnectedness of nature.

This unit is particularly relevant for my students because we look up from our school campus at Dook'o'oosłííd every day and it is a defining feature of our landscape. Northern Arizona is particularly unique in that eight distinct life zones can be observed over a short distance. Our mountain was the reference point for early foundational studies on the life zone concept as described by C. Hart Merriam in 1890 (Phillips, House & Phillips, 1989). In addition to our proximity to the mountain, we also benefit from world-class research at NAU in the fields of forest ecology, fire science, and dendrochronology– topics related to this unit.

The seniors taking AP Biology this year carry with them the heavy legacy of the Covid-19 pandemic interrupting their high school careers and lives. As freshmen, they left for the spring break holiday not knowing it was the last time they would be at school for more than a year. They weathered the rocky shift to online learning and went to great lengths to connect to digital classes however possible. Their sophomore year was almost entirely online with a hybrid fourth quarter as some students returned to the building and others remained at home. With the return of the whole school in person during their junior year, students still faced many novel challenges and mental health services straining to keep up with student needs.

It is my observation that students "toughened" over these years by persisting in the face of so many uncertainties. Students have experienced loss of loved ones, the loss of high school activities and opportunities, and have missed out on time interacting with their peers and with scientific content. They are very much in need of opportunities to build a community with their peers and to feel like their individual contributions are supporting a larger effort. Many of the seniors this year were my honors students in 2020 and didn't have the chance to experience our ecology curriculum. I hope that this unit will help to fill some of those gaps and provide links for them to become interested in related topics. Our unit allows us to spend intentional time outdoors, visiting multiple life zones. This can help build a respectful and reciprocal relationship to place and help build community among my students.

**Content Objectives**

Geologic History

Of the 600 volcanoes in the San Francisco Volcanic Field, the San Francisco Peaks are the largest, at an elevation of 12,630 feet and form the highest point in Arizona. The San Francisco Peaks is a stratovolcano with a long history of eruptions and glaciation. Although we will focus on more recent

history in this unit, the full story of the Peaks starts almost three million years ago. The following chart shows the major geologic and ecological events based on research compiled by Waring (2018).

| **6 million years ago** | **2.8 million years ago** | **2.6ma - 12,600 years ago** | **500,000 years ago** | **91,000 years ago** |
|---|---|---|---|---|
| The San Francisco volcanic field develops | First volcanic eruption of the Peaks starts to build the mountain | Multiple glacial periods | Central cone lava flow (the mountain was 4,000 feet taller before this eruption) | Last volcanic eruption of the Peaks |

| **35,000 years ago** | **27,000 years ago** | **12,400 years ago** | **9,000 years ago** | **130 years ago** | **100 years ago** |
|---|---|---|---|---|---|
| Mixed conifer forest is prevalent (temperatures much cooler than now) | Last glacial maximum in North America (Lockett Meadow glacier one of several on the Peaks) | Ponderosa pine trees now prevalent around the Peaks | Oldest evidence of humans on the Peaks | Fire suppression management practice begins on the Peaks | Epic Ponderosa pine establishment in the West |

## The Life Zone Concept

The San Francisco Peaks and the Painted Desert provided a backdrop for a scientific expedition in 1889 that delineated seven different "life zones" based on measurements of temperature, humidity, and plant distribution (Phillips, House & Phillips, 1989). The main scientist on this expedition, C. Hart Merriam, hypothesized that what could be observed across an elevational gradient on the Peaks would match the latitudinal pattern seen across the continent. The life zone concept marked a milestone in the field of ecology and the correlation between the Peaks and the larger landscape still provides a useful concept for ecological organization (Fulé et al., 2021).

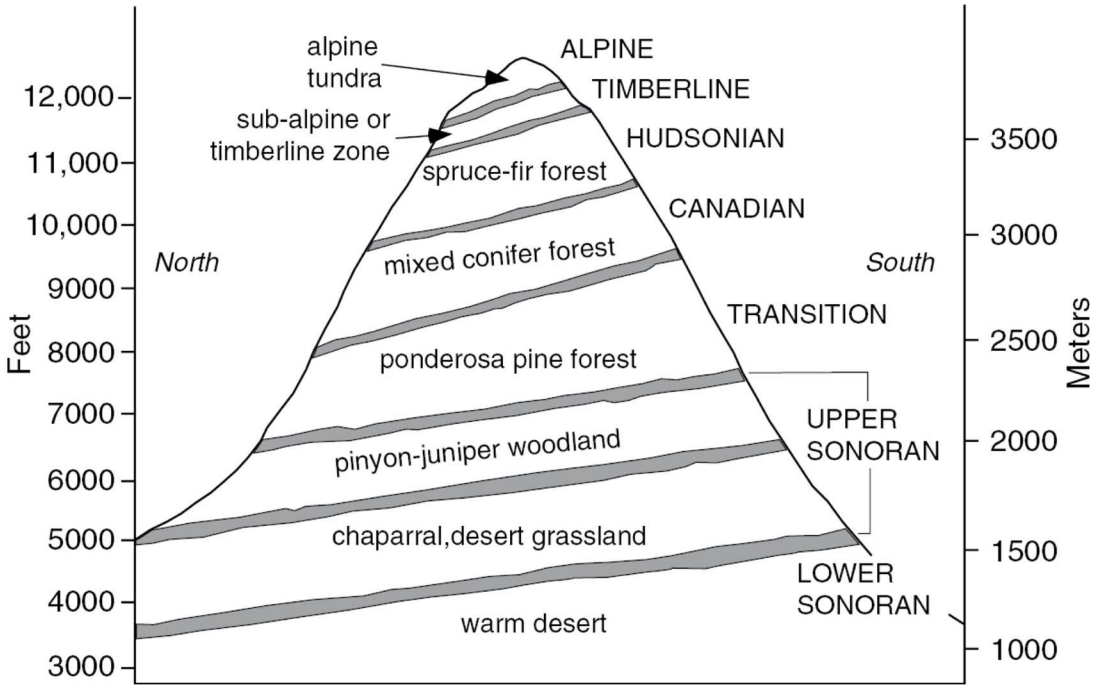


*Figure 1.* The San Francisco Peaks and the Life Zone Concept. Adapted from "Expedition to the San Francisco Peaks," by Phillips, House, & Phillips, 1989, *Plateau 60*(2), p. 19. Copyright 1989 by the Museum of Northern Arizona.

In 1908 Gustav Pearson furthered Merriam's research by examining the tree species specific to each life zone. His studies included transplanting seedlings to different zones to determine their range of survival. Highlights from his research show that temperature decreases and moisture increases as you move through life zones up the mountain. Ponderosa pine forest experiences the greatest daily temperature fluctuations (Waring, 2018).

At Flagstaff High School we have a life zone garden based on Merriam's life zones and modeled after a similar garden at the nearby Museum of Northern Arizona. Although the courtyard is one elevation, differential amounts of sunlight and shade are used to simulate three life zones. The zone with the most shade is designated as mixed conifer, the next as ponderosa pine forest, and the sunniest zone as pinyon-juniper. In each zone there are representative species that students have planted, in addition to opportunistic plants that have established. Through statistical tests, my AP students are able to show that there are consistent, significant differences in seasonal weed establishment in each life zone correlated with the amount of sunlight.

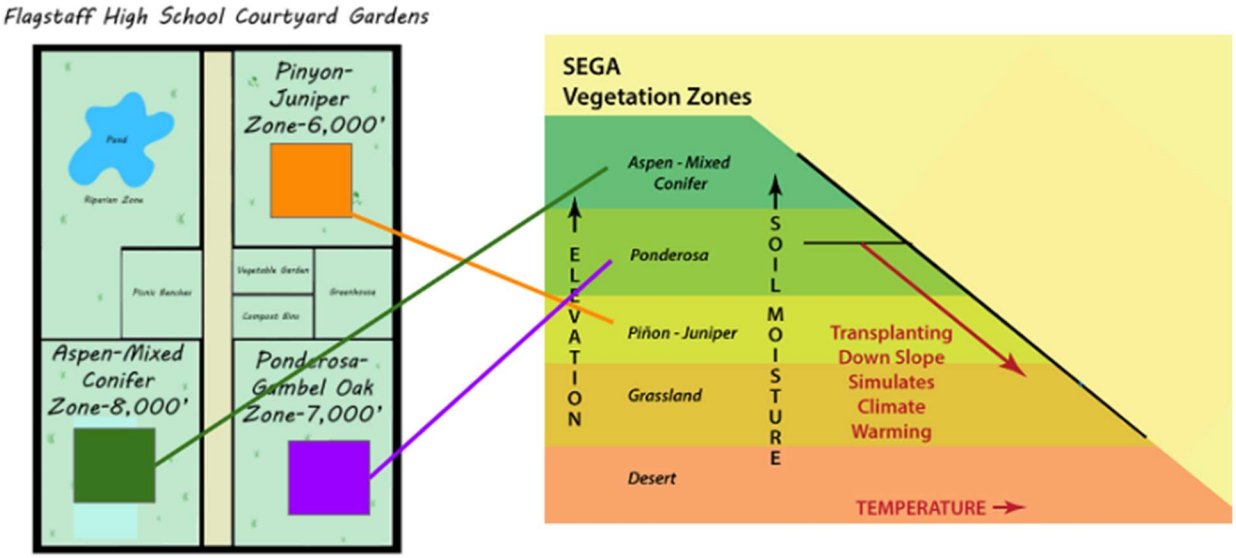


*Figure 2.* Flagstaff High School Life Zone Garden Concept. Created by Linda Lenz, (personal communication, 2015)

Human History

The Peaks are sacred and significant to many Indigenous peoples of the region. In Diné culture, the San Francisco Peaks are called Dook'o'oosłííd and are one of 12 sacred mountains found at the western side of a circle of mountains that each hold significance and stories (Long, 2022). Elder Paul Long (2022) explains that to Diné, Dook'o'oosłííd is a female mountain, the mother mountain, and is associated with abalone shell and stories about what is right and wrong. In the Diné Education Paradigm, which follows a sequence of thinking, planning, implementing, and evaluating, west is the direction for implementation and relates to the adult responsibilities in life.

The San Francisco Peaks go by several different names by other Peoples of the region (US Forest Service, n.d.):

- Tsii Bina — Aa'ku —(Acoma)
- Dził Tso — Dilzhe'e— (Apache)
- Hvehasahpatch or Huassapatch — Havasu 'Baaja — (Havasupai)
- Nuva'tukya'ovi — (Hopi)
- Wik'hanbaja—Hwal`bay — (Hualapai)

- 'Amat 'Iikwe Nyava — Hamakhav — (Mojave)
- Nuvaxatuh — Nuwuvi — (Southern Paiute)
- Sierra sin Agua — (Spanish)
- Wi:mun Kwa — (Yavapai)
- Sunha K'hbchu Yalanne — A:shiwi (Zuni)

By 1,400 years ago, Cohonina and Sinagua peoples had settlements all around the Peaks, with agricultural sites concentrated on the warmer alluvial plains of the eastern slopes, near present day Doney Park. There is also evidence of hunting camps located near higher elevation springs (Waring, 2018).

Dunbar-Ortiz (2019) explains that before European invasion, Indigenous peoples in North America managed their lands through the application of fire and the creation of roadways. Ponderosa pine forest, specifically, was used by Indigenous peoples for hunting, building materials, and to harvest medicinal and nutritional products from both the trees and the understory vegetation (Alcoze, 2003). Historic dendrochronology records from before 1900 show a fire interval of 2-20 years in southwestern forests (Fulé et al., 2021). Dendrochronological evidence has been used to predict that springtime fire scars may be the result of human ignitions as lightning-caused ignitions are more concentrated during the summer monsoon season (Alcoze, 2003). It is likely that the conditions of the forest described by early settlers near the Peaks were influenced by generations of people living here and managing their ecosystem (Dunbar-Ortiz, 2019). According to Alcoze (2013), when European settlers arrived in North America, they had little ability to understand how Indigenous peoples influenced their landscapes and instead thought they found a “pristine Eden” without human influence.

Several decades after the arrival of European colonists, the late 1800s saw extensive logging in the forests around Flagstaff, effectively removing the majority of old-growth trees where they were accessible to loggers (Friederici, 2003). Settlers further modified the forest by contributing to the overgrazing of the forest understory by sheep and cattle and actively removing predators. Over the course of a century, paired with fire exclusion policies overseen primarily by the US Forest service, major shifts occurred in the forest. These shifts moved the forest structure from parklike conditions with large diameter trees to dense thickets of small diameter trees (Friederici, 2003). This long period of fire exclusion from life zones in southwest forests has led to higher fuel loads with greater connectivity, leading to the potential for high-intensity, stand replacing fires (Fulé et al., 2021).

The Peaks currently lie within the boundary of Coconino National Forest, under the management of the US Forest Service, a branch of the US Department of Agriculture. A large portion of the upper mountain was designated as wilderness in 1984. This area, called the Kachina Peaks Wilderness, encompasses 18,960 acres. As a wilderness area, roads are discouraged and no motorized vehicles are allowed (Coconino National Forest, n.d.). Alcoze (2003) reminds us that viewing wilderness as separate from human experience is a Western concept, and that a Native American worldview places humans as equal partners in the cycle of all living things.

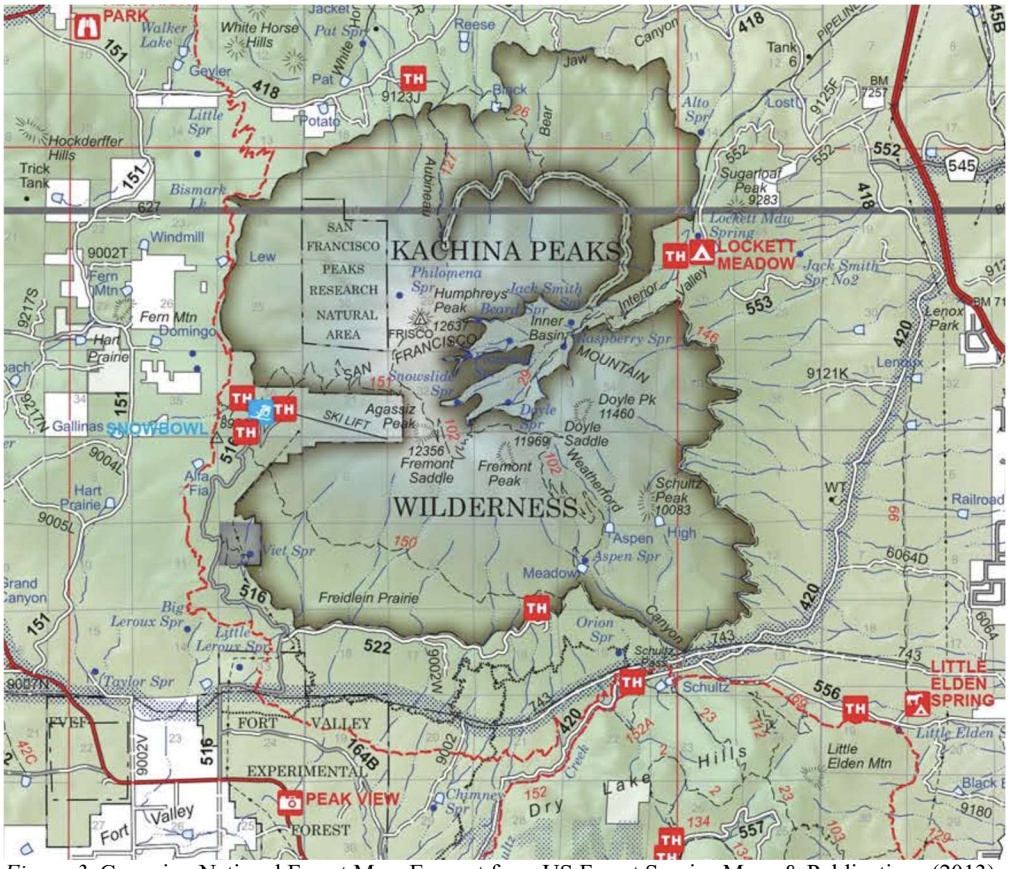


*Figure 3.* Coconino National Forest Map. Excerpt from US Forest Service Maps & Publications (2013). Note that green areas show National Forest, the wilderness area is outlined, and white areas indicate private land.

## Current Stresses and Responses in the Mountain's Ecosystems

*"A reorganization of almost all southwestern forest ecosystems is predicted to occur in the next 50-100 years because of global warming."*

- Swetnam and Falk, 2015

A legacy of fire exclusion in the forests of Dook'o'ooslííd over the last 150 years has had differential impacts on the tree species of certain life zones. Lower elevation ponderosa pine and mixed conifer forests, which have historical fire return intervals of 2-25 years, are dramatically altered as a result of fire exclusion (Cocke, et al., 2005). Higher elevation spruce-fir forest, which has a longer fire return interval of 70-400 years, has not experienced the same degree of alteration over the same time period. Since 1876, Cocke, et al., (2005) have found that the tree density within all forest types on the Peaks has increased significantly. Coupled with changes in density, tree species have shifted their elevational ranges over the same time period. Many species, including bristlecone pine, Engelmann spruce, Douglas fir, and ponderosa pine actually showed downhill shifts in elevation ranging from 25 meters to 400 meters (Cocke, et al., 2005). These downhill shifts may be the result of trees being able to survive and establish in areas where fire would normally have removed seedlings, and the effects are more pronounced at lower elevations. Increased forest density also makes ponderosa pines on the Peaks more susceptible to pathogenic invasions by bark beetles and dwarf mistletoe (Covington, 2003).

Climate change also affects forests on the Peaks. Long-term drought in the southwest has already led to decreased snowpack in the winter and increased wildfire in the spring and summer (GlobalChange.gov, 2014). Under current rates of global emissions, regional annual average temperatures are projected to rise from 5.5°F to 9.5°F by the end of this century (GlobalChange.gov, 2014). These changes may lead to

longer growing seasons and increased photosynthesis in forest ecosystems, but these shifts are coupled with longer fire seasons and reduced soil moisture (Covington, 2003).

Effects of climate change may contribute to shifts in forest composition and regeneration following wildfire. High-severity fire that results in entire stands of trees being killed causes loss of seed sources and may result in species like ponderosa pine not being able to recover in their previous habitat (Swetnam & Falk, 2015). Stoddard et al. (2018) measured forest plots before and after the 2001 Leroux fire on the Peaks and found that 15 years after the fire, drought tolerant ponderosa pine had very low rates of regeneration in burned areas. In the same study, aspen trees did regenerate in burned areas after the fire, but 15 years later had lower densities than before the fire in the same areas.

Trees compete with other plants by growing at their physiological limits, observed by trees inhabiting the transition areas between life zones. Because of climate changes, some species may shift up-slope to stay within their ideal range of temperature and precipitation (Swetnam & Falk, 2015). However, the rate of tree migration may not be able to match rapid variations in climate. Spruce-fir forest at the higher elevations on the Peaks is most at risk of running out of habitable area if trees germinate upslope and if high intensity fire opens up habitat for other tree species (Swetnam & Falk, 2015).

Fire frequency on the Peaks has increased, and due to high fuel loads as a result of fire suppression, fires are more likely to be frequent, and potentially stand-replacing (Dodge & Fulé, 2008). This pattern increases opportunities for invasive species to inhabit areas cleared by wildfire. While small fire disturbance is beneficial for native plants, they cannot compete with invasive species after high-intensity fires (Dodge & Fulé, 2008). Fire reduction efforts such as thinning and control burning can also inadvertently lead to invasive species colonization in areas of disturbance.

The forest ecosystems of the Peaks are utilized by humans for recreation, drawing locals and visitors from surrounding areas. Popular activities on and around the mountain include hiking, camping, biking, horseback riding, visiting the changing leaves, snowmobiling, dirt-biking, snowshoeing, and skiing. Over the course of its 80+ years of operation on the mountain, the Arizona Snowbowl ski resort has been the focus of many conflicts that magnify the cultural differences between government, Indigenous tribes, and the snow sports industry in their relationship to how landscapes should be treated (Necefer, 2019).

The Snowbowl occupies 777 acres of land on the Peaks and operates under a special use permit issued by the Coconino National Forest. During peak ski season the resort may have more than 3,000 visitors per day (McGivney, 2022). As climate warms and snowpack decreases, most of the ski resorts in the US employ artificial snow to supplement snowfall (Necefer, 2019). However, Snowbowl was the first ski resort in the country to use reclaimed water for snowmaking, and uses approximately 1.5 million gallons of treated wastewater per year for this purpose (McGivney, 2022).

Thirteen local Indigenous tribes consider the Peaks to be sacred. They are the Pueblo of Acoma, Fort McDowell Yavapai, Havasupai, Hopi, Hualapai, Navajo, San Carlos Apache, San Juan Southern Paiute, Tonto Apache, White Mountain Apache, Yavapai Apache, Yavapai Prescott, and Pueblo of Zuni tribes. Necefer (2019) explains:

> "While many of these tribes' beliefs about the mountain differ, there are commonalities. Namely, that the water, soil, plants and animals of the peaks have inalienable spiritual and medicinal properties; that the peaks represent a living being; that the peaks are home to deities and other beings; and that tribal members have a duty to protect them" (paragraph 9).

These tribes consider the presence of the Snowbowl on sacred lands and the use of treated wastewater as desecration, making it difficult or impossible to steward the land and to gather plants and other sacred objects for ceremonies that are not contaminated.

Steps to Move Forward: Forest Management & Traditional Ecological Knowledge

*"By acknowledging and treating tribes as partners in co-stewardship of our lands and waters, we will undoubtedly strengthen our federal land and resources management."*

- Interior Secretary Deb Haaland
(*Agriculture and Interior departments,* 2021)

How can we move forward with solutions to the challenges that face our mountain ecosystems? Examples of robust restoration initiatives to restore ponderosa pine forest are collaborative and rely on expertise from many fields of science and Traditional Ecological Knowledge. Thom Alcoze (2003) describes ecological restoration as restoring our human relationship with the environment. As many current managers are approaching retirement, there is an acute need for young people in the field of natural resource management. Effective ecological restoration incorporates knowledge gained from restoration projects into educational curricula for youth in order to set the foundations for future careers in land management (Alcoze, 2003).

In 2021, President Biden unveiled the Tribal Homelands Initiative, which promotes the role of tribal communities in federal land management by the Departments of Agriculture and Interior. Its aim is to improve federal stewardship of public lands, waters, and wildlife through these partnerships (Agriculture and Interior departments, 2021). Reed Robinson, the USDA Forest Service Director of the Office of Tribal Relations, says it is time to *indigenize* the Forest Service by not only acknowledging Indigenous Americans as original land managers of this country, but also by reincorporating Indigenous values and knowledge into land management systems (Red Lake Nation News, 2022). As the primary agency that oversees management of the forests on the Peaks, this approach may influence how the Forest Service makes local decisions in the future.

The Four Forest Restoration Initiative (4FRI) represents a major effort to restore over 2.4 million acres of ponderosa pine forest over the course of 20 years in four different national forests in Arizona, including Coconino National Forest (Four forest restoration initiative, n.d.). This landscape-scale goal involves forty-four different organizations whose efforts are divided into five working groups. 4FRI aims to restore the composition, and health of ponderosa pine systems that evolved with frequent fire (Four forest restoration initiative, n.d.). This includes reducing fuel loads and thereby reducing wildfire risk. Many small projects interact to support 4FRI's large goals.

Another collaborative effort that impacts forest restoration in our community is the Flagstaff Watershed Protection Project (FWPP). After learning hard lessons from the Schultz Fire in 2010, which caused significant flooding below the burned areas on the east side of the Peaks, Flagstaff voters approved a bond to form the FWPP. The state of Arizona, City of Flagstaff and Coconino National Forest work together to reduce the risks from high-intensity fire and subsequent flooding that could impact our city's watersheds (Flagstaff Watershed Protection Project, 2013). To date, 11,000 acres of forest have been thinned in the FWPP footprint. Because this project includes areas within the city limits, it brings restoration into focus for citizens and a chance to observe the process.

A difficulty with forest thinning projects is determining what to do with the small diameter trees that are cut. The National Forest Foundation, along with the Forest Service, the Ancestral Lands Conservation Corps, and the Navajo and Hopi tribes have come together to support the Wood for Life Tribal Fuelwood Initiative (Wood For Life, n.d.). Many homes on the Navajo and Hopi nations use fuelwood to stay warm in the winter, including elders. The Wood for Life initiative connects

tribal members with the small diameter wood that is cut for forest restoration and provides a sustainable source of fuelwood. After an initial attempt, the project has been successful enough to repeat and in 2022 won a Stewardship and Partnerships Award from the USDA *(Wood For Life,* n.d.).

Just as the life zones on the Peaks became world-famous for the life zone concept they illustrate; this region also serves as an example for how to carry out ecological forest restoration through collaborative management.

**Teaching Strategies**

Part I: Our Mountain- Looking Back

What is the history of our mountain?

Students will be presented with background information about the natural history and the human history of the San Francisco Peaks, including its significance to the study of ecology and to the Indigenous peoples of this area. Students will study maps of precipitation and elevation in Arizona to make predictions about life zone distribution. As a precursor to visiting different life zones, students will create a detailed diagram of life zones in Arizona, including elevation and dominant plant communities. Students will also be (re)introduced to our campus life zone garden which features a few of the life zones we will study. Students will identify and research stressors impacting the mountain ecosystems, including fire, climate change, and recreation. Students will summarize their understanding of stressors to mountain ecosystems in a detailed graphic organizer. To explore what the forests on the Peaks looked like historically, students will gather photographs from the Cline Library Colorado Plateau Digital Collections.

Part II: Visiting Life Zones

What ecological communities can be found at each life zone? What can we learn from the representative species in different life zones? What are the characteristics of different forest types?

Over a two-day field expedition, students will visit multiple life zones, moving up in elevation from around 6,000 feet to 10,000 feet, and collect observational data about the traits of tree species. Students will also gather photos of each life zone and add them to a class gallery. Observations will be supplemented with teacher-provided data about soil, root depth, and fire regimes.

Day one of the expedition is a trip through Sunset Crater National Monument, starting at the north end of the Loop Road, off of Highway 89. Observations of pinyon-juniper woodland will be collected near the Doney Mountain Trailhead. At a second stop, observations of ponderosa pine forest will be collected at the Cinder Hills overlook or from the Lava Flow Trail. Sunset Crater was selected because it shows the transition from desert grassland to pine forest over a relatively short distance and highlights the human history of this region.

Day two of the expedition is a trip up the mountain for students to observe higher elevations life zones. Mixed conifer forest will be observed near the Humphrey's Peak Trailhead. Based on student preference, spruce-fir forest can be observed by either hiking up the trail or by traveling up the mountain on the gondola. If hiking, observations of the alpine life zone will be indirect. If we travel by gondola, this life zone will be directly observable at 11,500 feet.

Part III: Bringing Knowledge to our Community

What did we learn from the mountain? How can our knowledge of life zones help us improve our campus garden?

Utilizing observations from our field expedition, students will choose a project related to either making improvements to one section of the garden or creating educational materials. Students will form into three teams, one for each life zone: pinyon-juniper, ponderosa, and mixed-conifer. Students will design their own projects from a menu of options and share them with our school community at the end of this unit.

Part IV: Our Mountain-Looking Forward

What can current research tell us about the future of our mountain ecosystems? What stories are in the data? How can we manage forests for restoration?

Students will engage with current research about climate projections and the way forests in the Southwest, particularly ponderosa pine, are responding. Students will read about local forest management plans and how Traditional Ecological Knowledge plays a role in the restoration and management of forests. As a summative process, students will create a visual poster comparing and contrasting one of the life zones on the Peaks as it was 150 years ago and how they predict it will be 30 years from now. Posters will include photographs gathered from the Colorado Plateau Digital Collections and the student photographs from our expeditions. Students will share their final projects with our school community during an open house poster session in the life zone garden.

**Classroom Activities**

This section contains an overview of three vital activities from this unit. The first is a description of the data students will collect during our life zones expeditions. At each location, they will answer a similar set of questions intended to highlight unique differences in tree species at each life zone and provide background to support students when they design their campus garden projects and when they create their compare and contrast posters.

At each site, students will first mark the location and elevation of the site on a life zone diagram. They will then draw and describe what they see looking at the landscape. Next, students will examine tree species in detail. Students will be provided with a field guide of the main tree species they are likely to find at the life zone sites, including juniper, pinion pine, ponderosa pine, Gamble oak, Engelmann spruce, corkbark fir, limber pine, Douglas-fir, aspen, and bristlecone pine. Using the tree profiles, students will identify tree species on site and for each one, collect a series of observations. These observations include details about the: bark, smell, number and arrangement of needles or leaves, presence of cones, tree shape, understory, evidence of fire scars, tree dispersion, duff layer, and any observed evidence of animals. After students have collected observational data, we will meet as a group and I will provide further information about properties that are not directly observable- fire regime, root depth, soil properties, and medicinal properties or traditional uses (if applicable). Students will also take photos at each site and add them to a class gallery that can be accessed later for use in the poster project.

The next activity highlighted here is the campus life zone garden project. Students will use their experiences from the expeditions and their knowledge about life zones and human history on the Peaks to design and carry out a project that contributes to the ecological or educational value of the Flag High's life zone garden.

The class will be divided into three groups, one for each of the life zones in the garden: pinyon-juniper, ponderosa, and mixed conifer. Whatever project students choose, it needs to be accomplished over a two-

week window with approximately four days of in-class work time provided. Students can choose from this menu of options for their project, or propose their own:

- Create labeled herbarium samples for at least three representative plant species in your life zone.
- Write a field guide entry for at least two plant or animal species that live in this life zone. See The Sonoran Desert: A Literary Field Guide edited by Eric Magrane & Christopher Cokinos for examples of writing a narrative field guide entry.
- Carry out a plan to restore your life zone section. This might include: removing invasive species, soil amendment, or planting representative species.
- Fabricate interpretative signage for your life zone.
- Research an endangered species that lives in your life zone and create an outdoor art representation of this species to display in the garden.

The third activity described here is the summative compare and contrast poster project. This assignment requires students to synthesize what they have learned throughout the unit to create a visual product that describes forest conditions in a selected life zone in the past and the predicted future. The historic photo will be used to represent the forest as it was 150 years ago. The modern photo will represent the forest as it is now and how it might be 30 years into the future. These time frames were selected because 150 years ago provides a view of local life zones before the effects of colonization and forest modification through logging and fire suppression. 30 years into the future may be relatable to students and allows them to predict upcoming changes on a shorter time frame. For an example of using comparative past and present photos, students will have the opportunity to look through the book The San Francisco Peaks and Flagstaff: Through the Lens of Time by John L. Vankat.

For their poster, each student will choose one of the life zones we studied. Their poster will have a historic photo of this life zone on the left side, and a modern photo on the right side. Each poster must include a title, the elevational range of the life zone, and labels to show where each photo was taken and in what year. Students will add a label for each of these categories in the center of the poster: Tree species, tree density, fire behavior & notable wildfires, recreational uses, restoration projects. For each category, students need to write up a description for both the historical forest (150 years ago) and the modern forest (present-30 years from now). These descriptions will be pasted to the poster on the left and right. For the future descriptions, students should describe evidence-based predictions, and they may also add what they personally hope to see happen within their life zone related to the topics.

**Student Assessment Plan**

| ***Learning Goal*** | ***Assessment Type*** | ***Assessment Format*** |
|---|---|---|
| Delineate major events in the mountain's history | Formative/background information | Student-created timeline based on in-class presentation |
| Study the relationship between precipitation and elevation in Arizona | Formative/data interpretation | Analyze data to show the relationship between elevation and precipitation |
| Delineate the life zones in Arizona | Formative/describe characteristics of a biological concept | Diagram elevations, life zones, and representative tree species |
| Compare the life zone concept to our life zone garden | Formative/comparison and observation | Compare and contrast the life zones on the Peaks and the ecosystems in the courtyard garden |

| | | |
|---|---|---|
| Identify stressors to life zone communities on the Peaks | Formative/brainstorm | Background research and class presentation |
| Describe the ecological conditions on the Peaks 150 years ago | Formative/data synthesis | Use climate data, forest history, and management information from our in-class presentations that will be used for the summative poster project |
| Ecological surveys at different life zones | Summative/data collection and analysis | Low and high elevation comparison of tree, forb, and flower species present |
| Improve the campus life zone garden | Summative/project-based group project | Differentiated garden projects- field guide or herbarium profiles or planting native species |
| Examine climate projections | Formative/explorative | Use En-ROADS website to explore future climate scenarios |
| Build background knowledge of forest management techniques and TEK | Formative/research skills | Access information from articles and class presentations |
| Compare and contrast ecological conditions on the Peaks 150 years ago and 30 years from now | Summative/poster project | Use compiled data and experiences from this unit to create a comparative poster for one of the life zones, share in a poster session |

**Alignment with Standards**

<u>9-12th Diné Cultural Standards</u>

- Concept 2: PO3: I will practice respect of nature in my daily life
- Concept 3: PO3: I will integrate different uses of plants

<u>9-12th Diné Character Building Standards</u>

- Concept 1: PO2: I will coordinate a plan to show respect of the environment
- Concept 1: PO 3: I will organize events to care for the environment

<u>Arizona State Science Standards</u>

- Essential HS.L2U3.18

Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.

- Plus HS+B.L4U1.2

Engage in argument from evidence that changes in environmental conditions or human interventions may change species diversity in an ecosystem.

- Plus HS+E.E1U1.3

Analyze geoscience data and the results from global climate models to make evidence-based predictions of current rate and scale of global or regional climate changes.

<u>AP Biology Skills</u>

- 2.A Describe characteristics of a biological concept, process, or model represented visually.
- 6.E.c Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on data.
- 4.A Construct a graph, plot, or chart.
- 6.D Explain the relationship between experimental results and larger biological concepts, processes, or theories.

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