Professional Portfolio

Colette Pansini

Northern Arizona University

Master of Forestry, Forest and Natural Resource Management

Spring 2026

Table of Contents

Introduction

Personal Background

My lifelong admiration of nature and wildlife led me to study natural resource management in my undergraduate degree in Louisiana. I entered the workforce in the field of environmental consulting where I learned how the regulated private sector interacts with and thinks about federal and state regulations and agencies. Consulting for largely the oil and gas industry helped me gain experience in data collection, monitoring, reporting, and environmental compliance. After this introduction to the natural resource management profession, I quickly learned that although foundational principles of biology and ecology underpin natural resource management throughout the world, region-specific priorities are driven by local challenges, people, and economies.

After moving to Arizona, I began working for the Arizona Department of Water Resources where I grew an appreciation for how life and natural resources revolve around water in the Southwest. In this new role, I was able to switch perspectives from representing regulated stakeholders to now representing a state agency and the people of Arizona. I dove deep into the rich history of water in Arizona and found satisfaction in helping protect such a critical resource.

A new journey at a water and power utility in Phoenix helped me develop a deep understanding of the interconnectedness of water, wildfire, forestry, and life in a desert. This new position sparked an insatiable interest in me to better understand the wildfire challenges the Southwest is facing and the stakeholders that are working together to come up with creative solutions to protect watersheds, public lands, and the inherent beauty of Arizona's natural resources. I decided to follow this interest and formally explore these topics integral to natural resource management in the Southwest by pursuing this Master of Forestry degree. This program

has allowed me to more deeply understand the scientific and ecological concepts that relate to wildfire, water, and wildlife, and overall has made me a more confident and well-informed contributor to the natural resource management profession.

Overview of Courses

The four courses that helped me achieve the required Program Learning Outcomes (PLO) are Ecosystem Science and Management Principles (FOR 500), Co-production and Translation Communication in Natural Resource Science (FOR 536), Applied Study Design and Analysis (FOR 691), and Ecological Forest Management (FOR 581).

Ecosystem Science and Management Principles explored ecological theories to demonstrate how ecosystems function and how management decisions rooted in these theories can provide anticipated outcomes. The course melded conservation history, basic ecology, and natural resource management challenges to demonstrate how current challenges can be addressed though core principles of ecology and supported with peer-reviewed literature. Beyond exploring the "basics" of each ecological theory or concept, the course allowed students to further investigate topics by applying those learnings to current topics of concerns or novel published research. Traditional Ecological Knowledge (TEK) was discussed and grounded conversations in relevant cultural perspectives to reflect modern challenges and opportunities in ecological management.

Co-production and Translation Communication in Natural Resource Science demonstrated how human dimensions and social science can help managers engage with stakeholders and produce actionable decisions that involve the community and regulated public. The course focused heavily on how to effectively communicate complex scientific information and tailor communication strategies to different audiences. Ethical considerations of co-

production, especially regarding TEK, were examined to ensure that the process and products of co-production are inclusive and moral. The course used real life case studies to discuss lessons learned, best practices, and the future of co-production and science communication.

Applied Study Design and Analysis focused heavily on developing literature search and analysis skills that culminated in a thorough literature review of a topic. The course reviewed widely accepted research ethics to understand the foundations of appropriate data collection. The lifecycle of a research project including types of data, developing research questions, and data analysis approaches provided students with the skills to identify knowledge gaps in literature and develop their own research questions. Moreover, the course prompted students to ground their discussions and assignments in appropriate science communication to be able to engage with the general public.

Ecological Forest Management focused on principles of forest ecology and management. Timely challenges like sustainable forestry, fire management, and climate change were discussed through ecological, economic, and social lenses. Important policy and regulatory frameworks such as the National Environmental Policy Act grounded learnings in the context of modern management challenges. A heavy emphasis on stakeholder identification and engagement and tradeoff and synergy analysis surrounding forest management helped students develop a management plan that culminated the course.

Program Learning Outcomes Reflection

Chapter 1: Ecological Processes Program Learning Outcome

The principles of PLO 1 were explored deeply in FOR 500, Ecosystem Science and Management Principles. I took this course to understand the complex relationships between the biotic and abiotic processes that are the foundation of the ecosystems that natural resource

professionals are managing. This course helped me understand how key ecological theories can help managers understand how management decisions may impact an ecosystem to achieve a given goal. This course was interesting because it covered a broad scope of ecosystem management topics by exploring foundational ecological theories and pairing those learnings with scientific literature that relate to contemporary ecosystem management challenges.

The course's final project required a deep analysis of a chosen ecosystem to demonstrate understanding of the abiotic and biotic characteristics that shaped the ecosystem, the historic relationship between humans and the ecosystem, current threats, and management actions that would be appropriate to mitigate those threats. I focused on pinyon-juniper woodlands in the United States and discussed what constitutes a healthy ecosystem, the history of human settlements and utilization of the ecosystem, and how the ecosystem has been altered since post-European settlement. I identified top management concerns including catastrophic wildfires, large-scale pinyon die off, and intentional woodland reduction activities in certain parts of the range. These concerns helped shape my management goals that centered around improving resiliency through strategic thinning, managing for un-even aged and diverse woodland structures, and retaining important habitat structures for specific species of management concern.

This assignment directly aligns with PLO 1 because it required me to apply the ecological theories and principles discussed in the course to a specific ecosystem and communicate how my management recommendations would concurrently interact to affect vegetation, wildlife, and humans. This project helped develop my research synthesis skills to produce defensible management goals and provide recommendations on how to determine what monitoring would be required to discern if implementation of the goals successfully achieved the

prescribed objectives. Pinyon-juniper woodlands are common throughout Arizona where I plan to continue to live and work, so gaining a better understanding of the ecosystem's management complexities throughout its range has made me a better steward of the resource.

Chapter 2: Social Perspectives Program Learning Outcome

PLO 2 focuses on applying social science methods to real-world natural resource management issues. FOR 536, Co-production and Translation Communication in Natural Resource Science, uniquely highlighted the synergies between human dimensions and social science theories and demonstrated how those principles can be used to collaborate and co-produce research and management solutions that impact society. I took this course to improve my ability to communicate complex natural resource management issues to diverse audiences and learn why co-production is so critical to successful management and the communities that are directly impacted. This course was interesting because it prompted me to consider the ethical implications of co-production and how to communicate multifaceted management issues to different stakeholder groups.

The course's translational communication project required students to develop a comprehensive communications plan that would help communicate the implications and findings of a natural resource management solution or initiative. I chose to use my plan to communicate the need for fuels reduction treatments to help reduce the risk of catastrophic wildfire in the Wildland-Urban Interface. I learned the importance of tailoring communications messaging and tools to different audiences including the general public, local officials, and the media, to achieve understanding and support from affected stakeholders. This project helped me consider the perspectives of those closest to the wildfire crisis and the fuels reduction efforts being used to

mitigate risk and helped me develop a better understanding of how management scenarios can impact the fabric of a community.

This assignment required me to understand foundational social science theories and methods and how to apply those principles to a real-world management topic that is prevalent in the Southwest. In order to develop a realistic and effective communication plan, I had to conduct an audience analysis that affected how I crafted key messaging and how to most effectively transmit that information. This assignment helped me understand how social science concepts can improve science communication to bridge gaps, address stakeholder concerns, and develop community advocates for management actions. Because natural resource management cannot exist without managing and influencing the people who utilize or live near natural areas, these takeaways proved to be relevant in the remainder of my courses and in my professional career.

Chapter 3: Management Techniques Program Learning Outcome

FOR 691, Applied Study Design and Analysis, focused on the principles of research ethics, approaches, and design. The course explored topics like data types, statistics, and even the proper way to navigate and utilize an array of online libraries to conduct efficient research. I took this course to delve deeper into literature review and synthesis to help me understand research gaps and to identify trends, commonalities, or divergences in natural resource management topics. This course was interesting because it provided me with foundational skills in research and data analysis that I continued to use throughout the remainder of the program and in my professional life.

The course's literature review assignment required students to evaluate and summarize existing research questions, create a synthesis of the current state of knowledge, and

recommend a new research approach to expand upon existing literature. This assignment was required to be written in plain language so that a general or layman audience could easily understand it, which necessitated breaking complex scientific concepts into easily digestible key points. I chose to synthesize research on the impacts of invasive grasses on fire regimes and ecosystem health in Western United States deserts due to its far reaching and increasing relevance in ecosystem management. The paper synthesized a subset of the most influential and current literature on the topic and examined how each study was designed, what methods were used, and how the authors handled data and statistical analysis. The key takeaways from the review were then used to discuss how invasive grasses in deserts are impacting fuel properties and fire regimes, ecosystem health and biodiversity, and how climate change will continue to catalyze these trends. I used this synthesized information to identify and discuss research gaps related to how to manage these landscapes in the face of altered fire regimes and proposed a research framework and recommendation that would investigate various mechanical removal and chemical control methods to mitigate the impacts of invasive grasses in the most cost-effective manner to achieve ecological management objectives. This assignment helped me understand the importance of thorough research synthesis and how to communicate science-based recommendations to a broader audience.

This assignment relates to PLO 3 because it required me to use principles of study design and analysis and research and synthesis skills to understand how an environmental trend is impacting a resource, compile strategies to mitigate ecosystem degradation, and propose a study that would ameliorate a research gap and help identify a multi-benefit solution that would achieve multiple objectives. The requirement to write the entire synthesis in an easy-to-

understand format was helpful practice in bridging the gap between research and on the ground practitioners and managers.

Chapter 4: Environmental Impacts Program Learning Outcome

FOR 581, Ecological Forest Management, explored an integrated approach to forest management that demonstrated the importance of addressing the policy, stakeholder, and economics needs within forested areas to create a holistic management approach. I took this course to better understand the long-term decision-making process of forest managers who are tasked with balancing diverse opinions and objectives. This course was interesting because it was rooted in exploring foundational forest management concepts and policies while also framing these concepts in real-life management scenarios to demonstrate that management decisions are not always straightforward.

The course's Collaborative Forest Management Plan required students to choose a forest area of interest to complete a thorough stakeholder and resource objectives analysis that helped inform a decision-making framework and management plan. My group focused on the Coconino National Forest in Arizona. The group interviewed three stakeholders to understand the challenges, alignments, and prominent resource concerns in the area of interest. This data informed my group's top management priorities and objectives and the associated stakeholder synergies and conflicts. Our analysis resulted in two prominent management suggestions: wildfire risk reduction and invasive species management. The plan also proposed monitoring indicators and methods and associated adaptive management options. This group project helped me understand the importance of creating a strong foundation in stakeholder analysis and engagement to help create realistic, actionable, and stakeholder-centric management suggestions.

This assignment is related to PLO 4 because it required us to take into consideration the economic, environmental, and social consequences of my group's implementation suggestions. The management plan required that we use data-informed decision making when balancing objectives and proposed management actions. The plan discussed the management of a vast array of needs including recreation opportunities, cultural resource protection, wildlife habitat, and forest health, while acknowledging implementation and management challenges like policy roadblocks, climate change, ethical considerations, and diverse stakeholder needs. Lastly, the impacts of our proposed management actions were accounted for in a proposed monitoring and data collection framework that would help managers determine if adaptive management is necessary.

Discussion

Philosophy Statement

My primary interest and duty as a natural resource manager is to ensure the wise use of resources today while safeguarding ample quantity and quality of natural resources for future generations. Additionally, I believe management decisions should be data-driven and framed in the context of climate change, long-term drought, and the ever-expanding and increasingly complex interactions among natural environments and societies. As a steward of public lands, I will strive to fairly and transparently balance the interests of all stakeholders while seeking to support resilient ecosystems. Natural resource management issues can often be polarizing, political, and affect a broad range of interests, but I will commit to acting ethically and honestly throughout my career in this field.

The courses I took throughout this program each offered their own contributions that shaped my personal philosophies as a manager of natural resources. FOR 536 (Co-Production

and Translation Communication in Natural Resource Science) demonstrated how and why social science and stakeholder engagement, particularly with respect to TEK, are paramount pillars of forestry and natural resource management. Creative assignments including a translational communication project required me to understand how to identify stakeholders, convey a message with communication campaigns, and integrate stakeholder engagement as an important part of my personal philosophy. FOR 500 (Ecosystem Science and Management Principles), FOR 581 (Ecological Forest Management), and their associated management-plan style assignments helped demonstrate how incorporating stakeholder analysis into an evaluation of management scenarios can help managers achieve mutually beneficial objectives. Lastly, FOR 691 (Applied Study Design and Analysis) and its literature review assignment demonstrated how data-based decisions can be used to ameliorate knowledge gaps and solve management problems.

Perspectives Reflection

Prior to completing this program, I largely moved through my career leaning on my understanding of Western science's principles, perspectives, and priorities- almost considering this the "default" when it came to knowledge systems. I now have a deep understanding of why it is critical to consider, incorporate, and seek out Indigenous perspectives and knowledge. These perspectives, built upon a wealth of generational and deep-rooted cultural knowledge, provide a different way to approach natural resource management goals and problems. Two-eyed seeing, incorporating and lifting up both ways of knowing and acknowledging they both have a place in natural resource management, will be something I lean on in my career as I work to tackle increasingly complex problems. Indigenous perspectives have helped me understand that sometimes the rigidity of Western science is not always the only way to achieve worthy answers-

place based, relationship-centered, Indigenous knowledge can often provide the nuance, specificity, and the test of time that modern western science is not always able to achieve.

Climate Change Reflection

Climate change will continue to be an underlying and ever-present challenge that natural resource managers must account for in their long-term planning and stewardship of the environment. This program has helped me prepare for possible changes in climate by providing me with a strong foundation and understanding of the ecological, social, and economic aspects that influence ecosystem management. Being able to balance multiple perspectives will be key when making the challenging decisions that will be required of managers in the years to come. Additionally, this program demonstrated the importance of long-term planning and monitoring to carry out effective adaptive management. As we approach unprecedented climatic circumstances, there will be no established path to follow that will lead to successful resource management, so collaborative and science-based decision making will be required to make the most informed decisions. The program's emphasis on stakeholder analysis and engagement and fundamentals of human dimensions will help me be prepared to communicate and engage with the communities and stakeholders that will be impacted by a changing climate.

Program Reflection

My original intention for completing this program was to build upon my undergraduate degree in natural resource management in the specific context of the Southwest where I now live and work. Because I completed my undergraduate degree in the South, I hoped to learn more about the challenges and management priorities that natural resource managers are focusing on in the Southwest. I aspired to gain experience in analyzing and synthesizing literature to help make data-based decisions and better understand the social science aspects of forestry in the Southwest. After two years of immersing myself in this program, the most

significant insights I have gained centered around the importance of intentional education and outreach to stakeholders and the general public. I connected with the social science courses that demonstrated the need to understand the populations impacted by decision makers and how to effectively communicate with different audiences.

One of the main reasons I pursued this program was to provide myself with a more well-rounded educational background in natural resource management. In my current position I work alongside managers and foresters in the public sector, and I feel that the courses I took in this program have allowed me to better understand the challenges they face and the prioritization required of them, especially federal and state forestry and fire staff. This program allowed me to dive deeper into the ecological, social, and economic facets of forestry, wildfire management, and recreation. Overall, I feel that I am leaving this program as a more well-rounded natural resource manager equipped with the knowledge of how to identify and analyze problems and devise fair, data-driven decisions.

This program has contributed to the development of my professional identity by helping me view problems through multiple lenses- whether that be the regulated public, Indigenous communities, recreationists, or stakeholders of an ecosystem. The management plan assignment in FOR 581 was paramount in helping me understand how to balance competing objectives and identify synergies where possible. Additionally, a strong part of my professional identity is now rooted in engaging with the public to help them understand and be invested in natural resource management decisions that affect their lives. Courses like FOR 536 and the translational communication project helped me better understand social science's place in management and how every unique management problem or project has its own public education and communication considerations.

Appendix A

FOR 500 Final Project

FOR500: Final Project

Our course covers several important ecological theories which can be useful in explaining how ecosystems operate. These concepts in turn can help inform ecosystem management. Your assignment is to connect ecological concepts learned in class to specific management decisions you'd make in a theoretical ecosystem.

NAME: Colette Pansini

Each section is worth a different amount of points (labeled below) and due at different times (see course schedule). Use complete sentences and proper formatting in your responses. Your writing and answers will be graded on the following rubric:

- Spelling/grammar: 10%
- Formatting of scientific names and citations: 10%
- Appropriate use of in-text citations: 10%
- Meets minimum length/citation requirements: 30%
- Quality of argument/completeness of answer: 40%

1. Choose your theoretical ecosystem and describe it's ecology (75pts). This can be literally any ecosystem. It's probably easiest to choose an ecosystem you know well, but you may learn more if you challenge yourself with an unfamiliar ecosystem. Fill in the naturalist facts of your ecosystem below.

- Name of chosen ecosystem (e.g. *Ponderosa pine forest*):
  Pinyon-juniper woodlands

- Size/geographic scope of ecosystem (1-2 sentence description):
  Pinyon-juniper woodlands encompass 40 million hectares across 10 states in the western U.S. (U.S. Department of the Interior, n.d.). The ecosystem stretches from Wyoming to Mexico and tends to cover large landscapes where it is present (Hood and Miller, 2007).

  References:

  Hood, S. M. and Miller, M. (2007). *Fire ecology and management of the major ecosystems of southern Utah*. Gen. Tech. Rep. RMRS-GTR-202. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 110 p.

  U.S. Department of the Interior. (n.d.). *Pinyon-Juniper Woodlands*. National Parks Service. https://www.nps.gov/subjects/swscience/pinyon-juniper-woodlands.htm

- Dominant flora and/or fauna. Name at least twenty species common in your chosen ecosystem. Put common name (if available) and scientific name:

Common name	Scientific name
e.g. Ponderosa pine	*Pinus ponderosa*
1. singleleaf pinyon	*Pinus monophylla*
2. two-needle pinyon	*Pinus edulis*
3. alligator juniper	*Juniperus deppeana*
4. gambel oak	*Quercus gambelii*
5. one-seed juniper	*Juniperus monosperma*
6. Rocky Mountain juniper	*Juniperus scopulorum*
7. black bear	*Urcus americanus*
8. pinyon mouse	*Peromyscus truei*
9. juniper titmouse	*Baeolophus ridgwayi*
10. javelina	*Pecari tajacu*
11. Clark's nutrcracker	*Nucifraga columbiana*
12. bighorn sheep	*Ovis canadensis*
13. mountain lion	*Puma concolor*
14. Steller's jay	*Cyanocitta stelleri*
15. Merriam's turkey	*Meleagris gallopavo merriami*
16. pinyon jay	*Gymnorhinus cyanocephalus*
17. Rocky mountain elk	*Cervus candadensis*
18. white-tailed deer	*Odocoileus virginianus*
19. pronghorn antelope	*Antilocapra americana*
20. mule deer	*Odocoileus hemionus*

References:

Arizona Game and Fish Department. (2022) *Arizona Wildlife Conservation Strategy: 2022-2032*. Arizona Game and Fish Department, Phoenix, Arizona. https://awcs.azgfd.com/

NatureServe. (2025). *NatureServe Network Biodiversity Location Data* accessed through NatureServe Explorer 2.0. NatureServe, Arlington, Virginia. Accessed October 11, 2025. https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.722899/Great_Basin_Pinyon-Juniper_Woodland

U.S. Forest Service and U.S. Bureau of Reclamation. (n.d.). *Pinyon Juniper Woodlands*. https://www.fs.usda.gov/sites/default/files/pinyon-juniper-fact-sheet.pdf

- Identify FIVE trophic relationships (i.e. predator-prey, competitive, mutualistic, etc.) among species in your ecosystem. Fill out these details below:

Trophic Relationship	Species involved	1-2 sentence summary of relationship
e.g. Herbivory	*Pandora moths and Ponderosa pine*	*As larvae, pandora moths eat ponderosa pine needles. Usually this results in little damage to the tree, but rare outbreaks can cause defoliation events.*
1. Mutualistic	Pinyon jays and pinyon pine	Pinyon Jays cache pinyon pine nuts and in the process help with seed dispersal (Johnson and Sadoti, 2023).
2. Parasitic	Pinyon dwarf mistletoe and pinyon pine	Pinyon dwarf mistletoe (*Arceuthobium divaricatum)* can parasitize pinyon pine when it is stressed from drought and cause mortality (Gibson, 2023; Colorado State Forest Service, n.d.).
3. Parasitic	Pinyon bark beetle and pinyon pine	Pinyon ips (*Ips confusus*) live and reproduce in the bark of pinyon pine and can cause large-scale mortality of the trees, especially in drought conditions (DeGomez and Celaya, 2025; Hansen et al., 2025)
4. Herbivory	Juniper berries and wildlife	Juniper berries act as a food source for an abundance of wildlife including birds, coyotes, and small mammals, who help disperse seeds (Miller, 2001).
5. Mutualistic	Pinyon and Ectomycorrhizal fungi	Ectomycorrhizal fungi improves the growth and survival of pinyon pine, especially in drought conditions, while pinyon pine fixes carbon that benefits the fungi (Gehring et al., 2017; Sevanto et al., 2023).

References:

Colorado State Forest Service. (n.d.). *Dwarf Mistletoe*. https://csfs.colostate.edu/forest-management/common-forest-insects-diseases/dwarf-mistletoe/

DeGomez, T. and Celaya, B. (2025). *The piñon IPS bark beetle*. UA Cooperative Extension. https://extension.arizona.edu/publication/pinon-ips-bark-beetle

Gehring, C. A., Sthultz, C. M., Flores-Rentería, L., Whipple, A. V., and Whitham, T. G. (2017). Tree genetics defines fungal partner communities that may confer drought tolerance. *Proceedings of the National Academy of Sciences - PNAS*, *114*(42), 11169–11174. https://doi.org/10.1073/pnas.1704022114

Gibson, Y. (2023). *Pinyon-juniper woodland ecosystems*. Rangeland Ecosystems of the Western US. https://open.oregonstate.education/rangelandecosystems/chapter/woodland/

Hansen, E. M., Powell, J. A., Graves, A., Souder, S., Vandygriff, J. C., Gaylord, M., McMillin, J., and Bentz, B. J. (2025). Empirical and mechanistic models predict pinyon ips (Ips confusus) phenology. *Ecological Modelling*, *510*, Article 111282. https://doi.org/10.1016/j.ecolmodel.2025.111282

Johnson, K., and Sadoti, G. (2023). A review of Pinyon Jay (Gymnorhinus cyanocephalus) habitat ecology. *The Wilson Journal of Ornithology*, 135(2), 232–247. https://doi.org/10.1676/22-00103

Miller, R. (2001). *Managing Western Juniper for Wildlife*. Washington State University Cooperative Extension. https://juniper.oregonstate.edu/sites/default/files/wildlife.pdf

Sevanto, S., Gehring, C. A., Ryan, M. G., Patterson, A., Losko, A. S., Vogel, S. C., Carter, K. R., Dickman, L. T., Espy, M. A., and Kuske, C. R. (2023). Benefits of symbiotic ectomycorrhizal fungi to plant water relations depend on plant genotype in pinyon pine. *Scientific Reports*, *13*(1), Article 14424. https://doi.org/10.1038/s41598-023-41191-5

- Are there any important (e.g. keystone, endangered, etc.) species that management should focus extra attention on in your ecosystem? Describe at least three below.

  1. The pinyon jay (*Gymnorhinus cyanocephalus*) is a species of conservation concern that is currently under review by the U.S. Fish and Wildlife Service and may warrant protections under the Endangered Species Act (U.S. Fish and Wildlife Service, n.d.). The species has shown population declines over the last 50 years and in pinyon-juniper woodlands is the fastest declining bird (Johnson and Sadoti, 2023). As a keystone species, this bird plays a critical role in pinyon-juniper woodlands, but data about their

habitat use, nesting behavior, and movement patterns are lacking for some states within their range (Johnson and Sadoti, 2023).

2. The juniper titmouse (*Baeolophus ridgwayi*) is considered a species of conservation need in states like New Mexico and Arizona due to declining populations since 1980 (Arizona Game and Fish Department, n.d.; New Mexico Department of Game and Fish, n.d.). This species is a pinyon-juniper specialist, meaning their populations are restricted to this ecosystem type (Pavlacky and Anderson, 2001). This bird nests in cavities in mature woodlands, so ensuring old growth trees remain throughout their range is important (Cornell Lab of Ornithology, n.d.).

3. Mule deer (*Odocoileus hemionus*) are an important game species found throughout the Western U.S. (Bender and Allison, 2014). Although they inhabit a variety of ecosystems and are not generally a species of concern, management of pinyon-juniper woodlands for their benefit occurs in states within their range (Johnston and Anderson Jr., 2023). Mule deer use these ecosystems for forage, cover, and as important migration corridors as they move from summer to winter ranges (Bender, 2020. U.S. Department of the Interior, 2025).

References:

Arizona Game and Fish Department. (n.d.). *Birds*. Arizona Wildlife Conservation Strategy. https://awcs.azgfd.com/species/birds

Bender, L. (2020). *Guidelines for Management of Habitat for Mule Deer: Piñon-juniper, Chihuahuan desert, arid grasslands, and associated arid habitat types*. New Mexico State University Cooperative Extension. https://pubs.nmsu.edu/_circulars/CR662/index.html

Bender, L. C. and C. Allison. (2014). *Mule Deer in New Mexico*. New Mexico State University Cooperative Extension. https://pubs.nmsu.edu/_l/L301/index.html

Cornell Lab of Ornithology. (n.d.). *Juniper Titmouse*. All About Birds. https://www.allaboutbirds.org/guide/Juniper_Titmouse/id

Johnson, K., and Sadoti, G. (2023). A review of Pinyon Jay (Gymnorhinus cyanocephalus) habitat ecology. *The Wilson Journal of Ornithology*, *135*(2), 232–247. https://oi.org/10.1676/22-00103

Johnston, D. B., & Anderson, C. R. (2023). Plant and mule deer responses to pinyon-juniper removal by three mechanical methods. *Wildlife Society Bulletin (2011)*, *47*(2). https://doi.org/10.1002/wsb.1421

New Mexico Department of Game and Fish. (n.d.). *Juniper Titmouse*. State Wildlife Action Plan. https://nmswap.org/species/163/juniper-titmouse

Pavlacky, D. C., and Anderson, S. H. (2001). Habitat Preferences of Pinyon-Juniper Specialists Near the Limit of Their Geographic Range. *The Condor, 103*(2), 322–331. https://doi.org/10.1093/condor/103.2.322

U.S. Department of the Interior. (2025). *Migration Corridors of Mule Deer in the Kaibab Herd in Arizona*. https://catalog.data.gov/dataset/migration-corridors-of-mule-deer-in-the-kaibab-herd-in-arizona#:~:text=Mule%20deer%20(Odocoileus%20hemionus)%20of,collected%20every%200.5%2D7%20hours.

U.S. Fish and Wildlife Service. (n.d.). *Pinyon Jay (Gymnorhinus cyanocephalus)*. Environmental Conservation Online System. https://ecos.fws.gov/ecp/species/9420

- Describe the abiotic conditions (e.g. climate, soil, etc.) of your ecosystem in 5-7 sentences.

Pinyon-juniper woodlands are located between 1,370-2,286 meters in elevation (U.S. Department of the Interior, n.d.; Gottfried and Severson 1994). Throughout the vast extent of this ecosystem, 15-50 centimeters of precipitation can be expected annually (Romme et al., 2009; Miller et al., 2019). Precipitation trends vary with elevation and geography and can be influenced by Pacific and Monsoonal storms (Miller et al., 2019). Dominant vegetation is adapted to arid and semi-arid conditions and can experience average annual temperatures ranging from 4°C-16°C with extremes as low as -37°C or high as over 43°C in portions of its range (Ronco, 1990; Miller et al., 2019; Noel et al., 2025). Differing parent material throughout the ecosystem's extent leads to high variability in soil types that range from gravelly, sandy loam to deep fine-textured soils (U.S. Department of the Interior, n.d.; Redmond et al., 2023). Areas with deep fine-textured soils tend to support more productivity in vegetation (Gibson, 2023).

References:

Gibson, Y. (2023). *Pinyon-juniper woodland ecosystems*. Rangeland Ecosystems of the Western US. https://open.oregonstate.education/rangelandecosystems/chapter/woodland/

Gottfried, G. and Severson, K. (1994). *Managing Pinyon-Juniper Woodlands*. Rangelands, 16(6), 234–236.

Miller, R. F., Chambers, J. C., Evers, L., Williams, C. J., Snyder, K. A., Roundy, B. A., and Pierson, F. B. (2019). *The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States*. Gen. Tech. Rep. RMRS-GTR-403. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 284 p.

Noel, A., Schlaepfer, D.R., Barrett, I.P., Duniway, M.C., Norris, J., Domschke, C.T., Butterfield, B.J., Swan, M.C., Hartwig, K., Crist, M.R., and Bradford, J.B. (2025). Shifts in suitability of pinyon-juniper communities: A climate adaptation framework for range-wide management of arid woodland resources. *Forest Ecology and Management*, *596*, Article 123075. https://doi.org/10.1016/j.foreco.2025.123075

Redmond, M.D., Urza, A.K., and Weisberg, P.J. (2023). Managing for ecological resilience of pinyon–juniper ecosystems during an era of woodland contraction. *Ecosphere*, *14*(5). https://doi.org/10.1002/ecs2.4505

Romme, W.H., Allen, C.D., Bailey, J.D., Baker, W.L., Bestelmeyer, B.T., Brown, P.M., Eisenhart, K.S., Floyd, M.L., Huffman, D.W., Jacobs, B.F., Miller, R.F., Muldavin, E.H., Swetnam, T.W., Tausch, R.J., and Weisberg, P.J. (2009). *Historical and Modern Disturbance Regimes, Stand Structures, and Landscape Dynamics in Piñon–Juniper Vegetation of the Western United States*. Rangeland Ecology & Management, 62(3), 203–222. https://doi.org/10.2111/08-188R1.1

Ronco, F. P. (1990). *Pinyon*. Silvics of North America. https://research.fs.usda.gov/silvics/pinyon

U.S. Department of the Interior. (n.d.). *Pinyon-Juniper Woodlands - Introduction & Distribution*. National Parks Service. https://www.nps.gov/articles/pinyon-juniper-woodlands-distribution.htm

- Describe what your ecosystem looks like in a 'healthy state'. Refer to concepts like ecosystem stability in your answer. Write at least two paragraphs.

  The density, composition, and structure of pinyon-juniper woodlands were historically maintained by fire that kept vegetation encroachment into adjacent forest and grassland ecosystems at bay (Baker and Shinneman, 2004; Huffman et al., 2006). Although estimating historic fire regimes is difficult for this ecosystem due to a lack of burn scars and tree rings, there are three fire regimes that are hypothesized for these systems: low intensity, frequent fires; variable frequency, high intensity, stand-replacing fires; and rare, small-scale fires (Romme et al., 2009; Shaw et al., 2018). Fires and other disturbances like insects, disease, and climate fluctuations, played a role in maintaining a healthy, open, patchy arrangement of vegetation (Dahms and Geils, 1997; Ffolliott and Gottfried, 2002; Romme et al., 2009).

  In an ideal state, these woodlands contain enough patchiness to allow understory grasses, forbs, and shrubs to grow which provides diversity in vegetation structure and important browse for wildlife (Marcus et al., 2011). Diversity of vegetation species, variable and complex stand structures, and uneven-aged patches support resilience in this ecosystem

(Redmond et al., 2023; Woolet et al., 2023). Heterogeneity in the structure of stands helps support rich biodiversity and improve the health of individual trees (Redmond et al., 2023). Obstacles like overgrazing, climate change, and fire exclusion have led to the large-scale infill of previously patchy, complex, stands which creates a significant challenge for modern ecosystem managers (Romme et al., 2009).

References:

Baker, W.L., and Shinneman, D.J. (2004). Fire and restoration of pinon–juniper woodlands in the western United States: a review. *Forest Ecology and Management*, 189(1-3), 1-21. https://doi-org.libproxy.nau.edu/10.1016/j.foreco.2003.09.006

Dahms, C.W. and B.W. Geils. (1997). *An assessment of forest ecosystem health in the Southwest*. General Technical Report RM-GTR-295. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 97 p.

Ffolliott, P.F. and G.J. Gottfried. (2003). *Dynamics of a Pinyon-Juniper Stand in Northern Arizona: A Half-Century History*. General Technical Report RMRS-RP-35. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p.

Huffman, D.W., P.Z. Fulé, K.M. Pearson, J.E. Crouse, and W.W. Covington. (2006). *Pinyon-Juniper Fire Regime: Natural Range of Variability*. NAU Ecological Restoration Institute, Flagstaff, United States.

Marcus, N., S. Woods, S. Simmons, N. Jester, D. Wand, M. Wiedeman, and C.K. Morey. (2011). *Pinon-Juniper Management*. Colorado State Forest Service, Fort Collins.

Redmond, M.D., Urza, A.K., and Weisberg, P.J. (2023). Managing for ecological resilience of pinyon–juniper ecosystems during an era of woodland contraction. *Ecosphere*, *14*(5). https://doi.org/10.1002/ecs2.4505

Romme, W.H., Allen, C.D., Bailey, J.D., Baker, W.L., Bestelmeyer, B.T., Brown, P.M., Eisenhart, K.S., Floyd, M.L., Huffman, D.W., Jacobs, B.F., Miller, R.F., Muldavin, E.H., Swetnam, T.W., Tausch, R.J., and Weisberg, P.J. (2009). Historical and Modern Disturbance Regimes, Stand Structures, and Landscape Dynamics in Piñon–Juniper Vegetation of the Western United States. *Rangeland Ecology & Management*, *62*(3), 203–222. https://doi.org/10.2111/08-188R1.1

Shaw, J.D., Menlove, J., Witt, C., Morgan, T.A., Amacher, M.C., Goeking, S.A. and Werstak, D.E. Jr. (2018). *Arizona's forest resources, 2001-2014*. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Woolet, J., Stevens-Rumann, C.S., Coop, J.D., and Pejchar, L. (2023). A bird's eye view of ecosystem conversion: Examining the resilience of piñon-juniper woodlands and

their avian communities in the face of fire regime change. *Forest Ecology and Management*, *546*, Article 121368. https://doi.org/10.1016/j.foreco.2023.121368

2. Describe the relationship between humans and your ecosystem (75pts). Many ecosystems have evolutionary history with humans, and all ecosystems are currently affected by modern human activity. What are the specifics for your ecosystem?

- What is your ecosystem's evolutionary history with humans (i.e. when did humans first start visiting/using your ecosystem)?

Humans have been living in and utilizing the resources available in pinyon-juniper woodlands for thousands of years, dating back to early Paleo-Indian people in 11,000-7,500 BCE (Arizona State University, n.d.; U.S. Department of the Interior, 2015). Indigenous peoples continued to utilize these woodlands for cooking, medicine, clothing, food, and many other aspects of daily life (Gottfried, 1995; Janetski, 1999). Post European settlement, humans began to alter landscapes through activities like fire suppression and livestock grazing which, in combination with modern stressors like climate change and long-term drought, have led to increasing woodland densities, shifts in dominant vegetation, and in some cases, the loss of herbaceous understory (Gottfried, 1995; U.S. Department of the Interior, 2015).

References:

Arizona State University. (n.d.). *Culture History of Southern Arizona*. Arizona State Museum. https://statemuseum.arizona.edu/online-exhibit/culture-history-southern-arizona/paleo-indian-archaic

Gottfried, G., Swetnam, T., Allen, C., Betancourt, J., and Chung-MacCoubrey A. (1995). *Pinyon-Juniper Woodlands*. In: Finch, D. and Tainter, J.A., tech eds. Ecology, diversity, and sustainability of the Middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p. 95-132.

Janetski, J. (1999). *Role of Pinyon-Juniper Woodlands in Aboriginal Societies of the Desert West*. Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West. RMRS-P-9. https://www.fs.usda.gov/rm/pubs/rmrs_p009.pdf

U.S. Department of the Interior. (2015). *Pinyon-Juniper Woodlands – Anthropogenic Use and Post-Settlement Stressors*. National Parks Service. https://www.nps.gov/articles/pinyon-juniper-woodlands-anthropogenic-use.htm

- Which species provide some benefit or service to humans? Describe at least three species from your ecosystem and how they are useful to humans.

  1. Pinyon pine nuts have functioned as a critical food source to humans since the Holocene (Janetski, 1999). These pine nuts are estimated to have been a part of the diet of ancient people for the past 10,000 years (Rhode and Madsen, 1998; Briand, 2024). Several Indigenous communities still utilize the nuts for food today and their gathering is an important ceremonial tradition (Grant Canyon Trust, 2025)

  2. Pinyon pine is burned for firewood and in some Indigenous communities and Mexico is still used heavily for home heating purposes (Muldavin and Triepke, 2019; Gibson, 2023; Magargal, 2023). Pinyon pine is easily ignitable, burns hot, and has a unique, favorable fragrance (Barger and Ffolliott, 1972; Gibson, 2023).

  3. Berries from Utah juniper and one-seed juniper were used as a food source in breads and stews and were relied upon for their medicinal value by Indigenous communities (Johnsen, 1962; Janetski, 1999). Some modern herbal medicine information notes that one-seed juniper contains anti-microbial properties that may be helpful in treating ailments (Yarnell, 2002).

References:

Barger, R.L and P.F. Ffolliott. (1972). *Physical Characteristics and Utilization of Major Woodland Tree Species in Arizona*. RM-83. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p. 1-73.

Briand, C. H. (2024). One hundred years of piñon nuts, a largely forgotten wild food crop from the American Southwest (1850–1950). *Trees, Forests and People*, 18, Article 100705. https://doi.org/10.1016/j.tfp.2024.100705

Janetski, J. (1999). *Role of Pinyon-Juniper Woodlands in Aboriginal Societies of the Desert West. Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West*. RMRS-P-9. https://www.fs.usda.gov/rm/pubs/rmrs_p009.pdf

Johnsen, T. N. (1962). One-Seed Juniper Invasion of Northern Arizona Grasslands. *Ecological Monographs*, *32*(3), 187–207. https://doi.org/10.2307/1942398

Gibson, Y. (2023). *Pinyon-juniper woodland ecosystems*. Rangeland Ecosystems of the Western US. https://open.oregonstate.education/rangelandecosystems/chapter/woodland/

Grand Canyon Trust (2025, January 26). *Cultural uses of pinyon and Juniper forests*. Native America. https://www.grandcanyontrust.org/blog/cultural-uses-pinyon-and-juniper-forests/

Magargal, K., Yellowman, J., Chee, S., Wabel, M., Macfarlan, S., and Codding, B. F. (2023). Firewood and Energy Sovereignty on Navajo Nation. *Human Ecology: An Interdisciplinary Journal*, *51*(3), 497–511. https://doi.org/10.1007/s10745-023-00411-2

Muldavin, E., & Triepke, F. J. (2013). North American Pinyon–Juniper Woodlands: Ecological Composition, Dynamics, and Future Trends. In *Reference Module in Earth Systems and Environmental Sciences*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-409548-9.12113-X

Rhode, D. and Madsen, D.B. (1998). Pine Nut Use in the Early Holocene and Beyond: The Danger Cave Archaeobotanical Record. *Journal of Archaeological Science*, 25(12), 1199–1210. https://doi.org/10.1006/jasc.1998.0290

Yarnell, E. (2002). Botanical medicines for the urinary tract. *World Journal of Urology*, *20*(5), 285–293. https://doi.org/10.1007/s00345-002-0293-0

- Identify TWO ecosystem services from your chosen ecosystem and describe a) how they benefit humans WITHIN the ecosystem, and b) how they benefit humans OUTSIDE the ecosystem. Fill out the information below:

Ecosystem benefit	Inside/outside chosen ecosystem	1-2 sentence summary of benefit
e.g. Canopy cover	*Inside a Ponderosa pine forest*	*Inside a ponderosa pine forest, people enjoy the ecosystem benefit of canopy cover which provides shade thereby cooling in the summer and protection from the wind thereby insulating in the winter.*
e.g. Watershed protection	*Outside a Ponderosa pine forest*	*Outside, specifically down-stream from a ponderosa pine forest, people benefit from access to water filtered through the forest. This filters the water, as well as holding back floods.*
1. Wildlife habitat	Inside pinyon-juniper woodlands	Pinyon-juniper woodlands create habitat and cover for game species (i.e., mule deer, elk, pronghorn) that provide important hunting opportunities throughout North America (U.S. Department of Agriculture, n.d.; U.S. Department of the Interior, 2024). Hunting provides

		support to wildlife management through license and tag revenues (U.S. Department of the Interior, 2024).
2. Carbon storage	Outside pinyon-juniper woodlands	Pinyon-juniper woodlands store carbon in live and dead biomass and soils (U.S. Forest Service and U.S. Bureau of Reclamation, n.d.; Fusco et al., 2019). The expansive extent of these woodlands across North America make the ecosystem a significant carbon sink that benefits humans beyond the ecosystem's boundaries (Muldavin and Triepke, 2019).

References:

Fusco, E.J., Rau, B.M., Falkowski, M., Filippelli, S., and Bradley, B.A. (2019). Accounting for aboveground carbon storage in shrubland and woodland ecosystems in the Great Basin. *Ecosphere*, *10*(8). https://doi.org/10.1002/ecs2.2821

Muldavin, E. and Triepke, F. J. (2013). North American Pinyon–Juniper Woodlands: Ecological Composition, Dynamics, and Future Trends. In *Reference Module in Earth Systems and Environmental Sciences*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-409548-9.12113-X

U.S. Department of Agriculture. (n.d.). *Juniperus monosperma*. Fire Effects Information System (FEIS). https://www.fs.usda.gov/database/feis/plants/tree/junmon/all.html

U.S. Department of the Interior. (2024). *Management and Conservation of Pinyon and Juniper Woodlands*. https://www.blm.gov/sites/default/files/docs/2024-08/Management%20and%20Conservation%20of%20Pinyon%20and%20Juniper%20Woodlands%20Comment%20Summary%20Report.pdf

U.S. Forest Service and U.S. Bureau of Reclamation. (n.d.). *Pinyon Juniper Woodlands*. https://www.fs.usda.gov/sites/default/files/pinyon-juniper-fact-sheet.pdf

- Are/were there indigenous people in your ecosystem? If so, who? __Yes_____

Pre-European settlement, Indigenous people inhabited pinyon-juniper woodlands across the West (Janetski, 1999; Whitehair et al., 2024). The desert west woodlands across Arizona and New Mexico were home to Indigenous groups including Ute, Southern Paiute, Navajo, and Apache while the Hopi and Zuni tribes settled in the Great Basin and Colorado Plateau woodlands (Janetski, 1999). The Anasazi people also occupied these areas from A.D. 1200-1500 (Gottfried et al., 1995). European colonization and the creation of reservations displaced native people, but their cultural ties to pinyon-juniper woodlands still remain (Whitehair et al., 2024).

References:

Gottfried, G., Swetnam, T., Allen, C., Betancourt, J., and Chung-MacCoubrey A. (1995). *Pinyon-Juniper Woodlands*. In: Finch, D. and Tainter, J.A., tech eds. Ecology, diversity, and sustainability of the Middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p. 95-132.

Janetski, J. (1999). *Role of Pinyon-Juniper Woodlands in Aboriginal Societies of the Desert West. Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West*. RMRS-P-9. https://www.fs.usda.gov/rm/pubs/rmrs_p009.pdf

Whitehair, L., Litson, B., Neztsosie, B., Skaltsas, D., Martin, J., Begay, J., O'Neill, L., & Fulé, P. Z. (2024). Ecological partnership: Restoring Pinyon woodlands on the Navajo Nation, USA. *Trees, Forests and People*, *17*, Article 100605. https://doi.org/10.1016/j.tfp.2024.100605

- Can you find any information on how the indigenous people used/managed the ecosystem (do a quick search online)? If so, describe it in 5-7 sentences. If not, describe why you think that knowledge is not accessible. *If your ecosystem has no people (e.g. deep sea thermal vents) then skip this question.*

Cultural burning was and is still utilized to manage the density, growth, and seed production of pinyon-juniper woodlands (U.S. Department of the Interior, 2024). These controlled fires also improved and managed the ecosystem for uses like agriculture and hunting (U.S. Department of the Interior, 2024). Indigenous people utilized resources including pinyon pine nuts for food and other parts of pinyon and juniper trees for construction materials, medicine, and commerce to build and sustain their communities (Janetski, 1999; Whitehair et al., 2024). Prescribed burns and harvest of pinyon and juniper likely helped open up woodlands which allowed herbaceous vegetation to grow in the understory, however Indigenous settlements likely did not result in large-scale impacts or changes to landscapes due to their dispersed locations and utilization (Gottfried et al., 1995). Specific information about the frequency, size, and location of cultural burns is not present in the literature, possibly because it is difficult to find in-tact fire-scarred pinyon and juniper trees to conduct fire scar analysis on (Monsen and Stevens, 1999).

References:

Gottfried, G., Swetnam, T., Allen, C., Betancourt, J., and Chung-MacCoubrey A. (1995). *Pinyon-Juniper Woodlands*. In: Finch, D. and Tainter, J.A., tech eds. Ecology, diversity, and sustainability of the Middle Rio Grande Basin. Gen. Tech. Rep. RM-GTR-268. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. p. 95-132.

Janetski, J. (1999). *Role of Pinyon-Juniper Woodlands in Aboriginal Societies of the Desert West. Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West*. RMRS-P-9. https://www.fs.usda.gov/rm/pubs/rmrs_p009.pdf

Monsen, S.B. and Stevens, R., comps. (1999). *Proceedings: ecology and management of pinyon-juniper communities within the Interior West*; 1997 September 15-18; Provo, UT. Proc. RMRS-P-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 411 p.

U.S. Department of the Interior. (2024). *Management and Conservation of Pinyon and Juniper Woodlands*. https://www.blm.gov/sites/default/files/docs/2024-08/Management%20and%20Conservation%20of%20Pinyon%20and%20Juniper%20Woodlands%20Comment%20Summary%20Report.pdf

Whitehair, L., Litson, B., Neztsosie, B., Skaltsas, D., Martin, J., Begay, J., O'Neill, L. and Fulé, P. Z. (2024). Ecological partnership: Restoring Pinyon woodlands on the Navajo Nation, USA. *Trees, Forests and People*, *17*, Article 100605. https://doi.org/10.1016/j.tfp.2024.100605

- Identify THREE human-caused threats to your ecosystem. Fill out the information below:

Threat	Cause of threat	1-2 sentence summary of threat
e.g. Catastrophic forest fires	*Climate change & past mismanagement*	*Ponderosa pine forests are at risk of catastrophic fires because the climate is warming from humans burning fossil fuels and past mismanagement of forests. Specifically ponderosa forests are overgrown because past clear-cutting resulted in a homogenous cohort of young trees and fires were suppressed for the next 100 years of their development.*
1. Large-scale pinyon pine die off	Long-term drought and climate change	Long-term drought and increasing temperatures due to anthropogenic climate change can weaken pinyon pine, make individual trees more susceptible to insect infestation and disease, and is contributing to large-scale mortality (Gaylord et al., 2013; Redmond et el., 2023). In the early 2000s alone, over 350 million pinyon pines were killed across the southwest in a drought event (Hicke and Zeppel, 2013).
2. Catastrophic wildfires	Historic fire suppression, invasive grasses	Humans suppressed wildfire for decades which is one of several factors that led to a disruption of the natural fire regime that maintained the density of pinyon-juniper woodlands (Romme et al., 2009). Overly dense woodlands contain a higher risk of high-

		severity, catastrophic wildfire, that can cause long-term ecosystem degradation (Hood and Miller, 2007). The natural fire regime of this ecosystem varies by woodland sub-type (i.e., persistent woodlands vs. wooded shrublands), but some estimates indicate that the natural fire return interval was historically 12-25 years and in present day has been increased to over 100 years (Miller and Tausch, 2001; Romme et al., 2009). Invasive grasses have also increased fuels continuity, contributing to large-scale wildfires (Miller and Tausch, 2001).
3. Intentional woodland reduction / Chaining	Encroachment of pinyon-juniper woodlands into adjacent sagebrush steppe and grasslands; desire for grazing habitat	Chaining has been employed to reduce woodland vegetation density for improved herbaceous grazing opportunity and to benefit specific wildlife species such as sage-grouse and mule deer (Redmond et al., 2013; Bombaci and Pejchar, 2016; Johnston and Anderson Jr., 2023). This indiscriminate removal of vegetation can negatively impact many wildlife species and is the center of much controversy in the natural resource management community (Gallo and Pejchar, 2016).

References:

Bombaci, S. and Pejchar, L. (2016). Consequences of pinyon and juniper woodland reduction for wildlife in North America. *Forest Ecology and Management*, *365*, 34–50. https://doi.org/10.1016/j.foreco.2016.01.018

Gallo, T. and Pejchar, L. (2016). Woodland Reduction and Long-Term Change in Breeding Bird Communities. *The Journal of Wildlife Management*, 81(2), 259–268. https://doi.org/10.1002/jwmg.21188

Gaylord, M.L., Kolb, T.E., Pockman, W.T., Plaut, J.A., Yepez, E.A., Macalady, A.K., Pangle, R.E., and McDowell, N.G. (2013). Drought predisposes piñon–juniper woodlands to insect attacks and mortality. The New Phytologist, 198(2), 567–578. https://doi.org/10.1111/nph.12174

Hicke, J.A., and Zeppel, M.J.B. (2013). Climate-driven tree mortality: insights from the piñon pine die-off in the United States. *The New Phytologist*, *200*(2), 301–303. https://doi.org/10.1111/nph.12464

Hood, S.M. and Miller, M. (2007). *Fire ecology and management of the major ecosystems of southern Utah*. Gen. Tech. Rep. RMRS-GTR-202. Fort Collins, CO: U.S.

Department of Agriculture, Forest Service, Rocky Mountain Research Station. 110 p.

Johnston, D.B. and Anderson, C.R. (2023). Plant and mule deer responses to pinyon-juniper removal by three mechanical methods. *Wildlife Society Bulletin (2011)*, *47*(2). https://doi.org/10.1002/wsb.1421

Miller, R.F. and Tausch, R.J. (2001). The role of fire in pinyon and juniper woodlands: a descriptive analysis. In: Galley, K.E.M and Wilson, T.P., eds. Proceedings of the invasive species workshop: the role of fire in the control and spread of invasive species. Fire Conference 2000: the first national congress on fire ecology, prevention, and management. Miscellaneous Publication No. 11. Tallahassee, FL: Tall Timbers Research Station: 15-30.

Redmond, M.D., Cobb, N.S., Miller, M.E., and Barger, N.N. (2013). Long-term effects of chaining treatments on vegetation structure in piñon–juniper woodlands of the Colorado Plateau. *Forest Ecology and Management*, *305*, 120–128. https://doi.org/10.1016/j.foreco.2013.05.020

Redmond, M.D., Urza, A.K., and Weisberg, P.J. (2023). Managing for ecological resilience of pinyon–juniper ecosystems during an era of woodland contraction. *Ecosphere*, *14*(5). https://doi.org/10.1002/ecs2.4505

Romme, W.H., Allen, C.D., Bailey, J.D., Baker, W.L., Bestelmeyer, B.T., Brown, P.M., Eisenhart, K.S., Floyd, M.L., Huffman, D.W., Jacobs, B.F., Miller, R.F., Muldavin, E.H., Swetnam, T.W., Tausch, R.J., and Weisberg, P.J. (2009). Historical and Modern Disturbance Regimes, Stand Structures, and Landscape Dynamics in Piñon–Juniper Vegetation of the Western United States. *Rangeland Ecology & Management*, *62*(3), 203–222. https://doi.org/10.2111/08-188R1.1

- For each of the proposed threats you chose above, identify a management strategy that has been proposed. Fill out the information below:

Threat	Management strategy	1-2 sentence summary of management strategy
e.g. Catastrophic forest fires	*Forest thinning*	*To reduce fuel loads and thereby fire danger, ponderosa pine forests are often thinned by hand or mechanically. These treatments usually remove smaller trees which allows the remaining trees to grow more quickly.*
1. Large-scale pinyon pine die off	Thinning with specific objectives	Thinning stands with objectives such as heterogeneity and uneven-aged structure can help reduce stress on the trees that remain on the landscape and ensure that if pinyon die-off does occur, there is more likely to be

		sufficient seed-producing individuals left on the landscape to help the species reestablish (Redmond et al., 2023). Ensuring that some rocks, snags, and coarse woody debris remains on the landscape post-thinning is important to help seedlings establish by creating microsites (Redmond et al., 2023).
2.Catastrophic wildfire	Fuels reduction treatments	Thinning of pinyon-juniper woodlands and subsequent prescribed fire can reduce the density of vegetation and therefore reduce the risk of high-severity crown fire by reducing the amount of available fuel and fuels connectivity (Huffman et al., 2009; Huffman et al., 2013). Thinning and prescribed fire can also restore the natural stand structure and allow for understory vegetation to establish, and (Huffman et al., 2013).
3. Intentional woodland reduction / Chaining	Decrease use of chaining or target treatments more specifically	Limit the use of chaining in sensitive pinyon-juniper woodlands, especially where biocrusts or important wildlife habitat exists (U.S. Department of the Interior, 2024). Strategic thinning and prescribed fire may be more appropriate efforts that may satisfy ecosystem managers, grazing, and wildlife habitat desires.

References:

Huffman, D.W., Fulé, P.Z., Crouse, J.E., and Pearson, K.M. (2009). A comparison of fire hazard mitigation alternatives in pinyon–juniper woodlands of Arizona. Forest Ecology and Management, 257(2), 628–635. https://doi.org/10.1016/j.foreco.2008.09.041

Huffman, D.W., Stoddard, M.T., Springer, J.D., Crouse, J.E., and Chancellor, W.W. (2013). Understory plant community responses to hazardous fuels reduction treatments in pinyon-juniper woodlands of Arizona, USA. Forest Ecology and Management, 289, 478–488. https://doi.org/10.1016/j.foreco.2012.09.030

Redmond, M.D., Urza, A.K., and Weisberg, P.J. (2023). Managing for ecological resilience of pinyon–juniper ecosystems during an era of woodland contraction. *Ecosphere*, *14*(5). https://doi.org/10.1002/ecs2.4505

U.S. Department of the Interior. (2024). *Management and Conservation of Pinyon and Juniper Woodlands*. https://www.blm.gov/sites/default/files/docs/2024-08/Management%20and%20Conservation%20of%20Pinyon%20and%20Juniper%20Woodlands%20Comment%20Summary%20Report.pdf

3. BEFORE STARTING THIS COMPLETE THE LAST DISCUSSION POST! Create a management scenario (150pts). Imagine you are the manager for part of this ecosystem (you can define the size/scope and specific management role). Using the details above and what you've learned in this class, write a report on what management plan you would implement. In this section, use & cite scientific research in your answers.

- First identify your management goals, methods to reach those goals, and ways to measure if the method/management was successful. What specific objectives are most important to your ecosystem's health and to the benefits it provides humans? How will you measure if your management is successful? *For example, a good management goal for a ponderosa pine forest may be to reduce fire risk through forest thinning, which can be measured by fuel loads.*
    - Identify three management goals
    - Find at least one scientific resource to cite for each goal
    - Write two paragraphs for each management goal describing…
        - Why it's important
        - One or more methods management can employ to reach the goal
        - One or more ways to measure successful management
        - How it's related to an ecological theory we learned in class

1. Management Goal #1:

    Large-scale catastrophic wildfires are increasing in frequency in pinyon-juniper woodlands (Huffman et al., 2019). Utilizing fuels reduction efforts and principles of ecological restoration to restore appropriate vegetation density and diversity is a widely implemented management goal tool to its ability to reduce fuel loading and wildfire severity (Huffman et al., 2009; Huffman et al., 2019). Although mechanical thinning alone can result in increased surface fuels, follow up prescribed fire can reduce these fuels and therefore mitigate the severity of future inevitable wildfire activity (Huffman et al., 2019). Preventing high-severity wildfires helps protect ecosystem health by reducing the likelihood and extent of post-fire hydrophobic soils developing that can degrade water quality, alter water flow, and local hydrology- all of which can harm the ability of woodlands to recover (Zvirzdin et al., 2017).

    To implement fuels reduction efforts and reduce wildfire risk, mechanical thinning via mastication should be conducted to reduce the density of vegetation and remove ladder fuels while aiming to preserve age-class diversity (Huffman et al., 2019). To mitigate concerns about the effects of large-scale fuels reduction efforts on wildlife, it may be beneficial to thin smaller portions of a landscape in a mosaic pattern to retain habitat diversity and avoid creating a monoculture of even-aged woodland species (U.S. Department of the Interior, 2024). Prescribed fire should be applied to

completed treatments to consume excess fuels (Huffman et al. 2019; Redmond et al., 2023). Pre- and post- treatment data on fuel loading (the quantity and arrangement of 1-, 10-, 100-, 1,000-, and 10,000-hour fuels) can demonstrate if the effort was successful (Cowan, 2023). Thinning utilizes the concepts of silviculture to alter the composition of a landscape to achieve wildfire risk reduction.

2. Management Goal #2:

   Ensuring adequate habitat and food resources are present for Pinyon Jays is a critical goal to preserve a declining pinyon-juniper woodland keystone species (Boone et al. 2018). One of the most important considerations to manage habitat for the species is ensuring a healthy population of seed-producing pinyon pine and a heterogenous woodland structure (Somershoe et al., 2020). Maintaining and managing for healthy pinyon pines that produce a significant crop of pine nuts can help ensure adult survivorship of pinyon jays (Somershoe et al., 2020). Additionally, Pinyon Jays are a colony nesting species that prefer to nest in slightly denser habitat compared to the more open portions of woodlands where they cache pine nuts (Somershoe et al., 2020).

   Strategic thinning can be used to create the habitat diversity needed to satisfy the species' habitat requirements for nesting and collecting and caching pine nuts (Boone et al., 2018). Although a general understanding of their habitat requirements exists, more research is needed to address data gaps that would help refine the specific thinning prescriptions that would be most appropriate (i.e., ideal trees per acre, spacing and gaps, etc.) (Somershoe et al., 2020). To determine if this effort is successful, baseline pinyon jay population data should be obtained in the treatment area using a standardized survey protocol (Boone et al., 2023). Post-treatment, the monitoring protocol should be repeated for several years to observe if the treatment has an impact on the local population (Boone et al., 2023). Managing the density and arrangement of vegetation on the landscape will help increase the fundamental niche of the species by creating ideal habitat that the species could occupy.

3. Management Goal #3:

   Climate change and drought will continue to be a threat to the health and resilience of pinyon-juniper woodlands as these factors stress individual trees and make them more susceptible to bark beetle infestation and large-scale die-off (Redmond et al., 2023). Significant die-off of pinyon pine has been observed in these woodlands, especially in Colorado where 90% mortality of several stands has been noted and in the Great Basin that has experienced a 10.9% decrease in pinyon pine canopy cover over the last 10 years (Flake and Weisberg, 2018; Redmond et al., 2023). Managing for the resilience of pinyon pines, one of the dominant tree species in pinyon-juniper woodlands, will help maintain the character and ecology of this ecosystem and help prevent large-scale ecosystem conversion.

   One of the key considerations to prevent large-scale die-off and ecosystem conversion is ensuring an un-even aged woodland structure exists with a variety of age classes (Redmond et al., 2023). Additionally, these ecosystems should ideally

contain a variety of rocks, snags, coarse woody debris, and shrubs that create microsites more conducive to successful regeneration of pinyon pine seedlings (Redmond et al., 2023). Targeted, strategic, thinning can be used to create stand diversity but should retain habitat features like snags and some shrubs and should use minimally invasive equipment to preserve features like rocks and downed logs that are critical for creating microsites (Redmond et al., 2023; Reid, 2024). By managing for a diversity of age classes and microsites that shade and protect seedlings, the likelihood of recovery of pinyon pine, even in drought and climate induced stress and die-off, increases significantly (Kane et al., 2015; Redmond et al., 2023). Success can be measured by surveying a site before and after treatment to quantify the change in stand structure by measuring canopy cover, age-class diversity, and species composition. Quantifying the number of snags, large rocks, and the volume of coarse woody debris should also be conducted to determine if the management efforts achieved objectives (Ståhl et al., 2001; Reid, 2024). Long-term monitoring plots can also be established to evaluate the regeneration of pinyon pine over time and could be especially useful if a disturbance like fire or drought occur. This goal will help utilize disturbance as a restoration catalyst by ensuring succession is possible in increasingly harsh environmental conditions.

References:

Boone., J.D., S.G. Somershoe, E.M. Ammon, C. Borgman, R. Chi, E. Duvuvuei, S. Gibson, K. Johnson, E. Juarez, E. Masters, and R. Norvell. (2023). *Pinyon Jay Survey Protocol for Landscape Applications*. Partners in Flight Western Working Group. 26 p.

Boone, J.D., Ammon, E., and Johnson, K. (2018*). Long-term declines in the Pinyon Jay and management implications for piñon–juniper woodlands*, in Trends and traditions: Avifaunal change in western North America (W. D. Shuford, R. E. Gill Jr., and C. M. Handel, eds.), pp. 190–197. Studies of Western Birds 3. Western Field Ornithologists, Camarillo, CA; doi 10.21199/SWB3.10

Cowan, A. (2023, June 15). Prescribed fire basics: Fuels. OSU Extension Service. https://extension.oregonstate.edu/catalog/pub/em-9386-prescribed-fire-basics-fuels

Flake, S. W., and Weisberg, P. J. (2019). Fine-scale stand structure mediates drought-induced tree mortality in pinyon—juniper woodlands. *Ecological Applications*, *29*(2), 1–14. https://doi.org/10.1002/eap.1831

Huffman, D.W., Fulé, P.Z., Crouse, J.E., and Pearson, K.M. (2009). A comparison of fire hazard mitigation alternatives in pinyon–juniper woodlands of Arizona. *Forest Ecology and Management*, *257*(2), 628–635. https://doi.org/10.1016/j.foreco.2008.09.041

Huffman, D.W., Stoddard, M.T., Springer, J.D., Crouse, J.E., Meador, A.J.S., and Nepal, S. (2019). Stand Dynamics of Pinyon-Juniper Woodlands after Hazardous Fuels Reduction Treatments in Arizona. *Rangeland Ecology & Management*, *72*(5), 757–767. https://doi.org/10.1016/j.rama.2019.05.005

Kane, J. M., Dugi, F. L., and Kolb, T. E. (2015). Establishment and growth of piñon pine regeneration vary by nurse type along a soil substrate age gradient in northern Arizona. *Journal of Arid Environments*, *115*, 113–119. https://doi.org/10.1016/j.jaridenv.2015.01.011

Redmond, M.D., Urza, A.K., and Weisberg, P.J. (2023). Managing for ecological resilience of pinyon–juniper ecosystems during an era of woodland contraction. *Ecosphere*, *14*(5). https://doi.org/10.1002/ecs2.4505

Reid, H.A. (2024). *Post-fire restoration of single-leaf pinyon pine: Above-and below-ground influences on seedling establishment* (Order No. 31764515). Available from ProQuest Dissertations & Theses Global. (3165632642). https://libproxy.nau.edu/login?url=https://www.proquest.com/dissertations-theses/post-fire-restoration-single-leaf-pinyon-pine/docview/3165632642/se-2

Somershoe, S. G., E. Ammon, J. D. Boone, K. Johnson, M. Darr, C. Witt, and E. Duvuvuei. 2020. *Conservation Strategy for the Pinyon Jay (Gymnorhinus cyanocephalus)*. Partners in Flight Western Working Group and U.S. Fish and Wildlife Service.

Ståhl, G., Ringvall, A., and Fridman, J. (2001). Assessment of Coarse Woody Debris: A Methodological Overview. *Ecological Bulletins*, *49*, 57–70. http://www.jstor.org/stable/20113264

U.S. Department of the Interior. (2024). *Management and Conservation of Pinyon and Juniper Woodlands*. https://www.blm.gov/sites/default/files/docs/2024-08/Management%20and%20Conservation%20of%20Pinyon%20and%20Juniper%20Woodlands%20Comment%20Summary%20Report.pdf

Zvirzdin, D.L., Roundy, B.A., Barney, N.S., Petersen, S.L., Anderson, V.J., and Madsen, M.D. (2017). Postfire soil water repellency in piñon–juniper woodlands: Extent, severity, and thickness relative to ecological site characteristics and climate. *Ecology and Evolution*, *7*(13), 4630–4639. https://doi.org/10.1002/ece3.3039

- Next pass a critical lens over your management goals. Where might management goals conflict? What outside of your three management goals are necessary for a healthy ecosystem (i.e., what are your three goals missing)? Are your "measurements of success" really indicative of what's happening in the ecosystem? Write at least a page describing potential troubles of implementing these management goals. Cite at least two scientific sources.

All of the listed management goals involve some level of manipulation to the structure, density, and arrangement of the fuels and vegetation in pinyon-juniper woodlands, which lends itself to several synergies. However, these goals are also targeting different management actions for specific species or outcomes, which results in some specifications that might conflict with other species-specific needs. For example, fuels reduction efforts that assist in creating a heterogenous un-even aged stand to increase the resilience of pinyon pine can result in an accumulation of woody biomass that actually increases the fire-risk of the stand (Reid, 2024). However, retaining some of this woody biomass and shrubs on the landscape can be critical to increasing the chance of successful seedling establishment with microsites and shading (Urza et al., 2019). Additionally, fuels reduction efforts in pinyon-juniper woodlands are sometimes touted as not being compatible with habitat needs of pinyon jays (Johnson et al., 2018). However, jays utilize both dense stands and more open heterogenous stands for different activities (i.e., nesting vs. caching nuts) and have been observed utilizing habitat near recently thinned areas, which demonstrates the opportunity for conservation of the species to be possible through coordination and planning (Johnson et al., 2018). Concurrently, in many cases, fuels reduction impacts on wildfire risk reduction increases as the size of treatments increases, meaning this may be sacrificed when treatments are scaled or combined with other objectives (U.S. Department of Agriculture, 2023). Ultimately, the actions associated with these goals should not be implemented in silos- the more coordination that occurs between managers and stakeholders, the more a mosaic, integrated approach can be implemented. In reality, this would look like a diversity of treatments across thousands of acres.

Outside of these three management goals, there are a suite of other ecological considerations and stakeholder and indigenous communities' perspectives that should be recognized. Ecologically, the potential for fuels reduction and managing stands in any capacity to result in increased invasion opportunities for species like cheatgrass (*Bromus tectorum*) is an important consideration (Matchett et al., 2010). Other uses like livestock grazing should also be considered in management. Even though grazing is often viewed as deleterious to these ecosystems, it is an activity that national forests are managed to support and should be considered (Barger et al., 2009). Traditional Ecological Knowledge should also be incorporated into management objectives by collaborating closely with the abundant Indigenous communities that have managed these woodlands for hundreds of years (Lefler, 2014).

The measures of success listed for the three management goals focus heavily on fuels and stand dynamics, but overlook other critical ecosystem health indicators including biodiversity metrics (i.e., species richness and diversity) and soil health. To obtain a more holistic understanding of how these suggested management actions will affect general ecosystem health, these indicators can be utilized in combination with the other suggested monitoring protocols.

References:

Barger, N.N., Adams, H.D., Woodhouse, C., Neff, J.C., and Asner, G.P. (2009). Influence of Livestock Grazing and Climate on Pinyon Pine (Pinus edulis) Dynamics. *Rangeland Ecology & Management*, *62*(6), 531–539. https://doi.org/10.2111/.1/REM-D-09-00029.1

Johnson, K., Petersen, N., Smith, J., and Sadoti, G. (2018). Piñon-juniper fuels reduction treatment impacts pinyon jay nesting habitat. *Global Ecology and Conservation*, *16*, Article e00487. https://doi.org/10.1016/j.gecco.2018.e00487

Lefler, B. J. (2014). *Nuwuvi (southern paiute) ecological knowledge of piñon-juniper woodlands: Implications for conservation and sustainable resource use in two southern nevada protected areas* (Order No. 1568621). Available from ProQuest Dissertations & Theses Global; Publicly Available Content Database. (1625427710). Retrieved from https://libproxy.nau.edu/login?url=https://www.proquest.com/dissertations-theses/nuwuvi-southern-paiute-ecological-knowledge-piñon/docview/1625427710/se-2

Matchett, J.R., Brooks, M.L., Halford, A., Johnson, D., and Smith, H. (2010). *Evaluating the Effects of Pinyon Thinning Treatments at a Wildland Urban Interface*. JFSP Research Project Reports. 69. https://digitalcommons.unl.edu/jfspresearch/69

Reid, H.A. (2024). *Post-fire restoration of single-leaf pinyon pine: Above-and below-ground influences on seedling establishment* (Order No. 31764515). Available from ProQuest Dissertations & Theses Global. (3165632642). https://libproxy.nau.edu/login?url=https://www.proquest.com/dissertations-theses/post-fire-restoration-single-leaf-pinyon-pine/docview/3165632642/se-2

Urza, A.K., Weisberg, P.J., Chambers, J.C., and Sullivan, B.W. (2019). Shrub facilitation of tree establishment varies with ontogenetic stage across environmental gradients. *The New Phytologist*, *223*(4), 1795–1808. https://doi.org/10.1111/nph.15957

U.S. Department of Agriculture. (2023). *How effective are landscape scale fuel treatments*? Connected Science. https://www.fs.usda.gov/rm/pubs_journals/rmrs/sycu/2023/cs_2023_09_how_effective.pdf

- Finally, describe what successful management in your ecosystem looks like, in your own opinion supported by scientific evidence. Explain how you would balance different management goals to maintain ecosystem health and benefits to people. Write at least a page and cite at least two scientific sources.

Successful management in pinyon-juniper woodlands needs to be context dependent. The three main types of woodlands (savannas, wooded shrublands, and persistent woodlands) differ in their natural historic states and therefore successful management may look slightly different in various parts of the range of the ecosystem (U.S. Department of the Interior, n.d.). Persistent woodlands are concurrently facing contraction and die-off while also expanding into adjacent grasslands and experiencing infill (Filippelli et al., 2020; Shriver et al., 2022). This management concern tends to be the basis of many other issues including catastrophic wildfires, invasive species, reduction in wildlife habitat, and loss of ecological function, which is why it would be the center of my management effort (U.S. Department of the Interior, 2024).

To balance the many competing interests in pinyon-juniper woodlands, I would address the most pressing and high-stakes issue of catastrophic, stand-replacing, wildfires that pose the largest risk of total ecosystem conversion (Tausch, 1999). Within this effort, which requires fuels reduction and thinning efforts, it is a great opportunity to pull in objectives from other management needs. For example, collaboration with Indigenous communities and wildlife managers would help inform the objectives, timing, goals, and prescriptions for thinning efforts to not only help reduce wildfire risk but also achieve improvements in wildlife habitat and manage for healthy, resilient, pinyon pines that are valuable to tribes. Collaboration with ranchers would inform where higher intensity thinning is needed and the type of vegetation removal required (i.e., juniper reduction) to support an herbaceous understory which could help find a balance (Almalki et al., 2023). Formal stakeholder engagement processes would be used to assemble stakeholders, learn about their priorities and concerns, and use that information to make adjustments to a large-scale thinning efforts (Talley et al., 2016).

A mosaic approach to fuels reduction would help implement stakeholder input. For example, grazing may only be a priority in a subset of the landscape, so a thinning intensity that satisfies ranchers does not need to be indiscriminately applied landscape wide. The same concept goes for a thinning intensity and prescription that benefits Pinyon Jays- surveys could help identify where colonies exist and therefore where wildlife-minded fuels reduction should occur. This concept is already being applied to other threatened and endangered species like the Mexican spotted owl (Strix occidentalis lucida) (U.S. Department of the Interior, 2022). The timing of forest thinning operations and the scale of vegetation removal is adjusted to accommodate the habitat needs of the owl (U.S. Department of the Interior, 2022). Lastly, Traditional Ecological Knowledge and coordination with Indigenous communities can help manage these woodlands for long-term resilience in a warming climate (Yazzie et al., 2019). The objectives of resilience and promoting the successful reestablishment of pinyon pine seedlings aligns closely with the values of tribes that utilize pinyon pine for their pine nut crops and wood.

The challenges facing pinyon-juniper woodlands are being rapidly exacerbated by a changing climate. A multi-benefit, stakeholder-minded, approach to management is an appropriate way to attempt to conserve an at-risk landscape in the face of many unknowns.

References:

Almalki, Y.M., Fernald, A.G., Ochoa, C.G., Cibils, A.F., Faist, A.M., Cram, D.S., and Steiner, R.L. (2023). Understory Vegetation Response to Thinning Pinyon-Juniper Woodlands. *Rangeland Ecology & Management*, *88*(1), 152–158. https://doi.org/10.1016/j.rama.2023.02.012

Filippelli, S. K., Falkowski, M. J., Hudak, A. T., Fekety, P. A., Vogeler, J. C., Khalyani, A. H., Rau, B. M., & Strand, E. K. (2020). Monitoring pinyon-juniper cover and aboveground biomass across the Great Basin. Environmental Research Letters, 15(2), 25004. https://doi.org/10.1088/1748-9326/ab6785

Shriver, R. K., Yackulic, C. B., Bell, D. M., Bradford, J. B., & Hampe, A. (2022). Dry forest decline is driven by both declining recruitment and increasing mortality in response to warm, dry conditions. Global Ecology and Biogeography, 31(11), 2259–2269. https://doi.org/10.1111/geb.13582

Talley, J.L., Schneider, J., and Lindquist, E. (2016). A simplified approach to stakeholder engagement in natural resource management: the Five-Feature Framework. *Ecology and Society*, *21*(4). http://www.jstor.org/stable/26270020

Tausch, R.J. (1999). *Historic Pinyon and Juniper Woodland Development. Proceedings: Ecology and Management of Pinyon-Juniper Communities Within the Interior West*. RMRS-P-9. https://www.fs.usda.gov/rm/pubs/rmrs_p009.pdf

U.S. Department of the Interior. (n.d.). *Pinyon-Juniper Woodlands- Species Composition and Classification*. National Parks Service. https://www.nps.gov/articles/pinyon-juniper-woodlands-species-composition-classification.htm

U.S. Department of the Interior. (2022). *Four Forest Restoration Initiative (4FRI) Rim Country Project Biological Opinion*. https://www.fws.gov/sites/default/files/documents/4FRI%20Rim%20Country%20BiOp%2003042022_final.pdf

U.S. Department of the Interior. (2024). *Management and Conservation of Pinyon and Juniper Woodlands*. https://www.blm.gov/sites/default/files/docs/2024-08/Management%20and%20Conservation%20of%20Pinyon%20and%20Juniper%20Woodlands%20Comment%20Summary%20Report.pdf

Yazzie, J.O., Fulé, P.Z., Kim, Y.S., and Sánchez Meador, A. (2019). Diné kinship as a framework for conserving native tree species in climate change. *Ecological Applications* 29(6):e01944. 10.1002/eap.1944

Appendix B
FOR 536 Translational Communication Project

FOR 536 Translational Communication Project

Communicating the positive impacts of fuels treatments on reducing the risk of catastrophic wildfire

Video presentation Link

Colette Pansini

Introduction

Uncontrollable, catastrophic wildfires are becoming a more frequent occurrence that threaten the safety of communities. These wildfire trends are being exacerbated by climate change and poor forest health due to historic fire suppression and a lack of forest management. Additionally, the wildland-urban interface, the area where human development and undeveloped wildlands meet or intertwine, is growing as urban and rural communities expand (Schug et al. 2023). Fuels treatments including mechanical thinning and prescribed burning are an effective way to reduce fuel loading and the risk of high-severity wildfires (Broadie et al. 2024).

These activities are necessary to restore forests to more natural densities and create conditions conducive to be able to safely manage natural ignitions. Although many wildland-urban interface communities are familiar with fuels reduction efforts, there is a need to continue community education efforts. This communication plan aims to educate the Payson, Arizona community about: 1) the state of unhealthy forests and the risk they pose to the community 2) what fuels treatments are and why they are effective, and 3) what to expect when fuels treatments are occurring. Additionally, the plan aims to equip local officials with education to help support the fuels reduction efforts.

Audience Analysis:

General public

The general public in Payson contains a wide range of ages and backgrounds. This plan would focus on adults since they are the age group primarily concerned about wildfire and fuels treatments. Thirty-seven percent of Payson's population is 65 years or older, so a hybrid approach of in-person and online communication is best (U.S. Census Bureau n.d.).

Local officials

Local police and fire staff and other Town leadership interact frequently with on-the-ground fuels managers and the public. They need to be apprised of fuels treatment plans, general information about fuels treatments and the benefits, and safety considerations to be able to help manage questions and concerns that they may be tasked with resolving.

Media

Local media who cover natural resource management topics can be great resources for spreading the word about fuels treatment effectiveness and when/where treatments will be occurring. They can help managers reach a larger audience and help gain trust.

Key Messages

General public

This audience would benefit from messaging about their current wildfire risk, information about fuels treatments, and how those treatments will impact their day-to-day life. Clear information about where they can go to get their questions answered will help build trust.

Main messages:

- We're experiencing more frequent and severe wildfires fueled by unhealthy forests
- Thinning and subsequent prescribed fire are an effective tool in reducing the risk of catastrophic wildfires
- Even though thinning and prescribed fire may cause inconveniences, they are necessary activities to protect the Payson community

Local officials

Information on logistics of fuels treatments and how the community will be impacted (road closures, smoke impacts, timelines) will be important for local officials to be able to aid the community. Equipping local officials with the who, what, when, where, and why of fuels treatments leads to a large amount of informed, trusted, people who can help communicate with the public.

Main messages:

- Basic information on the ecological and community benefits of fuels treatments and how these activities are going to protect the community long-term
- Logistics of how fuels treatments will be implemented
- How the community could be inconvenienced and how to mitigate those inconveniences
    - Road closures & alternate routes
    - Potential smoke impacts & how the public can mitigate health impacts

Media

Local media will benefit from similar information that local officials would be provided. Since community members often look to media for factual reporting, they should be equipped with information on why the work is occurring and how it will benefit the community.

Main messages:

- Basic information on the ecological and community benefits of fuels treatments
- Resources where listeners can learn more- they can help promote public meetings

Communication Channels and Tools

- Social media:

    - Most of the general public gets news from social media platforms, so a large audience can be reached. Content would be easily digestible and quickly communicate how fuels treatments are benefitting the community.
    - Ex:
        - "did you know"/"fun fact" content on Facebook and Instagram
        - Educational series of videos on YouTube/social media
    - Tools: Video editing software will be used to create short videos, canva will be used to create fun and engaging posts
- Community workshops:
    - Allows concerned citizens a chance to ask questions and feel that their voice is heard, allows managers to interface with the public and showcase their expertise to gain community support. These workshops may better target older members of the public, or those that are particularly interested in or concerned about the treatments. These would allow the public to receive immediate answers and provide feedback to managers that can be incorporated into treatments.
    - This could be marketed as an "ask the experts" session to promote engagement
    - Tools: Canva would be used to create promotional posters, GIS and StoryMaps to create interactive maps to show at the events, Google Forms to create a feedback survey or Q&A submission
- Media interviews:
    - Managers can raise awareness for the benefits of fuels treatments by participating in media interviews
    - Tools: Media would provide video equipment, media can promote the community to visit social media for more information

Timeline

- Month 1- Develop communication materials
- Month 2- Host a workshop for media and local officials to educate them on fuels treatments and prepare them to answer questions from the public
- Month 3- Host a community workshop for the general public, simultaneously launch social media campaign and start media interviews
- Month 4- Review reception of the campaign and any pain points. Revise any necessary materials to clarify messaging
- Month 5- Launch longer-term educational videos for stakeholders who want more depth of information

References

Brodie, E. G., Knapp, E. E., Brooks, W. R., Drury, S. A., & Ritchie, M. W. (2024). Forest thinning and prescribed burning treatments reduce wildfire severity and buffer the impacts of severe fire weather. *Fire Ecology*, *20*(1), 1-20. https://doi.org/10.1186/s42408-023-00241-z

Schug, F., Bar-Massada, A., Carlson, A. R., Cox, H., Hawbaker, T. J., Helmers, D., Hostert, P., Kaim, D., Kasraee, N. K., Martinuzzi, S., Mockrin, M. H., Pfoch, K. A., & Radeloff, V. C. (2023). The global wildland–urban interface. *Nature*, *621*(7977), 94–99. https://doi.org/10.1038/s41586-023-06320-0

U.S. Census Bureau. (n.d.). Payson Town, Arizona. Retrieved November 30, 2023, from https://data.census.gov/profile/Payson_town

COMMUNICATION PLAN

Positive impacts of fuels treatments on reducing the risk of catastrophic wildfire

COLETTE PANSINI

INTRODUCTION

Wildfire trends:

↑
- Acres burned
- Intensity

Exacerbated by:

- Climate Change
- Longer fire seasons
- Increased temperatures
- Historic fire suppression
- Poor forest health

Unthinned, overgrown stand of trees in the Coconino National Forest

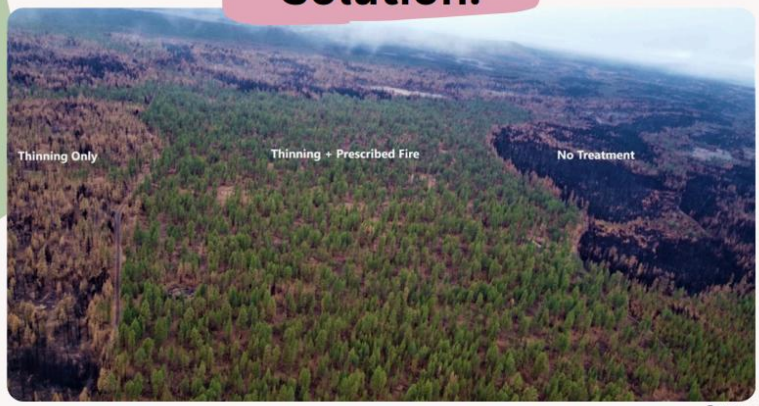
SIGNIFICANE

Communities in the Wildland-Urban Interface are at risk

The Town of Payson, AZ is at high risk of being affected by wildfire, according to AZ DFFM

Source

Solution:

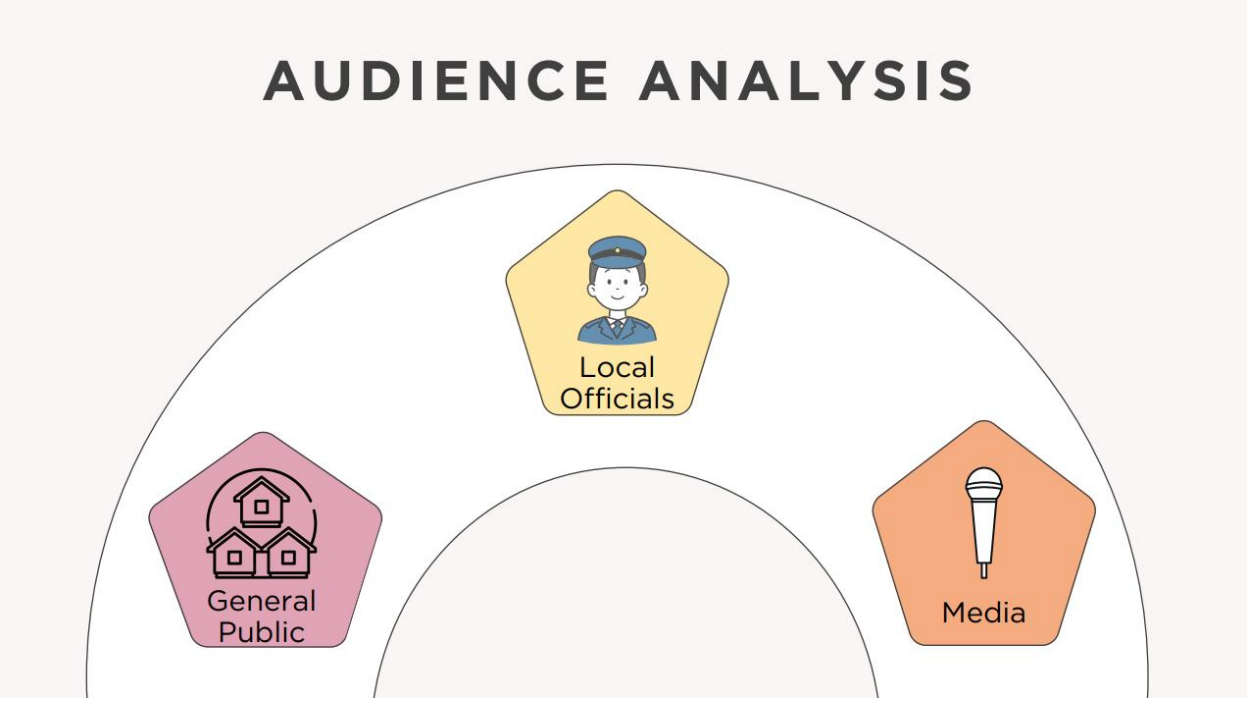


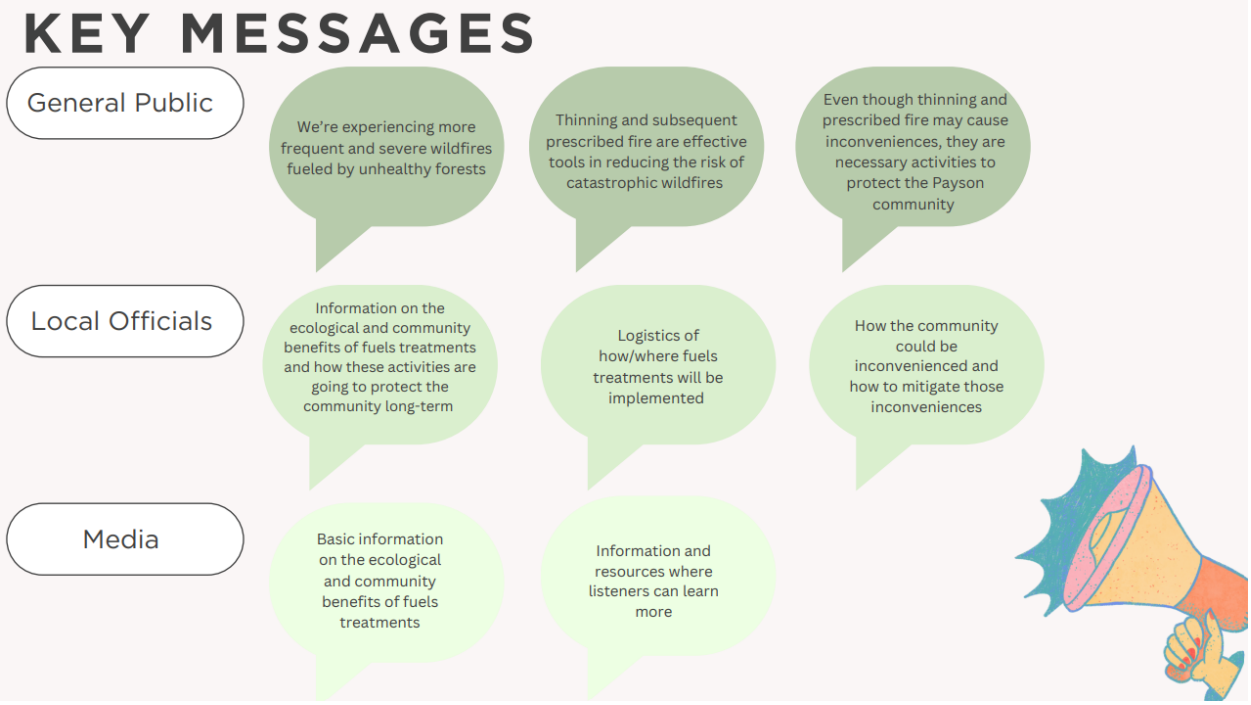
Source

GOALS

Educate the Payson community on their current risk, what fuels treatments are and why they are effective, and what to expect when fuels treatments are occurring

Equip local officials with education to help support the fuels reduction efforts.


AUDIENCE ANALYSIS
Local Officials
General Public
Media


KEY MESSAGES
General Public
We're experiencing more frequent and severe wildfires fueled by unhealthy forests
Thinning and subsequent prescribed fire are effective tools in reducing the risk of catastrophic wildfires
Even though thinning and prescribed fire may cause inconveniences, they are necessary activities to protect the Payson community
Local Officials
Information on the ecological and community benefits of fuels treatments and how these activities are going to protect the community long-term
Logistics of how/where fuels treatments will be implemented
How the community could be inconvenienced and how to mitigate those inconveniences
Media
Basic information on the ecological and community benefits of fuels treatments
Information and resources where listeners can learn more

COMMUNICATION CHANNELS & TOOLS

Social Media

Source

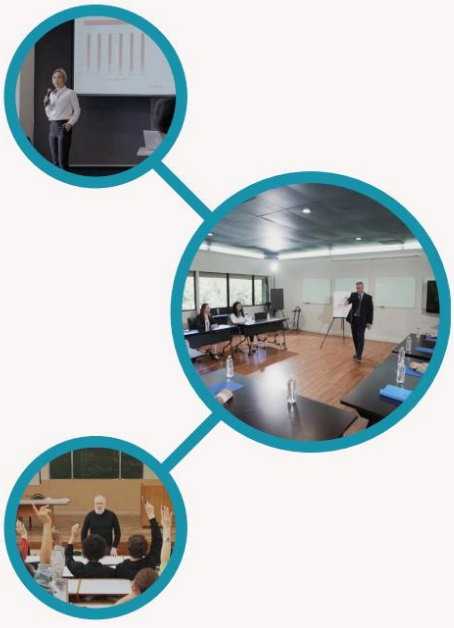
Source

Source

COMMUNICATION CHANNELS & TOOLS

Community Workshops

Graphic Source



COMMUNICATION CHANNELS & TOOLS

Media Interviews

Managers can raise awareness and gain trust from the community by participating in interviews and providing information

Photo Source

TIMELINE

MONTH 1

Develop communication materials

MONTH 2

Host a workshop for media & local officials to educate them on fuels treatment plans

MONTH 3

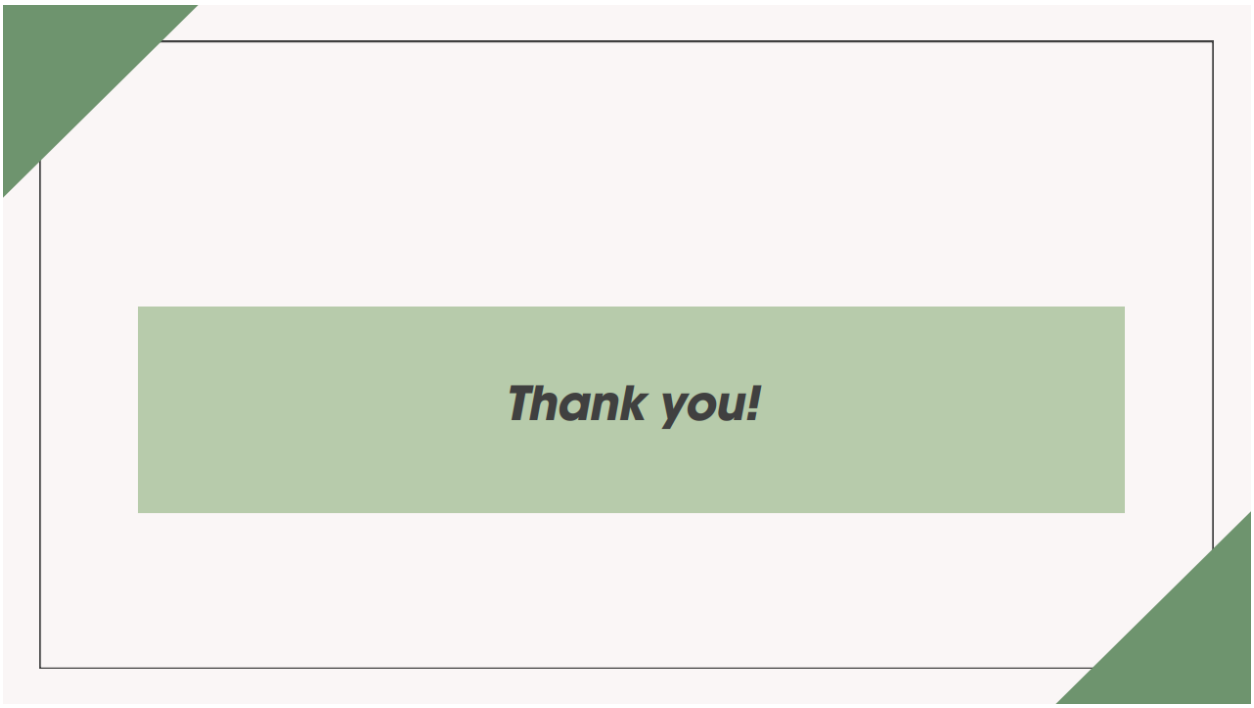
Host a community workshop for the public, launch social media campaign, start media interviews

MONTH 4

Review feedback from the social media campaign & community workshop to revise and improve messaging

MONTH 5

Launch longer-term educational videos for stakeholders who want more in-depth information


Thank you!

Appendix C
FOR 691 Literature Review

FOR 691 Literature Review

The impacts of invasive grasses on fire regimes and ecosystem health in Western U.S deserts

Colette Pansini

Reviewed by: Dr. Benjamin Cranston, Thomas Swanson, and Robert Culp

Executive Summary

In recent decades, invasive species like cheatgrass (*Bromus tecoturm*), buffelgrass (*Pennisetum ciliare*), and red brome (*Bromus rubens*) have overtaken sensitive desert ecosystems that are not adapted to frequent fire. These invasive species have the potential to alter historic fire regimes and fundamentally degrade ecosystem health by altering the soils, hydrology, and vegetation composition of landscapes. The impacts of grass invasion in Western U.S. deserts on fire regimes and ecosystem health and how to effectively mitigate for those impacts are at the forefront of minds of land managers throughout the Southwest. Climate change, changes in precipitation trends, and the increasing threat of uncontrollable wildfires will continue to create conditions conducive to the spread and persistence of invasive species across the world. A large body of literature on the impacts of invasive grasses exists, but in today's conditions of long-term drought, megafires, and grass-fire cycles, a synthesis of the impacts on fire regimes and ecosystem health in Western U.S. desert ecosystems is timely and needed.

Davies and Nafus (2013) conducted an empirical study that compared the fuels characteristics of cheatgrass invaded and non-invaded sites in Oregon. Similarly, Fusco et al. (2019) modeled the effects of several common invasive grasses on similar fuels characteristics across different U.S. ecoregions. Both studies yielded similar conclusions and support the larger consensus that many common invasive grasses contribute to changes in fire regimes and alterations of fuels characteristics. In addition to invasive grasses altering fire regimes, they can also play other roles in degrading ecosystem health through changes in species composition and biodiversity. Ravi et al. (2021) demonstrated that climate change and drought will play a role in the persistence of invasive species and mortality of native vegetation. Olsson et al. (2012) and Freeman et al. (2014) concluded that the richness and diversity of native plants and mammals decreases as invasive grass cover and abundance increases, showcasing how invasives can degrade ecosystem function.

More focused research across U.S. desert regions on the long-term implications of invasive grasses and potential management options is needed to most effectively inform management decisions, funding, and resource allocation. Acknowledging the ways in which invasive grasses threaten ecosystems can help land managers across sectors understand where the impacts are most prominent and therefore help target mitigation and restoration efforts most

efficiently. The purpose of this review is to propose conducting a long-term study on two mitigation methods (physical removal and herbicide application) to reduce the cover of invasive grasses across a gradient of sites in 3 desert ecosystems to help address the long-term impacts of mitigation measures and assess their effectiveness.

Introduction

The United States is home to four unique deserts- the Mojave, Sonoran, Chihuahuan, and Great Basin- that span seven states (U.S. Geological Survey 2024). Deserts- areas that are typically characterized by limited precipitation (<10 inches annually) and extreme temperature fluctuations- make up twenty percent of the earth's land surface (Harris 2003). Globally, these ecosystems contain rich biodiversity and are home to some 7,000 animal species (Safriel et al. 2005). The plants and animals that live in these ecosystems have evolved physiological (e.g. concentrated urine to preserve water), behavioral (e.g. foraging at night), and anatomical (e.g. waxy coating on leaves to reduce evaporation) adaptations that allow them to survive harsh environmental conditions (Harris 2003; Kirschner et al. 2021; Rocha et al. 2021; He 2023).

There are a number of pressures on Western U.S. deserts today that, in conjunction, threaten the health and resiliency of desert ecosystems. Human development in the desert Southwest has been expanding into natural areas for decades. The wildland urban interface is the area where human development and undeveloped wildlands meet or intertwine (Schug 2023). Some of the most populous cities in the United States are in or adjacent to deserts. Over 7.4 million people call the Phoenix, Arizona and Las Vegas, Nevada metropolitan areas home (U.S Census Bureau 2024). Those areas contain the 5th and 24th largest U.S. cities, respectively, and are located in the Sonoran and Mojave deserts (U.S. Census Bureau 2024). The increasing intersections of deserts and human development can lead to further habitat fragmentation, more frequent human-caused fires, and more homes and structures at risk of wildfire (Radeloff et al. 2018). Additionally, livestock grazing, a controversial activity in arid lands, has been in some contexts shown to have negative impacts on vegetation composition, soils, and overall ecosystem function (Hall et al. 2005). Given that grazing of livestock and agriculture account for 53% of the United States' land use, overgrazing poses a significant threat to deserts (U.S. Department of Agriculture 2024). Climate change is expected to result in a 1.5°C increase in the pre-industrial global temperature baseline in the next 5 years which will likely exacerbate the existing threats deserts are facing (IPCC 2023; World Meteorological Organization 2024). Deserts are particularly sensitive to climate change and its impacts as the plants and animals that live in these ecosystems are already stressed for resources (Vale and Brito 2015). Although these threats are of grave concern to these ecosystems, a relatively new threat has developed that is altering the structure and composition of deserts: invasive grasses. The impacts of invasive grasses and their

impact on fire regimes have been noted as an increasingly common threat across western U.S. deserts (Wilder et al. 2021).

Biological invasions have had profound impacts on economies, biodiversity, and native habitats for centuries. In fact, the human-caused spread and persistence of invasive species and alterations of habitats is one of the defining characteristics of the Anthropocene- a relatively newly proposed epoch that represents a geological time period defined by the impacts of human activities on the planet (Steffen et al. 2011; Le Roux 2022). Some of the most infamous invasive species in the United States such as kudzu, European starling, and Asian carp have become persistent and fundamentally changed the ecosystems where they thrive (Blaustein 2001; Linz et al. 2007; Kramer et al. 2019). Invasive species can spread intentionally (e.g. the cane toad being introduced to control agricultural pests in Australia) or unintentionally (e.g. ballast water transporting zebra mussels into the Great Lakes) and have far reaching ecological consequences (Strayer 2009; Shine 2012). The cost that is incurred for the mitigation of invasive species and their impacts to native habitats is high: to the tune of $423 billion per year globally (IPBES 2024). In recent decades, infamous invasive grass species like cheatgrass (*Bromus tecoturm*), buffelgrass (*Pennisetum ciliare*), and red brome (*Bromus rubens*) have overtaken sensitive desert ecosystems that are not adapted to frequent fire (Southwest Fire Consortium 2024). Cheatgrass, native to many parts of Europe, Asia, and Africa, made its way to the U.S. through several means including crop seed and ballast water in the late 1800s (Montana State University Extension 2012; FEIS 2024). Buffelgrass, native to Africa, was intentionally introduced to the U.S in the early 1900s for erosion control and was planted for livestock forage (Marshall et al. 2012; U.S. Department of Agriculture 2014). Red brome made its way into the U.S from the mediterranean by the 1880s, but a specific point of introduction is not widely agreed upon (Salo 2005; Reid et al. 2008). These invasive grasses have altered these historic desert fire regimes and fundamentally altered the health of these ecosystems.

Deserts are not historically fire-adapted landscapes, meaning they adapted with infrequent, or no, fires on the landscape (U.S. Department of Agriculture 2023). For example, prior to settlement, the Mojave Desert likely experienced fire every 100 years and the Sonoran Desert experienced fire at an even less frequent return interval of 100-1,000 years (Brooks and Matchett 2006; U.S. Department of Agriculture 2023). In comparison, some ecosystems like

Ponderosa pine (*Pinus ponderosa*) forests evolved with frequent, low severity, fire on the landscape, creating a shorter fire-return interval (Fulé et al. 1997). Invasive grasses have outcompeted native desert vegetation and created large monocultures across western U.S. deserts (Stanton et al. 2023). These invasive grasses have contributed to alterations of fire regimes and an increase in the number and frequency of fires in desert ecosystems (Germino 2016; Fusco et al. 2019). Some of the most devastating wildfires that the west has experienced over the last five years have been in grass-invaded deserts. In 2020, Arizona's Sonoran desert experienced two megafires (wildfires that burn > 100,000 acres) that were fueled by invasive grasses including red brome, stinknet (*Oncosiphon piluliferum*), and Lehmann lovegrass (*Eragrostis lehmanniana*) (Linley 2022; Southwest Fire Consortium 2024). The Bush fire burned almost 200,000 acres and the Bighorn fire burned 119,000 acres a few weeks later, becoming the 5th and 8th largest wildfire in the state's history, respectively (National Interagency Fire Center 2024). The York fire, fueled by red brome, burned 93,000 acres in the Mojave desert in 2023 (Southwest Fire Consortium 2024).

The impacts of invasive grasses in these desert landscapes on fire regimes and ecosystem health and how to effectively mitigate for those impacts are at the forefront of minds of land managers throughout the Southwestern U.S. A holistic investigation into how these invasive species impact the ecosystem health of western U.S. deserts and their fire regimes is needed to help inform management decisions and build a knowledge base for a relatively newly observed phenomenon.

Research Questions and Investigations

Researchers and land managers have a vested interest in understanding the different mechanisms by which invasive grasses are altering desert ecosystems. There is a census that invasive grasses are negatively impacting deserts globally, but there is much to learn about the specific mechanisms of change and the long-term impacts of these invasions in U.S. deserts. Understanding how and to what extent fire regimes and ecosystem health are impacted are common research questions being addressed. Additionally, researchers are aiming to determine if those impacts are different among various invasive grass species and desert regions.

Fusco et al. (2019) investigated how fire frequency and intensity are impacted by invasive grasses across a range of U.S. ecoregions, including deserts. They conducted a literature review to identify 18 fire-promoting invasive grass species in the U.S. and further limited the list to 12 species that had enough known spatial data to conduct analyses on. The authors downloaded and compiled spatial data of invasions for the 12 species and compared that location information to fire data from 2000-2015. Fire data (location, frequency, boundaries, burn severity) were obtained from the Fire Program Analysis fire-occurrence database and the Monitoring Trends in Burn Severity database. The fire boundaries were converted to a spatial grid that resulted in pixels that could be more easily analyzed. The authors were able to draw conclusions on 3 important fire regimes parameters- fire occurrence, size, and frequency- in areas with and without known invasive grasses (i.e. invaded vs uninvaded pixels). Modeling was used to determine if there was a statistically significant difference in the fire regime parameters among invaded and uninvaded pixels. For grass species that altered fire regime parameters, the authors tested if other factors (e.g. distance to road) impacted fire regime parameters. The authors concluded that invasive grasses do have a statistically significant impact on fire regimes, however it varied by grass species and the specific fire regime parameter. Eight species increased the rate of fire occurrence (buffelgrass and common Mediterranean grass showing the largest increases), 6 species were associated with a mean increase in fire frequency (buffelgrass and silk reed showing the largest increases), and only 2 of the species were significant in impacting fire size (Figure 1). The results of this study demonstrate the widespread impact of invasive grasses on fire regimes across the U.S. and convey that buffelgrass and cheatgrass- common invaders in deserts- have a proven impact on fire occurrence and frequency.

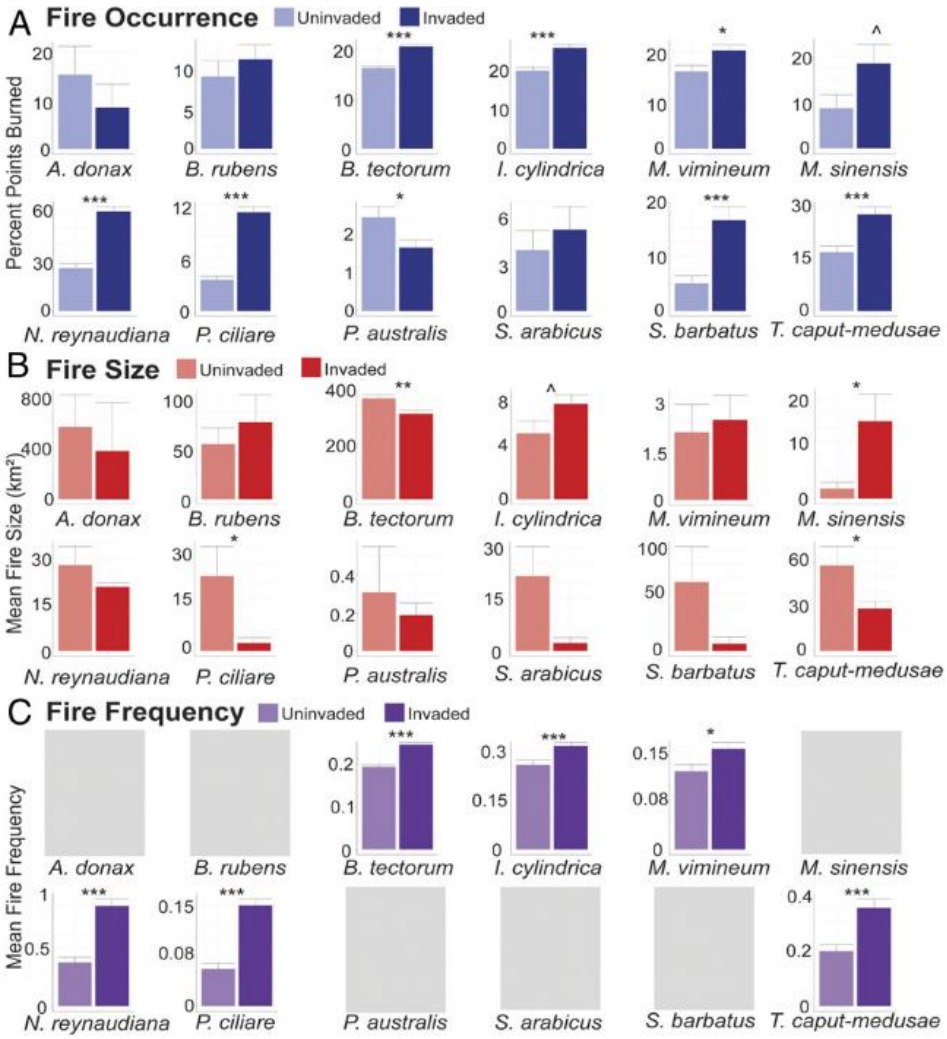


Figure 1. Statistical significance (P<0.05) is denoted with an asterisk. Results that are not statistically significant are denoted with ^. Some invasive grass species alter fire regime parameters including fire occurrence, size, and frequency.

Davies and Nafus (2013) investigated how invasive cheatgrass alters several fuel characteristics including fuel biomass, cover, continuity, and moisture content- important characteristics that can influence fire regimes. The researchers conducted a 2-year study in the northern stretches of the Great Basin in Oregon that compared these characteristics with a block design across 4 sites that were either invaded (dominated by cheatgrass) or non-invaded (dominated by native plants). Conditions among the 4 blocks were similar in terms of soil, topography, distance from roads, and the exclusion of grazing. Fuels characteristics were measured at intervals in 2010 and 2011. Moisture content was measured every 2 weeks in June-August to reflect conditions in wildfire season. Researchers harvested the grasses in five 0.20m^2

frames and compared the weight pre- and post- oven drying to determine fuel moisture. Fuel biomass was measured in August by collecting the grasses located in 15 randomly selected $1m^2$ frames. The vegetation was oven dried and weighed to measure biomass. Fuel continuity (i.e. connectedness) was measured using 20m transects where gaps between patches of vegetation were measured. Any gaps with a length ≥5cm that intersected the transects were classified as individual patches of vegetation. The researchers concluded that cheatgrass invaded sites had fuels characteristics that make them more prone to frequent, large, and fast spreading wildfires, including higher loads of fine fuels, more fuel continuity, and lower moisture content. The lower fuel moisture content in cheatgrass invaded sites make them conducive to burning about 1 month earlier than nearby non-invaded sites, highlighting how these differences in fuels can alter fire regimes (Figure 2).

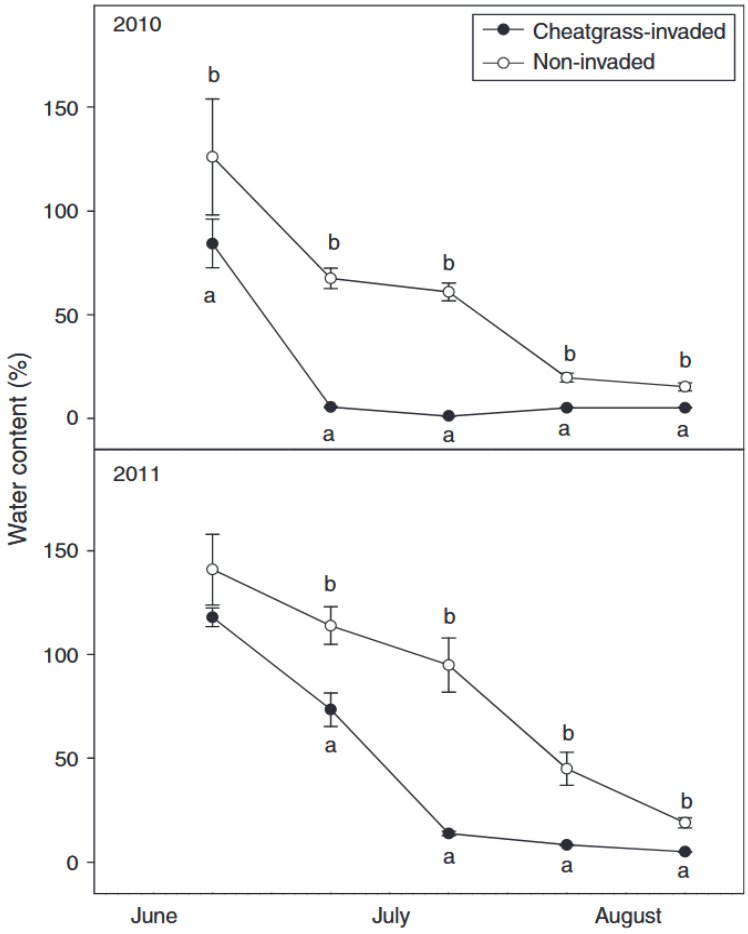


Figure 2. Fuel moisture content was lower in cheatgrass invaded blocks during the 3-month measurement period in 2010 and 2011. The lowercase letters (a,b) indicate statistical significance of results (P value<0.05).

Ravi et al. (2021) aimed to investigate how the interactions between non-native invasive buffelgrass and climate change can alter desert ecosystems. The researchers utilized Biosphere 2, a controlled environment research facility in the Sonoran Desert, to be able to manipulate temperature and moisture. Researchers harvested invasive buffelgrass and native tanglehead (*Heteropogan contortus*) tillers (shoots) from a preserve in Tucson, Arizona and allowed them to grow for 3 months before selecting specimens to be planted in containers in Biosphere 2. Four variables were manipulated in the experiment- temperature, watering, plant community, and species. Containers were planted with either only buffelgrass, only tanglehead, or intermixed, and equipped with soil moisture monitors. The containers were placed in different simulated biomes to study the interactions of climate and invasive species. Half of the containers were exposed to a changed climate (5℃ warmer than ambient temperature) and the other half remained at the ambient temperature. Half of each of the containers in the warmed vs. ambient groups were then exposed to either simulated drought conditions or normal irrigation.

Ecophysiological characteristics (photosynthesis, respiration, leaf water potential, soil moisture) were measured throughout the experiment. The study concluded that although both species were able to survive drought conditions by entering dormancy, the combination of drought and increased temperatures lead to higher mortality rates in tanglehead compared to buffelgrass (100% mortality for tanglehead in warmed, monoculture planted containers). The results of the study support the hypothesis that the combination of climate change and biological invasions will likely lead to widespread degradation of desert ecosystems (Figure 3).

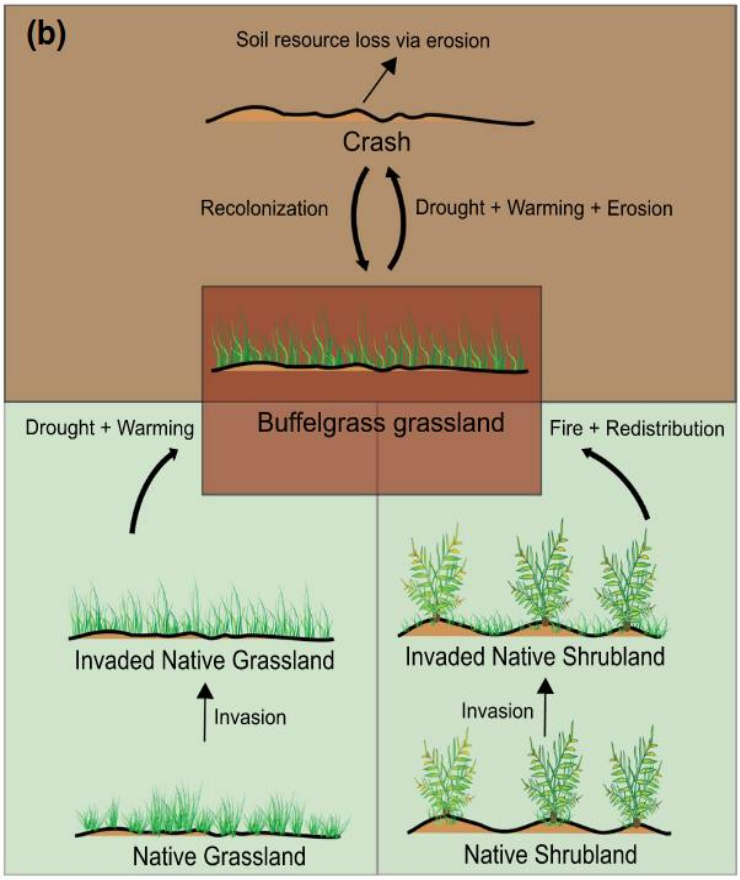


Figure 3. The interactions of climate change and invasive species will likely lead to increasing rates of desertification and ecosystem degradation.

These three studies examined fundamental interactions among invasive species, fire regimes, and ecosystem health. Some of the most common invasive grasses (buffelgrass and cheatgrass) were proven to have significant impacts on fuels characteristics, fire regimes, and overall health of native desert ecosystems. Future challenges such as climate change and drought have the potential to exacerbate invasions and their subsequent impacts on fire regimes.

Research Synthesis

The impacts of invasive grasses vary by ecosystem, species, and climate. Deserts in particular are facing large-scale ecosystem conversion from these invasions that will further be heightened by long-term drought, megafires, and grass-fire cycles. Deserts within the U.S. contain unique habitat characteristics that may alter the way invasive grasses interact with the landscape. A synthesis of the current impacts on fire regimes and ecosystem health in western U.S. desert ecosystems and expected changes in the face of climate change is warranted.

Fuel properties and Fire Regimes

There is an overwhelming consensus that invasive grasses alter fire regimes in Western U.S. deserts, but much is still unknown about the long-term impacts and if these changes are sustained over time. More focused research across U.S. desert regions on long-term impacts and the effectiveness of mitigation options is needed to most effectively inform management decisions, funding, and resource allocation.

Davies and Nafus (2013) and Fucso et al. (2019) demonstrated that invasive grasses contribute to changes in fire regimes, rates of fire occurrence, and fuels characteristics. Brooks and Matchett (2006) and Wilder et al. (2021) also support conclusions that invasive grasses have altered fuels characteristics and without mitigation and management, invasive grasses will continue to spread, and therefore the impacts on fire regimes will continue to grow. Several studies have highlighted how precipitation plays a large role in the growth, density, and continuity of invasive grasses, and therefore make certain areas more prone to fire (Gray et al. 2014; Moloney et al. 2019; Wilder et al. 2021). This is important considering that climate change will alter precipitation trends (Giorgi et al. 2019). Another perspective to consider is Olsson et al. (2012) who concluded that buffelgrass invasions do not impact fire regimes in the early stages of invasion and that the invasions impact on outcompeting native vegetation is the larger concern. Smith et al. (2023) demonstrated that invasive grass establishment in the Mojave Desert is predictable by assessing soils, topography, and climate at a larger regional scale, allowing for opportunities to assess risk and target management activities in most at-risk areas.

Ecosystem Health and Biodiversity

The range of effects of invasive grasses on desert ecosystem health and biodiversity varies widely, and often reflect other patterns found in other non-desert ecosystems. Impacts to soils and biodiversity, key components of ecosystem health, are most prominent in the literature. Invasive grasses have been shown to impact desert soils in several ways including altering the soil's microbiomes and nitrification processes and decreasing the number and types of fungi and invertebrates (Allen et al. 2011; Gornish et al. 2020; Afzal et al. 2023). Most widely discussed in the literature are the impacts of invasive grasses on desert biodiversity. Across the U.S., about 40% of species listed under the Endangered Species Act are at risk due to competition with or predation by invasive species (Pimentel et al. 2005). Common grass invaders have turned areas

of most western U.S. deserts into monoculture grasslands through the self-perpetuating grass-fire cycle (Brooks et al. 2004; Wilder et al. 2021). Native desert species that are not adapted to frequent fire such as saguaro cactus (*Carnegiea gigantea*) and creosote bush (*Larrea tridentata*) have shown high mortality rates due to altered fire regimes (McDonald and McPherson 2011). Invasive grasses are able to easily colonize these landscapes post-fire and significantly reduce the cover and species richness of native vegetation. In fact, several studies have shown a quantified negative relationship between the density of invasive grasses and native species diversity (D'Antonio and Vitousek 1992; Franklin et al. 2006; Abella et al. 2012; Davies and Nafus 2013). These vegetation composition impacts can shape other aspects of biodiversity in deserts- including animal communities. Mojave Desert tortoises (*Gopherus agassizii*), lesser long-nosed bat (*Leptonycteris yerbabuenae*), cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*), and several other desert bird species have been shown to be threatened by grass invasions and subsequent habitat alterations from fire (Frost 2010; Young and Schlesinger 2014; Drake 2016; U.S. Fish and Wildlife Service 2016). Freeman et al. (2014) sampled small mammal diversity at a gradient of cheatgrass invaded sites in the Great Basin and found that as cheatgrass abundance increases, the diversity and quantity of small mammal species decreases.

The long-term impacts of grass invasion and fire regime alterations on food webs and overall ecosystem biodiversity seem to be missing from the literature. This broader perspective can help identify geographies or species of most concern, and where resources should be targeted.

Climate Change

The effects of climate change have been and will be far-reaching as the climate continues to warm. Like many other ecological processes, increased temperatures and changes in precipitation patterns will exacerbate the already detrimental impacts of invasive species in deserts. The susceptibility of native vegetation to a warmed climate and drought showcased in Ravi et al. (2021) is further supported by McAuliffe and Hamerlynck (2010) and Hantson et al. (2020) where the authors highlight the already observed changes and risks to native desert vegetation as the climate will continue to warm. Modelling efforts by Diffenbaugh et al. (2008) highlight that the Southwestern U.S. is a climate change hotspot, meaning this area will be

particularly sensitive to warming from climate change. This is similarly represented by Liu et al. (2010) who suggests that based on predicted temperature and precipitation changes, the Southwest will experience a year-long fire season, compared to the current ~6-month season, leading to more opportunity for altered fire regimes. A suite of modeling efforts have predicted that precipitation in arid regions will decrease, contributing to drier, more water stressed conditions (Seager 2007; Liu et al. 2010). The expected increase in carbon dioxide in the atmosphere will only benefit invasive species like cheatgrass and provide more opportunity for the species to outcompete native vegetation (Smith et al. 1987; Dukes and Mooney 1999; Harvey et al. 2020). Increases in carbon dioxide and decreases in precipitation will likely favor the growth of invasive grasses and perpetuate the existing grass-fire cycle in U.S. deserts.

Climate change will undoubtedly play a role in how invasive grasses continue to impact deserts. At this point, few studies explicitly take climate change into consideration in their research questions and set up, which is understandable considering that in order to manipulate climate in a study, a controlled environment is required. Modeling efforts have shown that the Southwest will be highly impacted by climate change which will bring with it changes to fire seasons and regimes, but more specific information on when these changes are expected is needed.

Research Recommendation

Many fundamental questions regarding the impacts of invasive species on Western U.S. deserts have been investigated, but questions remain on how to manage these deserts in the face of the inevitable spread of invasive grasses. Many prominent studies that acknowledge how invasive grasses impact fire regimes highlight the need to understand what management actions are most effective at controlling these invasive grasses to help prevent, minimize, and mitigate changes to fire regimes. Understanding the long-term effects of different control methods and how their effectiveness may vary across different desert landscapes will help policy-makers and land managers identify areas most at risk and where the strategic targeting of limited resources (e.g. staffing and funding) can be focused. The reality is that funds for natural resource management are already stretched thin, so any guidance on where resources would be most effective at addressing the problem and preventing permanent conversion of deserts to grasslands would be beneficial. Many biodiversity impacts from invasive grasses are primarily present due

to alterations in fire regimes, so addressing the options for management of invasive grasses is an important step to protecting the biodiversity at risk. This proposed study aims to address the long-term impacts of two invasive grass management options and how to most effectively reduce the cover of buffelgrass across a suite of sites in 3 different U.S. deserts. Studies such as Li et al. (2023) have started to explore how to control invasive grasses via mechanical and chemical removal, but many studies have focused on the Sonoran Desert and buffelgrass specifically. This study will aim to expand upon that body of work to the Mojave and Great Basin deserts to explore if there are differences in responses in buffelgrass cover to treatments.

The proposed study will focus on 6 areas across 3 western U.S. deserts as shown in Table 1 to represent desert sites with varying elevation and climate gradients that are all currently being impacted by buffelgrass. Aerial imagery and boundaries of the preserve, park, refuge, or monument (study areas) will be split into a 5m grid and analyzed in ArcGIS to delineate where buffelgrass invasion is present (similar to Fusco et al. 2019). Within each study area, two sites will be established that will be randomly selected from the aerial imagery analysis that each will contain three $5m^2$ plots. Since the goal of the study is to gain a basic understanding of how two common mitigation actions (physical removal and herbicide application) vary in success across different desert ecosystems, plot sizes will be kept at $5m^2$ (Figure 4) to allow for two person teams to efficiently complete application and subsequent monitoring. The three plots will contain three different treatment types- a control with no treatment, physical removal of buffelgrass, and application of herbicide.

Researchers will visit each site once per year to apply the treatment to each plot during April. To evaluate the long-term impacts of the two treatments, a baseline percent cover of buffelgrass and native vegetation within each plot will be recorded pre-treatment and 6-months post-treatment annually. Application of treatments will occur from 2025-2035 to obtain long-term observations of how percent cover will change over time.

Sonoran Desert	Mojave Desert	Great Basin
McDowell Sonoran Preserve	Mojave National Preserve	Great Basin National Park
Saguaro National Park	Desert National Wildlife Refuge	Basin and Range National Monument

Table 1. The study will take place across 6 different sites located within the Sonoran, Mojave, and Great Basin deserts.

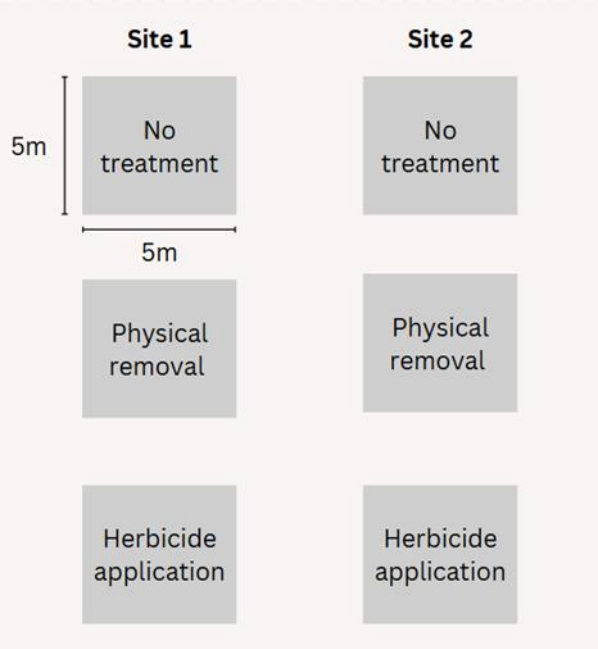


Figure 4. Each site will contain three plots with no treatment, physical removal of buffelgrass, and herbicide application.

The expected resources required for the project will mainly consist of staff time and fuel/travel. Since field work will only be occurring a few days per year, regional field teams of two will be established to reapply treatments annually and monitor vegetation responses. The supplies needed for setting up plots and applying treatment include rebar, backpack sprayers, hand tools, and glyphosate herbicide. The estimated cost for field supplies and staffing for data collection and data processing for the 10-year duration of the study is $35,000, but could vary greatly depending on travel distances for field teams.

Results from the study will provide insight into what treatment method is most effective at reducing and sustaining reductions in cover of buffelgrass across 3 deserts ecosystems. Studying the difference in impact among the two sites in each desert will help determine if even within a region there are local differences that make the vegetation respond differently.

Invasive grasses are reshaping U.S. deserts at rates that research has not been keeping pace with. Researchers and managers must work together to start evaluating the most effective methods of management to preserve the desert habitats that have not been affected and restore areas that have been severely degraded.

References

Abella, Scott R, Lindsay P Chiquoine, and Dana M Backer. “Ecological Characteristics of Sites Invaded by Buffelgrass (Pennisetum Ciliare).” Invasive Plant Science and Management 5, no. 4 (2012): 443–53. https://doi.org/10.1614/IPSM-D-12-00012.1.

Afzal, Muhammad Rahil, Misbah Naz, Waqas Ashraf, and Daolin Du. “The Legacy of Plant Invasion: Impacts on Soil Nitrification and Management Implications.” *Plants* 12, no. 16 (2023): 1-14. https://doi.org/10.3390/plants12162980.

Allen, Edith B., Robert J. Steers, and Sara Jo Dickens. “Impacts of Fire and Invasive Species on Desert Soil Ecology.” *Rangeland Ecology & Management* 64, no. 5 (2011): 450–462. https://doi.org/10.2111/REM-D-09-00159.1.

Blaustein, Richard J. 2001. “Kudzu’s invasion into Southern United States life and culture.” In: *The Great Reshuffling: Human Dimensions of Invasive Species*, ed. McNeeley, J. A., 55-62. IUCN, Gland, Switzerland and Cambridge, UK.

Brooks, M.L, and J.R Matchett. “Spatial and Temporal Patterns of Wildfires in the Mojave Desert, 1980–2004.” Journal of Arid Environments 67 (2006): 148–164. https://doi.org/10.1016/j.jaridenv.2006.09.027.

Brooks, Matthew L., Carla M. D’Antonio, David M. Richardson, et al. “Effects of Invasive Alien Plants on Fire Regimes.” *Bioscience* 54, no. 7 (2004): 677–688. https://doi.org/10.1641/0006-3568(2004)054[0677:EOIAPO]2.0.CO;2.

“City and Town Population Totals: 2020-2023,” U.S. Census Bureau, Accessed November 29, 2024. https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-cities-and-towns.html.

D’Antonio, Carla M, and Peter M Vitousek. “Biological Invasions by Exotic Grasses, the Grass/Fire Cycle, and Global Change.” *Annual Review of Ecology and Systematics* 23, no. 1 (1992): 63–87. https://doi.org/10.1146/annurev.es.23.110192.000431.

Davies, Kirk W., and Aleta M. Nafus. “Exotic Annual Grass Invasion Alters Fuel Amounts, Continuity and Moisture Content.” *International Journal of Wildland Fire* 22, no. 3 (2013): 353–358. https://doi.org/10.1071/WF11161.

"Deserts," USGS Land Management Research Program, United States Geological Survey, Accessed October 13, 2024, https://www.usgs.gov/programs/land-management-research-program/deserts.

Diffenbaugh, Noah S., Filippo Giorgi, and Jeremy S. Pal. "Climate Change Hotspots in the United States." *Geophysical Research Letters* 35, no. 16 (2008): 1-5. https://doi.org/10.1029/2008GL035075.

Drake, K. Kristina, Lizabeth Bowen, Kenneth E. Nussear, et al. "Negative Impacts of Invasive Plants on Conservation of Sensitive Desert Wildlife." *Ecosphere* 7, no. 10 (2016). 1-20. https://doi.org/10.1002/ecs2.1531.

Dukes, Jeffrey S, and Harold A Mooney. "Does Global Change Increase the Success of Biological Invaders?" *Trends in Ecology & Evolution* 14, no. 4 (1999): 135–139. https://doi.org/10.1016/S0169-5347(98)01554-7.

Franklin, Kim A., Kelly Lyons, Pamela L. Nagler, et al. "Buffelgrass (Pennisetum Ciliare) Land Conversion and Productivity in the Plains of Sonora, Mexico." *Biological Conservation* 127, no. 1 (2006): 62–71. https://doi.org/10.1016/j.biocon.2005.07.018.

Freeman, Eric D, Tiffanny R Sharp, Randy T Larsen, Robert N Knight, Steven J Slater, and Brock R McMillan. "Negative Effects of an Exotic Grass Invasion on Small-Mammal Communities." *PloS One* 9, no. 9 (2014): 1-8. https://doi.org/10.1371/journal.pone.0108843.

Frost, Herbert C., "War on Buffelgrass," U.S. Department of the Interior, April 10, 2010, https://www.doi.gov/ocl/hearings/111/WarOnBuffelgrass_041010#:~:text=Buffelgrass%20is%20an%20existing%20and,to%20restore%20sustainable%20native%20habitats.

Fulé, Peter Z, W.Wallace Covington, and Margaret M Moore. "Determining Reference Conditions for Ecosystem Management of Southwestern Ponderosa Pine Forests," *Ecological Applications* 7, no. 3 (1997): 895-908. https://doi.org/10.2307/2269441.

Fusco, Emily J., John T. Finn, Jennifer K. Balch, R. Chelsea Nagy, and Bethany A. Bradley. "Invasive Grasses Increase Fire Occurrence and Frequency across US

Ecoregions." *Proceedings of the National Academy of Sciences* 116, no. 47 (2019): 23594–23599. https://doi.org/10.1073/pnas.1908253116.

Germino, Matthew, Jayne Belnap, John M. Stark, Edith B. Allen, and Benjamin M. Rau. "Ecosystem Impacts of Exotic Annual Invaders in the Genus Bromus," in *Springer Series on Environmental Management* (Switzerland: Springer International Publishing, 2016) 61-95.

Giorgi, Filippo, Francesca Raffaele, and Erika Coppola. "The Response of Precipitation Characteristics to Global Warming from Climate Projections." *Earth System Dynamics* 10, no. 1 (2019): 73–89. https://doi.org/10.5194/esd-10-73-2019.

Gornish, Elise S., Kim Franklin, Julia Rowe, and Albert Barberán. "Buffelgrass Invasion and Glyphosate Effects on Desert Soil Microbiome Communities." *Biological Invasions* 22, no. 8 (2020): 2587–2597. https://doi.org/10.1007/s10530-020-02268-8.

Gray, Miranda E., Brett G. Dickson, and Luke J. Zachmann. "Modelling and Mapping Dynamic Variability in Large Fire Probability in the Lower Sonoran Desert of South-Western Arizona." *International Journal of Wildland Fire* 23, no. 8 (2014): 1108–1118. https://doi.org/10.1071/WF13115.

Hall, John A., Stephanie Weinstein, and Cheryl L. McIntyre. 2005. The Impacts of Livestock Grazing in the Sonoran Desert: A Literature Review and Synthesis. The Nature Conservancy in Arizona, Tucson.

Hantson, Stijn, Travis E Huxman, Sarah Kimball, James T Randerson, and Michael L Goulden. "Warming as a Driver of Vegetation Loss in the Sonoran Desert of California." *Journal of Geophysical Research. Biogeosciences* 126, no. 6 (2021): 1-15. https://doi.org/10.1029/2020JG005942.

Harvey, Audrey J., Lisa J. Rew, Tim S. Prather, and Jane M. Mangold. "Effects of Elevated Temperature and CO2 Concentration on Seedling Growth of Ventenata Dubia (Leers) Coss. and Bromus Tectorum L." *Agronomy* 10, no. 11 (2020): 1-9. https://doi.org/10.3390/agronomy10111718.

Harris, Nathaniel, "Introduction," in *Atlas of the World's Deserts* (New York: Fitzroy Dearborn, 2003) 1-4.

He, Guandi, Chengqi Zhang, and Zhichao Dong. "Survival in Desert: Extreme Water Adaptations and Bioinspired Structural Designs." *iScience* 26, no. 1 (2023): 1–22. https://doi.org/10.1016/j.isci.2022.105819.

Intergovernmental Panel on Climate Change (IPCC). 2023. *Climate Change 2023 Synthesis Report: Summary for Policymakers* by Hoesung Lee, Katherine Calvin, Dipak Dasgupta et al. Geneva, Switzerland. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2024. *The Thematic Assessment Report on Invasive Alien Species and their Control: Summary for Policymakers* by Helen E. Roy, Anibal Pauchard, Peter Stoett et al. Bonn, Germany. https://zenodo.org/records/11254974

Kirschner, Gwendolyn K., Ting Ting Xiao, and Ikram Blilou. "Rooting in the Desert: A Developmental Overview on Desert Plants." *Genes* 12, no. 5 (2021): 1-12. https://doi.org/10.3390/genes12050709.

Kramer, Nicholas W., Quinton E. Phelps, Clay L. Pierce, and Michael E. Colvin. "A Food Web Modeling Assessment of Asian Carp Impacts in the Middle and Upper Mississippi River, USA." *Food Webs* 21 (2019): 1-9. https://doi.org/10.1016/j.fooweb.2019.e00120.

Le Roux, Johannes, "Setting the Scene," in *The Evolutionary Ecology of Invasive Species* (London: Academic Press, 2022) 1-9.

Li, Yue M, Seth M Munson, Ya-Ching Lin, and Perry Grissom. "Effectiveness of a Decade of Treatments to Reduce Invasive Buffelgrass (Pennisetum Ciliare)." *Invasive Plant Science and Management* 16, no. 1 (2023): 27–37. https://doi.org/10.1017/inp.2023.2.

Linley, Grant D., Chris J. Jolly, Tim S. Doherty, et al. "What Do You Mean, 'Megafire'?" *Global Ecology and Biogeography* 31, no. 10 (2022): 1906–1922. https://doi.org/10.1111/geb.13499.

Linz, George M., H. Jeffrey Homan, Shannon M. Gaulker, Linda B. Penry, and William J. Bleier. 2007. "European starlings: a review of an invasive species with far-reaching impacts." P 378-386 in *Proceedings of an International Symposium: Managing Vertebrate Invasive Species*, Fort Collins, CO. https://digitalcommons.unl.edu/nwrcinvasive/

Liu, Yongqiang, John Stanturf, and Scott Goodrick. "Trends in Global Wildfire Potential in a Changing Climate." *Forest Ecology and Management* 259, no. 4 (2010): 685–697. https://doi.org/10.1016/j.foreco.2009.09.002.

"Major Land Uses," USDA Economic Research Service, United States Department of Agriculture, September 13, 2024, https://www.ers.usda.gov/topics/farm-economy/land-use-land-value-tenure/major-land-uses/.

Marshall, V.M, M.M Lewis, and B. Ostendorf. "Buffel grass (Cenchrus Ciliaris) as an Invader and Threat to Biodiversity in Arid Environments: A Review." *Journal of Arid Environments* 78 (2012): 1–12. https://doi.org/10.1016/j.jaridenv.2011.11.005.

McAuliffe, J.R., and E.P. Hamerlynck. "Perennial Plant Mortality in the Sonoran and Mojave Deserts in Response to Severe, Multi-Year Drought." *Journal of Arid Environments* 74, no. 8 (2010): 885–896. https://doi.org/10.1016/j.jaridenv.2010.01.001.

McDonald, C.J, and G.R. McPherson. "Fire Behavior Characteristics of Buffelgrass-Fueled Fires and Native Plant Community Composition in Invaded Patches." *Journal of Arid Environments* 75, no. 11 (2011): 1147–1154. https://doi.org/10.1016/j.jaridenv.2011.04.024.

Moloney, Kirk A., Erika L. Mudrak, Andres Fuentes-Ramirez, Hadas Parag, Marjolein Schat, and Claus Holzapfel. "Increased Fire Risk in Mojave and Sonoran Shrublands Due to Exotic Species and Extreme Rainfall Events." *Ecosphere* 10, no. 2 (2019): 1-21. https://doi.org/10.1002/ecs2.2592.

Montana State University Extension. 2012. *Cheatgrass: Identification, Biology and Integrated Management* by Fabian Menalled, Jane Mangold, and Ed Davis. Publication MT200811AG. https://www.montana.edu/extension/carbon/documents/ag%20cheatgrass.pdf

Olsson, Aaryn D., Julio Betancourt, Mitchel P. McClaran, and Stuart E. Marsh. “Sonoran Desert Ecosystem Transformation by a C4 Grass without the Grass/Fire Cycle.” *Diversity & Distributions* 18, no. 1 (2012): 10–21. https://doi.org/10.1111/j.1472-4642.2011.00825.x.

“Pinal County, Arizona; Maricopa County, Arizona; Clark County, Nevada” QuickFacts, United States Census Bureau, Accessed November 29, 2024, https://www.census.gov/quickfacts/fact/table/pinalcountyarizona,maricopacountyarizona,clarkcountynevada/PST045223.

Pimentel, David, Rodolfo Zuniga, and Doug Morrison. “Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States.” *Ecological Economics* 52, no. 3 (2005): 273–288. https://doi.org/10.1016/j.ecolecon.2004.10.002.

Radeloff, Volker C, David P Helmers, H. Anu Kramer, et al. “Rapid Growth of the US Wildland-Urban Interface Raises Wildfire Risk.” *Proceedings of the National Academy of Sciences* 115, no. 13 (2018): 3314–3319. https://doi.org/10.1073/pnas.1718850115.

Ravi, Sujith, Darin J. Law, Joshua S. Caplan, et al. “Biological Invasions and Climate Change Amplify Each Other’s Effects on Dryland Degradation.” *Global Change Biology* 28, no. 1 (2022): 285–295. https://doi.org/10.1111/gcb.15919.

Reid, Chad R., Sherel Goodrich, and James E. Bowns. 2008. “Cheatgrass and Red Brome: History and Biology of Two Invaders.” P 27-32 in *Proceedings- Shrublands Under Fire: Disturbance and Recovery in a Changing World*, Cedar City, UT. https://www.fs.usda.gov/rm/pubs/rmrs_p052.pdf

Rocha, Joana L., José C. Brito, Rasmus Nielsen, and Raquel Godinho. “Convergent Evolution of Increased Urine-concentrating Ability in Desert Mammals.” *Mammal Review* 51, no. 4 (2021): 482–491. https://doi.org/10.1111/mam.12244.

Safriel, Uriel, Adeel Zafar, David Niemeijer, et al. “Dryland systems,” in *Millennium Ecosystem Assessment: Ecosystems and Human Well-being: Current State and Trends, Volume 1* (Washington, D.C., Island Press, 2005), 623–662.

Salo, Lucinda F. “Red Brome (Bromus Rubens Subsp. Madritensis) in North America: Possible Modes for Early Introductions, Subsequent Spread.” *Biological Invasions* 7, no. 2 (2005): 165–180. https://doi.org/10.1007/s10530-004-8979-4.

Sayedi, Sayedeh Sara, Benjamin W. Abbott, Boris Vannière, et al. “Assessing Changes in Global Fire Regimes.” *Fire Ecology* 20, no. 1 (2024): 1-22. https://doi.org/10.1186/s42408-023-00237-9.

Schug, Franz, Avi Bar-Massada, Amanda R. Carlson, et al. “The Global Wildland–Urban Interface.” *Nature* 621, no. 7977 (2023): 94–99. https://doi.org/10.1038/s41586-023-06320-0.

Seager, Richard, Mingfang Ting, Isaac Held, et al. “Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America.” *Science (American Association for the Advancement of Science)* 316, no. 5828 (2007): 1181–1184. https://doi.org/10.1126/science.1139601.

Shine, Richard. “Invasive Species as Drivers of Evolutionary Change: Cane Toads in Tropical Australia.” *Evolutionary Applications* 5, no. 2 (2012): 107–116. https://doi.org/10.1111/j.1752-4571.2011.00201.x

Smith, S. D, B. R. Strain, and T. D. Sharkey. “Effects of CO2 Enrichment on Four Great Basin Grasses.” *Functional Ecology* 1, no. 2 (1987): 139–143. https://doi.org/10.2307/2389717.

Smith, Tanner Corless, Tara B. B. Bishop, Michael C. Duniway, et al. “Biophysical Factors Control Invasive Annual Grass Hot Spots in the Mojave Desert.” *Biological Invasions* 25, no. 12 (2023): 3839–3858. https://doi.org/10.1007/s10530-023-03142-z.

Southwest Fire Science Consortium. 2024. *Fire in the Sonoran Desert: An overview of a changing landscape* by Benjamin T. Wilder, Jacob Shelly, Kara S. Gibson, and Jim Malusa. https://www.swfireconsortium.org/2024/05/22/desert-fire-invasion/

“Species: Bromus Tectorum,” Fire Effects Information System (FEIS), United States Department of Agriculture, Accessed October 20, 2024, https://www.fs.usda.gov/database/feis/plants/graminoid/brotec/all.html.

Stanton, Rebekah L, Baylie C Nusink, Kristina L Cass, et al. “Fire Frequency Effects on Plant Community Characteristics in the Great Basin and Mojave Deserts of North America.” *Fire Ecology* 19, no. 1 (2023): 1-9. https://doi.org/10.1186/s42408-023-00222-2.

Steffen, Will, Jacques Grinevald, Paul Crutzen, and John McNeill. “The Anthropocene: Conceptual and Historical Perspectives.” *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 369, no. 1938 (2011): 842–867. https://www.jstor.org/stable/41061703.

Strayer, David L. “Twenty Years of Zebra Mussels: Lessons from the Mollusk That Made Headlines.” *Frontiers in Ecology and the Environment* 7, no. 3 (2009): 135–141. https://doi.org/10.1890/080020.

United States Department of Agriculture, Forest Service, Southwestern Region. 2014. *Field Guide for Managing Buffelgrass in the Southwest.* Report TP-R3-16-03. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5410107.pdf

U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 2023. *Fire regimes of Sonoran desert scrub communities* by Kristin Zouhar. www.fs.usda.gov/database/feis/fire_regimes/Sonoran_desert_scrub/all.html.

U.S. Fish and Wildlife Service Southwest Region. *Species status assessment for the lesser long-nosed bat*. December 2016. https://www.fws.gov/sites/default/files/documents/news-attached-files/Lesser%20Long-Nosed%20Bat.Final%20SSA.12_16_16.pdf

Vale, Cândida Gomes, and José Carlos Brito. “Desert-Adapted Species Are Vulnerable to Climate Change: Insights from the Warmest Region on Earth.” *Global Ecology and Conservation* 4 (2015): 369–379. https://doi.org/10.1016/j.gecco.2015.07.012.

Wilder, Benjamin T., Catherine S. Jarnevich, Elizabeth Baldwin, et al. “Grassification and Fast-Evolving Fire Connectivity and Risk in the Sonoran Desert, United States.” *Frontiers in Ecology and Evolution* 9 (2021): 1-20. https://doi.org/10.3389/fevo.2021.655561.

"Wildland Fire Summary and Statistics Annual Report 2020." National Interagency Fire Center (NIFC), Accessed October 27, 2024. https://www.nifc.gov/sites/default/files/NICC/2-Predictive%20Services/Intelligence/Annual%20Reports/2020/annual_report_0.pdf.

World Meteorological Organization. 2024. *WMO Global Annual to Decadal Climate Update*. Accessed October 31, 2024. *https://library.wmo.int/idurl/4/68910*

Appendix D
FOR 581 Collaborative Forest Management Plan

Final Collaborative Forest Management Plan

FOR 581

Group 5: Chad Smith, Colette Pansini, Jillian Bennett

Executive Summary

Project Overview

As a group, our objective was to identify stakeholder priorities across the Coconino National Forest (forest; Coconino) and gain an understanding into the inner workings of forest management and collaboration. In order to gain insight into our goals, we interviewed three different stakeholders who take on different roles within the Coconino. From their feedback, we were able to develop a number of potential management plans and objectives which were used to create a weighted decision making matrix to determine our top priorities. Eventually, we honed in on a specific area to meet our goals and objectives within the forest.

Key Findings

From our experiences throughout the project, we have a number of key takeaways. Firstly, management can be cost prohibitive, especially when planning restoration at a large-scale. Second, when defining management goals and objectives, stakeholder collaboration is crucial in understanding the array of people, communities, and entities that are affected by decision-making. Finally, we found that utilizing adaptive management is a crucial step in ecologically-based forest management.

Major Recommendations

Our recommendations for the Coconino National Forest are mainly based on our findings from this project. Generally speaking, continuity of stakeholder collaboration should be a priority. Continuing this approach can help managers achieve all objectives and benefit our suggested recommendations. We suggest working to find creative solutions that minimize disturbance in an area while still reaching the desired effects. Finally, and most importantly, we

recommend that there is an aim for forest resilience through different methods, such as developing forest heterogeneity and different stand age cohorts.

Implementation Highlights

We have two primary objectives to implement. The first objective is implementation of forest thinning and prescribed burning to promote heterogeneity in our treatment area. The second objective is based on treatment of invasive cheatgrass (*Bromus tectorum*) to preserve habitat for native and endemic species. We plan to do 5,322.37 acres of thinning, 5,920 acres of prescription burning, and 290 acres of cheatgrass treatment. These treatments will be done with the goal to reduce the risk of high-severity wildfire while protecting and promoting the health of the native habitat.

Introduction

Project Context and Background

The goal of our management plan was to evaluate the ecosystems in the Coconino National Forest, determine the most pressing management needs, and develop management strategies to address the various environmental, economic, social, and cultural challenges facing the forest.

Forest Type

The Coconino National Forest consists of a rich, diverse, and magnificent ecosystem, with an area that spans over 1.8 million acres and is home to one of the largest and continuous stretches of ponderosa pine (*Pinus ponderosa*) in the world. Ponderosa pine is the dominant forest type on the Coconino National Forest. It is known for its fire resistance and resilience and holds a cultural significance to many Indigenous peoples of North America. The Coconino also has other major forest types that are characterized by species like Douglas fir (*Pseudotsuga*

menziesii), quaking aspen (*Populus tremuloides*), which is known for its golden fall foliage, and leaves that tremble in the breeze, and juniper trees (*Juniperus sp.*) (National Park Field Guide, 2023). Other forest types include montane willow riparian forest, pinyon-juniper woodlands, and the Madrean Encinal Woodland (which is considered a transition zone), all which emphasize the abundance, diversity, and richness of the Coconino National Forest (U.S. Department of Agriculture, n.d., A).

Flora and Fauna

The Coconino National Forest is home to some of the most variable flora and fauna due to the wide spectrum of ecosystems and vegetation types. The forest contains abundant plant and animal diversity and a variety of ecosystems that are characterized by species like piñon pine (*Pinus edulis*), juniper, (*Juniperus sp.),* ponderosa pine, Gambel oak (*Quercus gambelii*), Engelmann spruce (*Picea engelmannii*), bristlecone pine (*Pinus aristata*), and corkbark fir (*Abies lasiocarpa*). The Coconino is home to over 300 native bird species, almost 100 species of mammal, 16 native fish species, and numerous other invertebrate species, making it one of the most diverse national forests in Arizona (U.S. Department of Agriculture, n.d., B).

Current Management Practices

The diverse set of habitats across the Coconino National Forest necessitates a wide range of management practices. The forest determined desired conditions, objectives, and management practices for each Ecological Response Unit (ERU) in the forest's 2018 Land and Resource Plan. Wildfire management objectives prioritize the safety of Wildland Urban Interface (WUI) communities and the public but also encourages the use of prescribed fire and wildfire managed for resource objectives (i.e., “managed wildfire”) to achieve desired conditions across ERUs (U.S. Department of Agriculture, 2018). The forest supports using timber resources for forest

products and encourages that silvicultural treatments benefit the sustainability of the ecosystem and are centered around "natural disturbance regimes" (U.S. Department of Agriculture, 2018). Part of the timber management objectives is allowing tribes to access and collect forest products for traditional and ceremonial purposes (U.S. Department of Agriculture, 2018). In terms of invasive species, the primary management objective is to maintain, monitor, and document invasives across the forest (U.S. Department of Agriculture, 2018). Control efforts are focused in ecologically sensitive areas, high-recreation areas, and areas of new invasions that are still relatively contained (U.S. Department of Agriculture, 2018). Lastly, the forest aims to provide ample recreational opportunities while focusing on visitor safety (U.S. Department of Agriculture, 2018). Management for recreation includes providing both developed and dispersed recreation sites, infrastructure that can support a wide range of activities, and appropriate signage (U.S. Department of Agriculture, 2018). The forest manages for a suite of other uses and objectives including livestock grazing, mineral resources, heritage sites, education, and scenic resources (U.S. Department of Agriculture, 2018).

Management Objectives

Our management objectives center around two main priorities- decreasing fuel loads to reduce the risk of high-severity fire and managing invasive cheatgrass. Through thinning and prescribed fire, we aim to promote heterogeneity of the ponderosa pine forest in the project area, decrease fuel loading, and create an ecosystem that can better support a historic fire regime of frequent low severity fire. By surveying, delineating, and treating invasive cheatgrass, we aim to reduce the density of the existing invasion and protect native biodiversity.

Scope and limitations

We broadly evaluated resource objectives, stakeholder priorities, and management needs across the Coconino. Due to the span of the landscape, our analysis and management plan is purposefully limited in scope and focuses on a small project area within the forest. Due to the narrow scope, management objectives are not broadly applicable across the forest's various ecosystems and further investigation is needed beyond the boundaries of our project area.

Methods Overview

We conducted a thorough stakeholder priorities analysis that gave us insight into what people and entities are impacted by management decisions on the forest and resulted in a few key priorities rising to the top. Focused stakeholder interviews allowed for a more thorough analysis of common stakeholder concerns that helped mold our management decisions. Researching historical reference conditions and existing management plans and management concerns helped us narrow the focus of our objectives. Implementation and monitoring goals and guidelines were created to be able to evaluate treatment effectiveness and apply adaptive management principles throughout the plan's cycle.

Stakeholder Analysis

Stakeholder Identification and Categorization

An effective forest management plan requires a diverse collection of stakeholders, in which each stakeholder brings a unique perspective and understanding, based upon their levels of interest and expertise. The stakeholders are categorized based upon their individualized interest, engagement, contribution and level of influence upon the decision making process. Each stakeholder is identified, valued, categorized, collaborated with, and included to ensure balance of interest, social equity and that interests and concerns are prioritized when making forest management decisions. Below are the main stakeholder groups that were identified:

- Environmental Groups
    - E.g. National Forest Foundation, The Nature Conservancy, Friends of the Verde River, Diablo Trust, Center for Biological Diversity, and the Sierra Club.
    - Environmental groups have a unique role with forests. They are often public groups and organizations who call for change or push for regulation on different fronts. Generally, environmental groups do a great job at getting the public involved and educated on programs, policies, and strategies for their local forests. These groups tend to have less influence on management processes and decisions but bring a lot of valuable information to the public.
- Federal, State and Local Government
    - E.g. Cities (Flagstaff, Sedona), Counties (Coconino, Yavapai, Gila), State agencies (AZ Game & Fish, AZ Dept of Forestry and Fire Management, AZ Dept of Transportation), Federal agencies (U.S. Fish and Wildlife Service, Bureau of Reclamation, U.S. Geological Survey, USDA, USFS, DOI, NRCS).
    - Stakeholders at all different levels come together to collaborate, share ideas, and continue efforts towards a common goal on a continuous basis. Local citizens share a continued interest in local issues, and significantly influence forest management decisions through bond issues being passed to contribute to the management of the forest. At the state and federal levels, federal funding and grants are issued each year, along with consultation, collaboration, and cooperation between agencies at all levels, to create a joint effort towards specific objectives. Federal and state governments are considered primary stakeholders and are vital on major management decisions. One relevant collaboration at the

state and federal levels are NEPA, and the Good Neighbor Authority, which are major components on the Coconino.

- Institutions
    - E.g. NAU Ecological Restoration Institute, 4FRI
    - Institutions are able to provide research, insight, and "feet on the ground" to aid larger agencies. Their largest concerns are often accessibility, current management, and communications. Their level of influence is often variable, but can be major if the institution communicates with the forest very directly. Depending on the institution, forest contributions can be very high, but typically collaboration is used in further development of management strategies.
- General public
    - E.g. Recreationists, hikers, campers, hunters, fishers, Wildland-Urban Interface community residents
    - The public can have many different roles in the National Forest, but typically their role is as recreationists in many different fashions. The public often want to see their parks be well maintained, easily accessible, and safe. They want to be able to use the forest to their advantage and for their hobbies. Public citizens are often less involved in the management of forests, but are definitely considered due to their high visitation frequency.
- Private Companies
    - E.g. Forest Products Industry, Novo Biopower, Loggers, AZ Snowbowl, Pink Jeep Tours

    - There are many private companies that are directly affected by management of the Coconino, primarily in the forest products and tourism/recreation industries. The forest products industry is imperative to help carry out timber and vegetation management to achieve desired conditions. Their primary concerns are being able to obtain a steady supply of projects, wood, and biomass. The nascent forest products industry in Arizona carries influence in the scale and types of restoration projects that forests implement due to the high demand and small workforce for this type of work currently. The tourism industry is primarily interested in any activities or decisions that would discourage visitors to the forest (i.e. wildfire, prescribed fire, road closures, forest closures). Because they can be large economic drivers in cities like Flagstaff and Sedona, their influence in forest management decisions can be strong.
- Tribes
    - E.g. - The Navajo Nation, The Hopi Tribe, The Havasupai Tribe, The Hualapai Tribe, The San Juan Southern Paiute, The White Mountain Apache Tribe, The Tonto Apache Tribe, The San Carlos Apache Tribe, The Yavapai-Prescott Indian Tribe, Fort McDowell Yavapai Nation, The Pueblo of Acoma, The Pueblo of Zuni
    - Many American Indian Tribes have a historical stake and cultural ties to the Coconino National Forest and the forest is home to many sites that are considered sacred to numerous tribes. Tribal contributions in forest management decisions include consultation and collaboration on matters that may affect tribal rights and interest, and contributing Indigenous Traditional Knowledge to restore and

manage Coconino National Forest. The Forest Service and Tribes coordinate land and resource management plans to promote the health of the ecosystem, suggesting that the tribes are influential in many forest management plans (USDA, 2012).

- Utilities
    - E.g. Salt River Project, Arizona Public Service, local water providers
    - Electric and power utilities own and operate assets located throughout the Coconino including water and power delivery and storage infrastructure. Their primary interests are in protecting those assets from wildfire and overall watershed health. Their contributions to forest management tend to be through support for forest restoration projects that reduce the risk of high-severity wildfire, mitigating risk of wildfire starts from transmission lines, and drafting policy/legislation. Utilities can hold significant political influence in natural resource management.

Interview Findings and Analysis

The NAU Ecological Restoration Institute (ERI) interview started off by explaining the significance of the forest to their work, stating, "...it's what we call our home forest…so we work hand in hand with the Coconino to establish new research studies on the Ponderosa pine forest to maintain sets of anywhere from 5 to 30 year old study sites on their forest and to collaboratively work with them to implement experimental designs such as prescribed fire or even thinning and things like that…". By defining the significance and motivation of the Coconino, the ERI was able to dive into key issues with the forest's management. ERI told us that staffing and expense is the most difficult challenge with the forest currently, as they are often understaffed and don't

have the resources to implement management strategies forest-wide. When I asked the ERI how they would like to see a management shift, their primary response was, "...small scale to large scale."

The Arizona Department of Forestry and Fire Management's (DFFM) priorities reflect the agency's tasks as a state agency. Their responsibilities and the projects they engage in are wide-reaching, but John and Travis' work focuses on utilization of the Good Neighbor Authority (GNA) to conduct thinning projects on federal lands, especially on the Mogollon Rim Ranger District where they have over 17,000 acres of projects ongoing. Their priorities align closely with the environmental priorities of the Coconino National Forest including reducing the risk of stand-replacing wildfire by reducing stand densities and inter-tree competition. These priorities are reflected in the prescriptions for their forest thinning projects. Some of the biggest threats identified by the interviewees included climate change, particularly the challenges that come with it like disease, insect outbreaks, and stressed trees that become less resilient.

Salt River Project's (SRP) biggest priority is fulfilling their mission of delivering reliable, affordable, and sustainable water supplies to over two million people in the Phoenix metro area. This translates to their biggest concerns in the forest's management including wildfire risk reduction through fuels reduction, increasing the use of prescribed fire and managed wildfire, and streamlining the preparation work for forest restoration projects (e.g. archaeology surveys, Mexican spotted owl surveys). Their concerns included industry not having the capacity to keep up with the demand for restoration activities, wildfire, climate change, and drought.

Key Stakeholder Priorities and Concerns

From our interviews, we were able to generate a small list of stakeholder priorities. Collaboration is definitely a key takeaway, with all three interviewees commenting on the

Coconino's management being particularly focused on their collaborative efforts. Another highlight from our discussions is that wildfire risk needs to be mitigated in different ways as it affects almost all stakeholders and their goals. Finally, there is a large emphasis on conservation (of species, habitat, fire regime, etc.) in a changing political and physical climate.

Stakeholder Relationship Analysis

Stakeholders are known to have different perspectives on management when it comes to their goals and objectives. The Coconino National Forest contains a large number of stakeholders with a wide variety of objectives. Naturally, their goals will not always align.

See the Synergies and Conflicts section for a more in depth analysis of potential interactions

Resource Objectives Analysis

Analysis of Economic Objectives

The analysis of our economic objectives consisted of evaluating three different sets of criteria to determine the need and importance of prioritizing proposed objectives. One economic objective was maximizing timber use and production by collaboration with stakeholders and identifying additional areas to support commercial permits, personal use paid permits, and free use permits to the general public. Our second objective was engaging with stakeholders to increase the pace and scale of thinning projects through partnerships including the Good Neighbor Authority. Economic objectives were placed in the middle of our priority list, due to their rating and scoring in the categories of feasibility, resources required, and their benefit to forest resilience.

Environmental Objectives Assessment

The assessment of our environmental objectives followed the same three sets of criteria that were used for the analysis of economic objectives. The first environmental objective was

reducing the risk of high-severity wildfire through increased fuels reduction activities to reduce vegetation density and support low-severity fires. The second objective revolved around improving and protecting habitat for threatened and endangered species by prioritizing surveys, research, and restoration. And our last objective was surveying, identifying, and documenting invasive plant and animal species and preventing, slowing or eradicating invasions. The environmental objectives scored highest in our weighted decision matrix due to their importance, contribution, and value to overall forest resilience.

Social and Cultural Considerations

When considering social and cultural objectives, the same evaluation criteria was used to determine its importance and need, regarding forest resiliency. One objective included enhancing recreation opportunities on the forest by improving existing facilities and providing new dispersed and developed recreation opportunities. The second objective was surveying, identifying, and documenting cultural resources and taking appropriate actions to preserve at-risk sites. Our social and cultural objectives ranked lowest in our weighted decision matrix, not because of their lack of importance, but because of their tangential nature to support forest health, function, and resilience.

Trade-Off Analysis

Determining the appropriate forest management plan objectives, collaboration and compromise was needed because of the diverse interests, priorities and benefits that each unique stakeholder possesses. Objectives and priorities will rarely align perfectly to benefit all stakeholders at a designated time, so compromising and transparent communication will help balance and benefit the interests of all stakeholders. Trade-off analysis can be challenging, but

weighing objectives in a decision making framework can help objectively determine priorities in forest management objectives.

Synergies and Conflicts

Conflicts may arise due to the wide ranging objectives included in our matrix, but these conflicts have been constant throughout forestry management, and are not necessarily unique to the Coconino. Timber production and environmentalists have fundamentally opposing perspectives, with one focused on preservation and the other on economic goals. Increased timber usage, thinning, and recreation could all have negative effects on threatened and endangered species populations through habitat loss or fragmentation, impacts to critical nesting areas, decreasing foraging areas, and even soil erosion. Mitigation and monitoring measures will need to be taken to address these potential concerns. Thinning can also lead to a level of canopy openness that could provide opportunities for invasive species to colonize and establish. This could have negative effects on the forest's native and threatened and endangered species by creating competition for limited resources and disrupting the natural balance of the ecosystem. Lastly, efforts to preserve cultural resources and limit use of land that is considered sacred to Indigenous peoples could lead to conflict with other priorities like recreation and fuels reduction that requires access to land.

There are many potential synergies with our decision matrix. More broad synergies include our environmentally focused goals paired with environmentalist groups and our economic objectives with stakeholders who benefit from increased economic opportunity. Increases in recreation facilities and capacity would allow for more opportunity to sell permits for wood collection and camping. Habitat has the potential to be improved by working to reduce high-severity fire through increased thinning efforts. Another important synergy is between

objectives to prioritize cultural preservation coupled with people from that culture. There are multiple research and surveying opportunities combined with environmental objectives that would produce more opportunities for research institutes and stakeholders to get involved. Ultimately, these synergies are potential and interactions may have different outcomes than anticipated.

Management Framework

Decision-Making Processes

We want the opinions and voices from as many stakeholder sectors as possible to be represented. When we are requesting stakeholder opinions to take into consideration in our decision making, we will provide opportunities for comments and concerns to be voiced in person in monthly stakeholder group (SHG) meetings or via our website to ensure there are ample opportunities for interested parties to convey their opinions. We will hold formal votes for proposed management actions that will have significant impacts. Votes can be cast in the in-person stakeholder meetings, or via our feedback tool on the website. Some stakeholder sectors will naturally have more representation in the SHG, and we want to ensure all groups have equal say in decision making (e.g. there are a lot of environmental non-profits who tend to participate in stakeholder processes, but a stakeholder group like private companies may not have as much representation). We will attempt to weigh those votes and opinions equally. Ultimately, final decisions will rest with us as the managers and the forest's staff of scientists and natural resources professionals.

Conflict Resolution Procedures

Identifying Potential Conflicts

As managers, our goal is to prepare a five-year management plan that includes our proposed actions over the time period. This allows us to make informed management decisions and begin to think about conflicts and potential pushbacks early on. When preparing our proposed actions, we will identify stakeholder groups that may be affected by or interested in our actions so that we may be as prepared as possible. For management actions that may be deemed controversial, we will hold individual group work sessions where affected stakeholders may voice their concerns. Providing the ability to communicate first hand with stakeholders will ultimately allow us to incorporate their feedback, find potential alternatives, and evaluate the efficacy of our plans.

Mediating Disagreements

In the instance where we need to mediate disagreements, our primary focus will be on the identification of alternatives and reaching a generally accepted resolution. Identifying the points of contention is a critical first step that will help us evaluate the effectiveness of alternative solutions. These alternatives will be reviewed to determine if they are realistic and still meet management objectives. If alternatives are not deemed to be viable, we will do our best to find a generally agreeable path forward and compromise between stakeholder groups. Our understanding as managers is that listening to stakeholders and their concerns is the largest piece of the puzzle, but in the end, we as managers will have the final say in decision making.

Building Consensus

To build consensus, getting stakeholder input is our most important priority. We need to be as informed as possible about varying opinions so we may find overlap and decide what the strengths and weaknesses are of proposed management opportunities. In order to understand the pros and cons more thoroughly, we intend on using a majority voting system while ensuring that

all stakeholders are represented in the vote. We will provide an even weight to each group's opinion as we see fit. Ultimately, we understand that a full consensus is unlikely, but a majority vote will represent what is the most accepted plan of action among stakeholders.

Documenting Decisions

Before we can make decisions, there will be an agenda posted on our website so that stakeholders have the ability to plan their discussions and the public can see what is to be discussed. A scribe will be present at all meetings and will transcribe the entire meeting process. These notes will be condensed and summarized to be posted to our website with explanation to our decision making process. In the same vein, results from surveys and votes will also be posted as extra documentation of involvement from stakeholders. We will provide advance notice and ample explanation for all meetings and decision making processes.

Ethical Considerations

Indigenous Rights

Indigenous communities, groups, and government agencies are vital stakeholders in the Coconino National Forest. Emphasis will be placed upon collaborating with Indigenous stakeholders to understand their needs, goals, and values and ensure fairness, equality, and respect for the rights of the sovereign people. One of our goals as managers is to create a plan that ensures Indigenous communities have plentiful and equitable access to land that they hold sacred. Additionally, traditional practices will be protected and honored to acknowledge their importance as stakeholders. Lastly, the Indigenous ecological knowledge that these stakeholders provide will be invaluable to us as managers to help us better understand the purposes and value of specific plants and wildlife to help us make better management decisions.

Environmental Justice

A critical part of our management plan involves environmental equality throughout communities, individuals, and all the diverse stakeholders within the Coconino National Forest. As WUI communities grow and expand, fuels reduction efforts will be planned and implemented thoughtfully and equally among at-risk communities. Smoke will be managed properly during prescribed fires to have the least possible impact upon all communities, and herbicide treatment on invasive species will be carefully implemented, being mindful of important community waterways. Post-fire rehabilitation and flooding mitigation management efforts will be distributed equally among affected communities. Recreation opportunities and access points will be improved or created throughout the forest to ensure all communities will have equal access to the Coconino's abundance of natural resources.

Intergenerational Equity

When formulating our management plan, the importance of future generations will be critical in decision-making. We as managers aim to ensure the preservation, resilience, and health of the forest and its natural resources so that future generations can have equal access to the benefits and resources the forest provides. We will consider future generational challenges like climate change and long-term drought in our management plan through long-term planning that will adapt and evolve to changing circumstances. This will help minimize the effects of present and future disturbances on the long-term health and sustainability of forest resources. One example of this effort will be to manage invasive species so future generations will be able to experience the benefits of healthy resilient forests where native species are thriving.

Resource Sustainability

The health and resilience of the Coconino National Forest is of the utmost importance. To ensure that resources will be sustainably used for future generations, we will prioritize thorough

monitoring of forest resources. For example, timber resource utilization, including the approval and distribution of firewood collection permits and commercial permits, will be adjusted according to data collected in order to maintain the health and prosperity of the forest. Reforestation will be encouraged to help restore forest cover, and timber harvesting will be strategized to target areas at high-risk of experiencing catastrophic wildfire. To preserve resources for future generations, we will implement management techniques to maintain varying stages of succession to create different age classes, promote biodiversity, and maintain resilience.

Stakeholder Engagement Strategies

Stakeholder Engagement Processes

The Coconino National Forest is a vast, varied landscape that naturally brings with it a vast and varied group of stakeholders. At the core of our management plan, we want to engage with stakeholders to understand and take into consideration their goals, needs, and concerns. The first basic step we will take to engage stakeholders is to create a SHG to help guide our priorities and objectives. This SHG would consist of 10-20 core members from different stakeholder sectors (e.g. federal, state, and local government agencies, nonprofits, industry, private companies), but could change size to accommodate new interest. We will invite a representative from all identified sectors to be a part of the group in order to prevent any preconceived biases (Walpole et al., 2017). The group will assemble monthly in-person and provide a virtual meeting option to encourage remote attendance from group members or members of the public. Meetings will focus on upcoming management objectives, including how, where, and when management actions will take place, which can tend to be polarizing in collaborative forest management groups (Walpole et al., 2017) . A survey voting system will be used to gauge stakeholders opinions. Although we will not require a consensus vote to move forward with a decision or

management action, we will work with the SHG to consider alternatives, adjustments, and/or mitigation for decisions that may be more controversial. SHG opinions will help shape the specific protocols of management actions (i.e. thinning prescriptions).

Communication Protocols

We will work with the SHG to create a publicly available website to host any relevant materials, references, and information about the group's relation to this management effort. To maximize transparency, managers will work with the SHG to create an agenda ahead of monthly meetings that will be emailed out to SHG members and posted on the group's website. Any relevant materials will be included for review before the meeting. After monthly meetings, meeting minutes and detailed notes will be uploaded within one week. Additionally, the website will contain a "comments and feedback" submission area where members of the public who may not be able to attend monthly meetings can submit their feedback for consideration. A quarterly newsletter will be created that highlights the most significant decisions, upcoming events, and implementation progress.

Management Plan

Resource Allocation Strategies

Objective 1: Reduce the risk of high-severity wildfire through fuels reduction activities

The increasing scale and frequency of high-severity fires across the country necessitates the prioritization of management efforts that help prevent catastrophic fire effects. Objective number one is to implement fuels reduction efforts to minimize high-severity wildfires through thinning and prescribed and managed wildfires to protect the forest, its conservation areas, cultural sites, recreational zones, and adjacent WUI communities. We plan to utilize thinning to reduce the density of ponderosa pine and incorporate prescribed and managed wildfire in order to

reduce fuel loads, decrease ladder fuels, and reduce fuel continuity. These actions will create heterogeneity, a balance of mixed-age stands, and will reduce the risk of high-severity fires. Case studies produced by the U.S. Fish and Wildlife have shown that prescribed fires can mitigate wildfire severity by reducing fuel density, removing ladder fuels, creating safer zones for fire crews, improving forest resilience, and establishing strategic fuel breaks that limit fire spread and allow for more effective fire management to help protect communities (U.S. Fish and Wildlife Services, n.d.). Emphasis will be placed on management of the Coconino's growing WUI communities, as well as for archaeological, historical, and cultural sites located in the Coconino National Forest. Managers will conduct archaeological surveys and obtain clearance from the State Historic Preservation Office and appropriate subject matter experts to ensure the preservation of cultural sites. Buffer zones and fuel mitigation strategies will be utilized around known sites to ensure their integrity. Recreation zones will also be prioritized in fuels reduction efforts to increase public safety, and protect infrastructure from unforeseen wildfires.

Objective 2: Survey, document, and treat Bromus tectorum to prevent or mitigate invasions of non-native species.

Our second objective as managers is to prioritize mitigating the current invasion and preventing further spread of cheatgrass (*Bromus tectorum)*. Previous surveys have demonstrated that over 290 acres of our management area contain cheatgrass (Appendix D). Cheatgrass is known to be a highly competitive species that can increase fire severity and spread (United States Geological Survey, n.d., B). We intend to implement surveys to gain a better representation of current cheatgrass populations and delineate the extent that they have spread. Our goals are to prevent the spread of cheatgrass in a unique Cinder Field habitat to protect native and endemic species, such as Sunset Crater beardtongue (*Penstemon clutei)*. In order to

reach these goals, we will utilize a number of different restoration and mitigation methods including hand-pulling and spreading native seed (U.S. Department of Agriculture, 2014). We only plan to rely on chemical controls in extreme circumstances.

Addressing the spread of cheatgrass will benefit other aspects of our management plan as well. Timber management can benefit by burning fuels and cheatgrass populations within the forest mixture, as it increases fire risk (United States Geological Survey, n.d., B). When assessing cultural sites, we will conduct surveys and try to preserve them by buffering our mitigation efforts away from known sites. Ultimately, management of cheatgrass spread within our treatment area allows for extensive surveying efforts, which has the possibility to bring other aspects of the forest to our attention.

Zoning Plan and Justification

The zoning and vicinity maps in Appendices B and C depict the long-term planning area where we plan to carry out our objectives. Our management actions will take place in Townships 22N and 23N and Range 8E and 9E. The planning area is located adjacent to the community of Doney Park, AZ and approximately 9 miles NE of Flagstaff, AZ. The 5,920 acre planning area consists of three Ecological Response Units (montane/subalpine grassland, pinyon-juniper woodland, and ponderosa pine forest), but is primarily dominated by ponderosa pine forest. We chose to focus our management plan and objectives in this ecosystem because of the biodiversity contained in the greater San Francisco Volcanic Field (U.S. Geological Survey, n.d., A). The project area is approximately two-miles south of Sunset Crater Volcano National Monument.

Access and Infrastructure Considerations

The project area contains approximately six miles of Forest Service roads, one of which bisects the area diagonally. This road network will help create access for thinning equipment and

act as control lines for prescribed fire. Additional temporary roads may need to be constructed to allow access to more remote areas and to create landings. The Cinder Fields environment can be hard terrain to traverse, and ideally we will try to leave the least permanent impact as possible by using existing roads. The project area is adjacent to a WUI community, so we will need to be mindful of the proximity to the public when machinery is brought to the site.

Timeline for Implementation

We plan to implement actions to achieve our objectives within five years of the plan being published. After implementation, we will conduct annual monitoring to determine if additional treatments are warranted. Every five years we will reassess our management actions and use adaptive management to achieve desired results.

Budget Considerations

Costs for restoration and management work vary greatly by habitat type, treatment type, and size of treatment. Pine thinning in the Coconino tends to cost around $800/acre (E. Barton, personal communication, April 17, 2025). Prescribed fire is estimated to cost around $78.13/acre (Cleaves et al., 1999). Data on mechanical treatment of cheatgrass is lacking, but chemical control averages between $15 and $28/acre (Hewlett, 2024). Although these actions can be quite costly across a large project area, the cost of no action could be far more expensive (Appendix F). Investments in these types of restoration work in high fire risk areas have been shown to have an economic return of seven dollars for every dollar invested (Hjerpe et al., 2024).

Monitoring and Adaptive Management

Monitoring Indicators and Methods

Objective 1: Reduce the risk of high-severity wildfire through fuels reduction activities

Indicators we will use to determine the success of our treatments include fuel depth, stand density, and canopy cover. Following a prescribed fire or managed wildfire we will use quantitative and qualitative data such as burn severity, fire intensity, and the extent of the fire to determine if the desired objective of fuels reduction were met. Additionally, we will utilize acres treated with thinning or fire to determine if our efforts are occuring at an appropriate scale.

Objective 2: Survey, document, and treat Bromus tectorum to prevent or mitigate invasions of non-native species.

Our indicators of success include establishing and monitoring permanent plots to assess cheatgrass cover and population. Areas known to have populations of cheatgrass will be monitored annually to document changes in spread and extent, while different removal operations will be done to combat increasing population numbers.

Data Collection Procedures

Objective 1: Reduce the risk of high-severity wildfire through fuels reduction activities

In measuring methods, we will establish permanent fixed monitoring plots to resurvey and assess thinning treatments to analyze if we have reached our conditional goals and objectives for fuels reduction treatments. In the prescribed fires treatment areas we will analyze and determine if the amount treated meets our fuels reduction objectives and specificity.

Objective 2: Survey, document, and treat Bromus tectorum to prevent or mitigate invasions of non-native species.

Methods for measuring will include the establishment of permanent ten by ten meter plots with rebar placed at each corner. Crews will be assembled to survey the plots annually. Plots will be resurveyed by use of the point-intercept method and estimating percent cover.

Certain plots will be determined as controls, where no treatment will be done. Others will have different treatments done to analyze the efficacy of our methods.

Evaluation Criteria

When evaluating the success of treatments, we will focus on the treatment's contribution to forest health and resiliency. This will include impacts to fire-risk reduction and achievement or movement of the ecosystem towards historical reference conditions. Our main focus as managers is to help support the function of the ecosystem and create conditions conducive to supporting native biodiversity.

Adaptive Management Triggers and Responses

Objective 1: Reduce the risk of high-severity wildfire through fuels reduction activities

Through our evaluation, reporting, and continual studies, we will determine if adaptive measurements need to be made. If desired fuels conditions and planned objectives are not being met, we will proceed with further treatments at a different pace and scale. If there is no indication of positive impacts of fuels reduction efforts upon the environment or the decreasing of fire severity within five years, we will adjust our management strategies and adapt to what is needed.

Objective 2: Survey, document, and treat Bromus tectorum to prevent or mitigate invasions of non-native species.

In the case that our studies and methods show no change in cheatgrass cover (or an increase in cover) we will pivot our methodology. Depending on the results we will consider increasing efforts to be more intense or try to utilize different management techniques. We will prioritize the techniques with the least environmental impact to use first, and work farther into less sustainable methods if deemed necessary. If there is no indication of improvement in

cheatgrass spread and population within five years, we will adjust our management strategy according to what we see fit.

Conclusions and Recommendations

Summary of Key Findings

Our key findings were rooted in the importance of stakeholder involvement, collaboration across the forest, and the potential cost prohibitive aspects of management. Generally from our stakeholder interviews, we were able to see that there is a lot of collaboration and involvement built into the management of the Coconino, and how important it is to our stakeholders. Although there are a lot of goals incorporated in the management of the forest, these goals can be cost prohibitive, as we found in our research of implementation of our objectives.

Critical Success Factors

The success of our management objectives hinges on several foundational assumptions. First, appropriate funding and staffing from the Forest Service is critical to being able to carry out the full extent of the planned treatments. Federal budgets can be difficult to predict so we will turn to our funding and implementation partners to help carry out the project if this becomes problematic. Second, we must prove to stakeholders why the proposed treatment types, locations, and goals are necessary in order to gain their approval and support for the work. As a stakeholder-focused management team, we want to ensure that we are moving forward with generally acceptable management actions.

Implementation Challenges

There are numerous funding, workforce, and policy standards that will make implementation of our planning challenging. One major challenge will be obtaining National Environmental Policy Act (NEPA) clearance which requires a thorough environmental

assessment and public involvement process. Archaeological site clearance will take time due to preservation requirements and management responsibilities to ensure the protection of the historical and cultural significance of the sites. Another challenge is the unpredictability of the weather, such as a severe fire season or a prolonged winter season that could limit and disrupt forest management plans and efforts.

Future Recommendations

Our future recommendations are relatively broad, but hold importance for the project area. We found that there is a lot of value in adaptive management and identifying the efficacy of management techniques. We urge the Coconino National Forest management team to see how their management works, and adjust if they don't see their desired effects. We suggest that there are more treatments to be done adjacent to our focus area, and they can be adjusted accordingly. In general, we found that the Coconino was a very collaborative forest that depends on a variety of stakeholders to reach desired results.

References

Cleaves, D.A., Haines, T.K., and J. Martinez. (1999). Prescribed burning costs: trends and influences in the National Forest System. Gen. Tech. Rep. PSW-GTR-173. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 11 p.

Hjerpe, E.E., Colavito, M.M., Waltz, A.E M., and Meador, A.S. (2024). Return on investments in restoration and fuel treatments in frequent-fire forests of the American west: A meta-analysis. *Ecological Economics*, *223*, 108244-. https://doi.org/10.1016/j.ecolecon.2024.108244

Hewlett, J. (2024). Extension education: does cheatgrass mitigation cost too much? An economic analysis. https://www.wylr.net/2024/09/13/extension-education-does-cheatgrass-mitigation-cost-too-much-an-economic-analysis/

National Park Field Guide. (2023). The Beauty and Biodiversity of Coconino National Forest; A Look at its Rich Ecosystem. Retrieved from https://nationalparkfieldguide.com/the-beauty-and-biodiversity-of-coconino-national-forest-a-look-at-its-rich-ecosystem/

U.S. Department of Agriculture. (n.d., A). Chapter 8: Ecological and Biological Diversity of the Coconino National Forest. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_021061.pdf

U.S. Department of Agriculture. (n.d., B) Viewing wildlife. United States Forest Service. Retrieved from https://www.fs.usda.gov/activity/coconino/recreation/natureviewing/?recid=54884&actid=62

United States Department of Agriculture. (2014). Field Guide For Managing Cheatgrass in the Southwest. TP-R3-16-04. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5410110.pdf

U.S. Department of Agriculture. (2018). Land and Resource Management Plan for the Coconino National Forest (MB-R3-04-31). https://www.fs.usda.gov/detail/coconino/landmanagement/planning/?cid=fseprd606734

United States Fish and Wildlife Service. (n.d.) Thinning, Prescribed Fire, and Managing Wildfire for Resource Benefit. https://www.fws.gov/project/thinning-prescribed-fire-and-managing-wildfire-resource-benefit

U.S. Geological Survey. (n.d., A) San Francisco Volcanic Field. https://www.usgs.gov/volcanoes/san-francisco-volcanic-field

United States Geological Survey. (n.d., B). *What is cheatgrass and how is it harmful?*. USGS. https://www.usgs.gov/faqs/what-cheatgrass-and-how-it-harmful

Walpole, E.H., Toman, E., Wilson, R.S., and Stidham, M. (2017). Shared visions, future challenges: a case study of three Collaborative Forest Landscape Restoration Program locations. *Ecology and Society*, *22*(2), 35. https://doi.org/10.5751/ES-09248-220235

Appendices

Appendix A- Stakeholder Interview Summaries

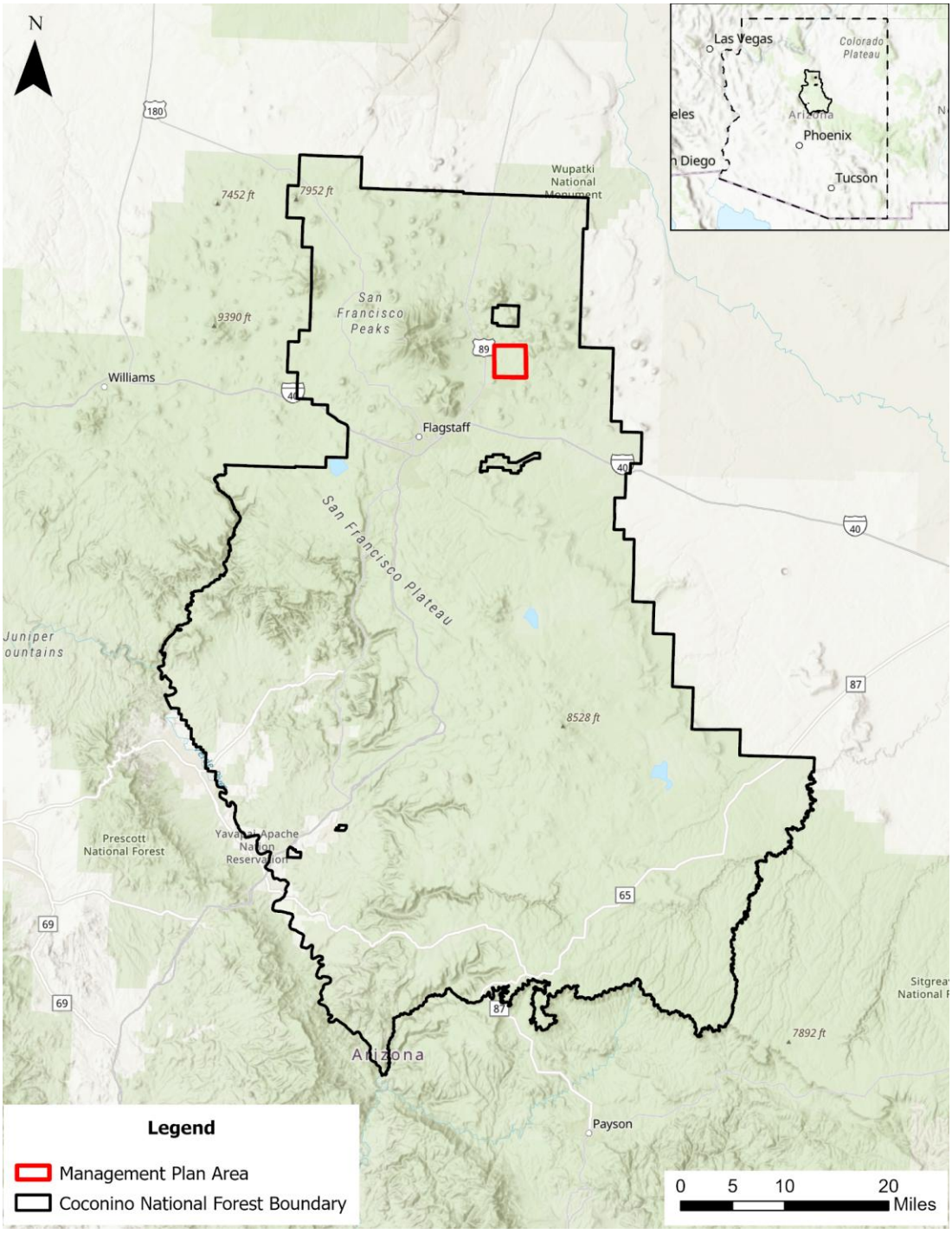
The Ecological Restoration Institute's (ERI) interview (with Amy Waltz) was focused on her insight as a science communicator within the ERI and her collaboration with the Coconino National Forest and other land management agencies. Amy was very forthcoming about the struggles with management as an ERI communicator. Ultimately, her information and communication leads to physical field work done by the institute. Their goal is to advance management techniques and do research on how forests are changing in this modern era with new administration in the government.

We interviewed John Pelak, Northern Arizona District Forester, and Travis Aldrich, Assistant District Forester, from the Arizona Department of Forestry and Fire Management (DFFM) via email. The discussion centered around DFFM's goals as a state agency to reduce wildfire risk, increase public safety, improve forest health, and protect infrastructure. They emphasized the general alignment of goals between DFFM and the Coconino National Forest, which helps them accomplish work through the Good Neighbor Authority (GNA).

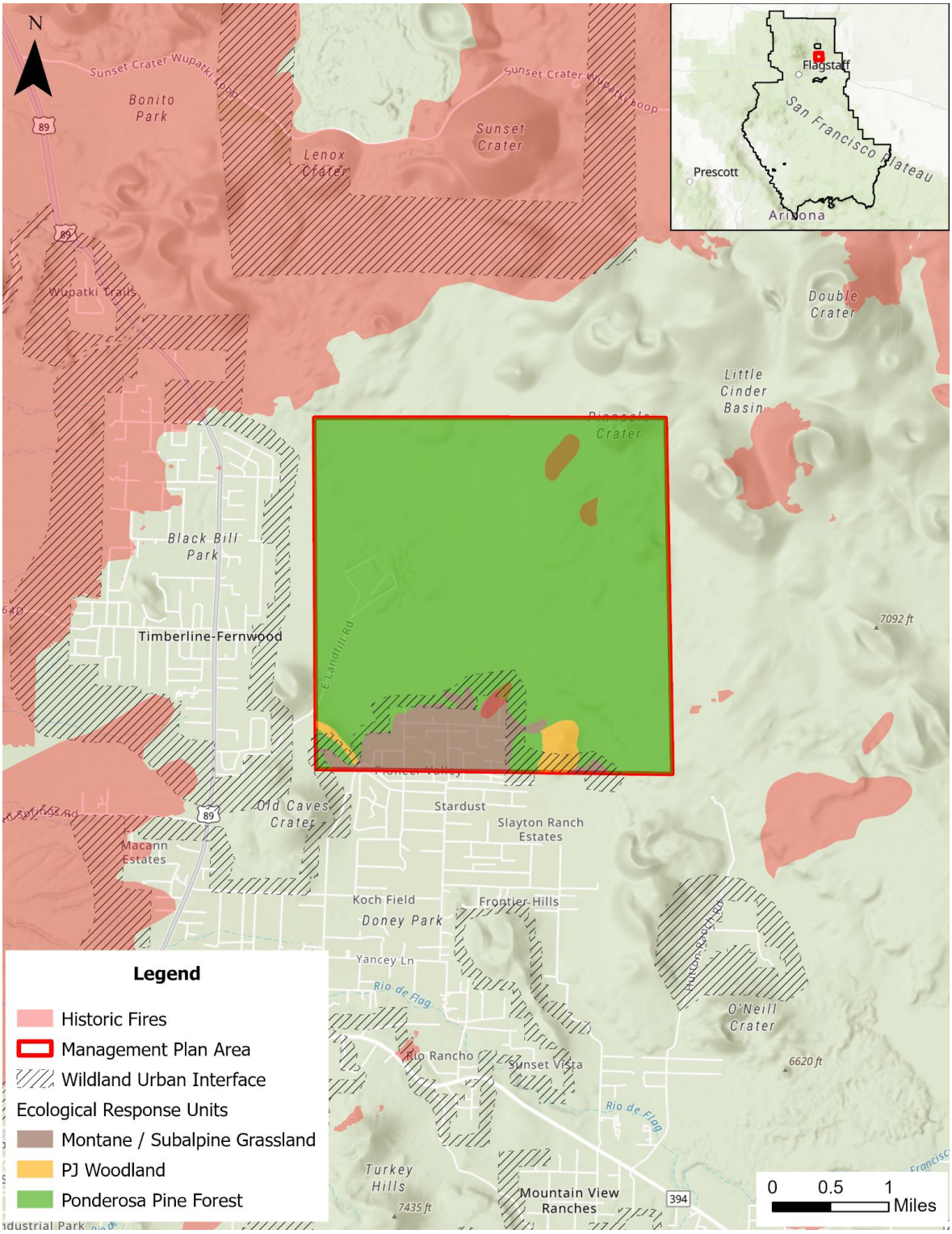
We interviewed Hannah Buchanan, Forest Health Analyst, and Elvy Barton, Senior Manager of Water and Forest Sustainability, at Salt River Project (SRP) via video conference. The discussion centered around SRP's goals and how management of the Coconino National Forest impacts water supplies, water quality, and maintenance of water storage reservoirs. They emphasized how overly dense areas of forests can be at higher risk for experiencing high-severity wildfire and how those areas should be prioritized and targeted for fuels reduction efforts. They discussed why SRP invests in forest restoration projects in the Coconino National Forest due to the infrastructure they depend on that is located on federal lands (e.g. C.C. Cragin

Reservoir, water delivery infrastructure) and the risk that wildfire and post-wildfire poses to those assets. Because a large majority of the Verde watershed contains lands managed by the federal government, decisions made in the Coconino can have significant impacts on the company.

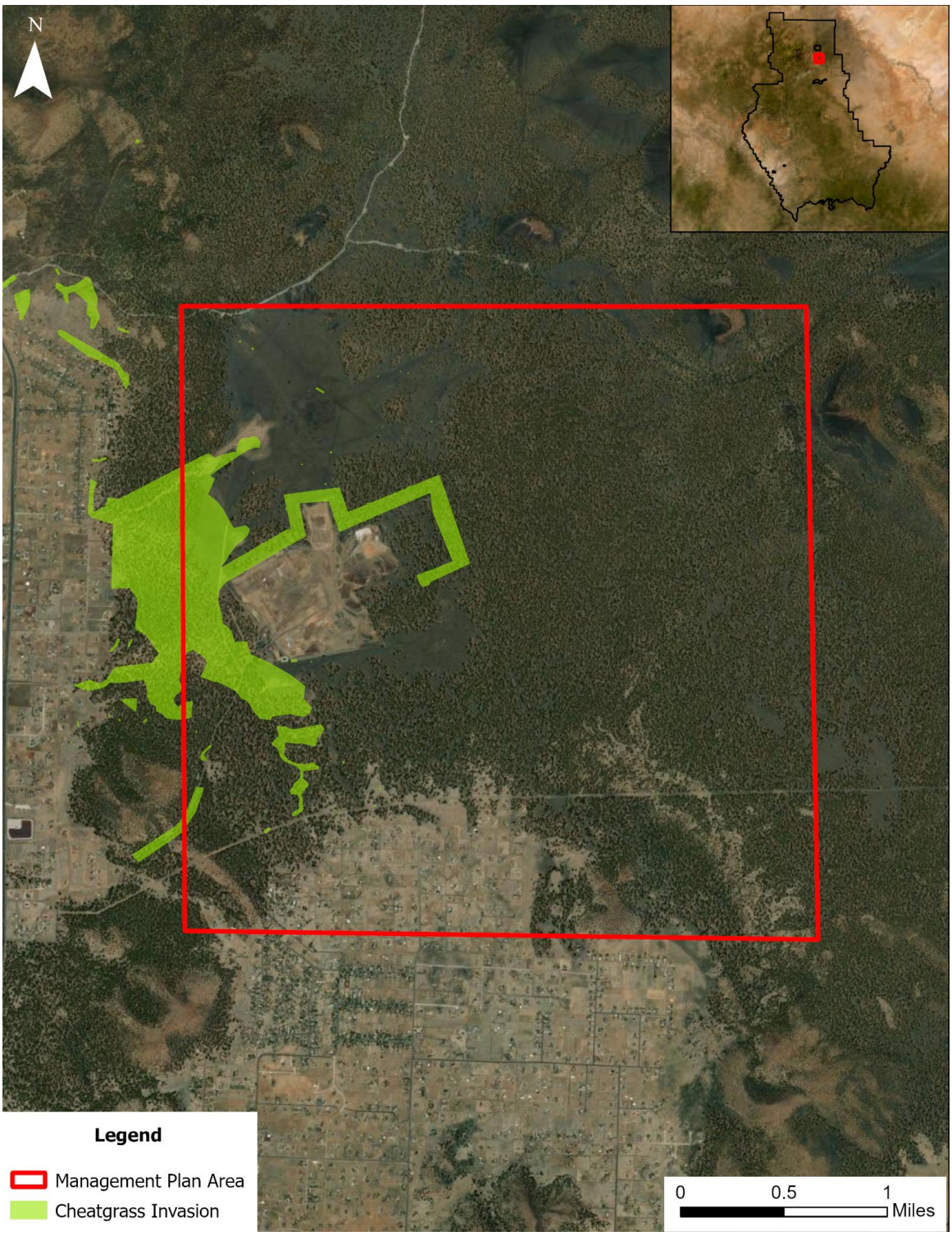
Appendix B- Vicinity Map



Appendix C- Zoning Map



Appendix D- Cheatgrass Invasion Map



Appendix E- Monitoring Protocols

Objective 1: Reduce the risk of high-severity wildfire through fuels reduction activities

For thinning:

1. Establish fixed-radius 1/10th-acre monitoring plots in planned treatment areas
2. Conduct pre-treatment data collection to determine baseline conditions (This will include measurement of tree diameters, tree heights, canopy cover, and stand density)
3. Conduct post-treatment data collection and determine if objectives were met
4. Continue annual data collection to monitor regrowth and success of subsequent treatments

For prescribed fire:

1. Establish fixed 10x10 meter monitoring quadrants
2. Conduct pre-treatment data collection to determine baseline conditions (This will include measurement of fuel bed depth, fine woody debris, coarse woody debris, and vegetation cover)
3. Conduct post-treatment data collection and determine if objectives were met
4. Continue annual data collection to monitor regrowth and success of subsequent treatments

Objective 2: Survey, document, and treat Bromus tectorum to prevent or mitigate invasions of non-native species.

1. Establish fixed 10x10 meter monitoring quadrants with rebar at each corner
2. Conduct pre-treatment data collection to verify the existing field data collected by the Forest Service and make and corrections to the delineation of the species' extent

3. Conduct post-treatment data collection and determine if objectives were met
4. Continue annual data collection in entire management plan area to monitor new invasion areas to inform adaptive management

Appendix F- Treatment Budget Details

Treatment	Estimated Cost/Acre	Estimated Total Cost
Thinning	$800 x 5,322.37 acres of ponderosa pine	$4,257,896
Prescribed Fire	$78.13 x 5,920 acres	$462,529.60
Cheatgrass Treatment	$15-$28 on average x 290 acres of cheatgrass	$4,350-$8,120
	TOTAL	**$4,724,775.60 - $4,728,545.60**

Collaborative Forest Management Plan:

Coconino National Forest

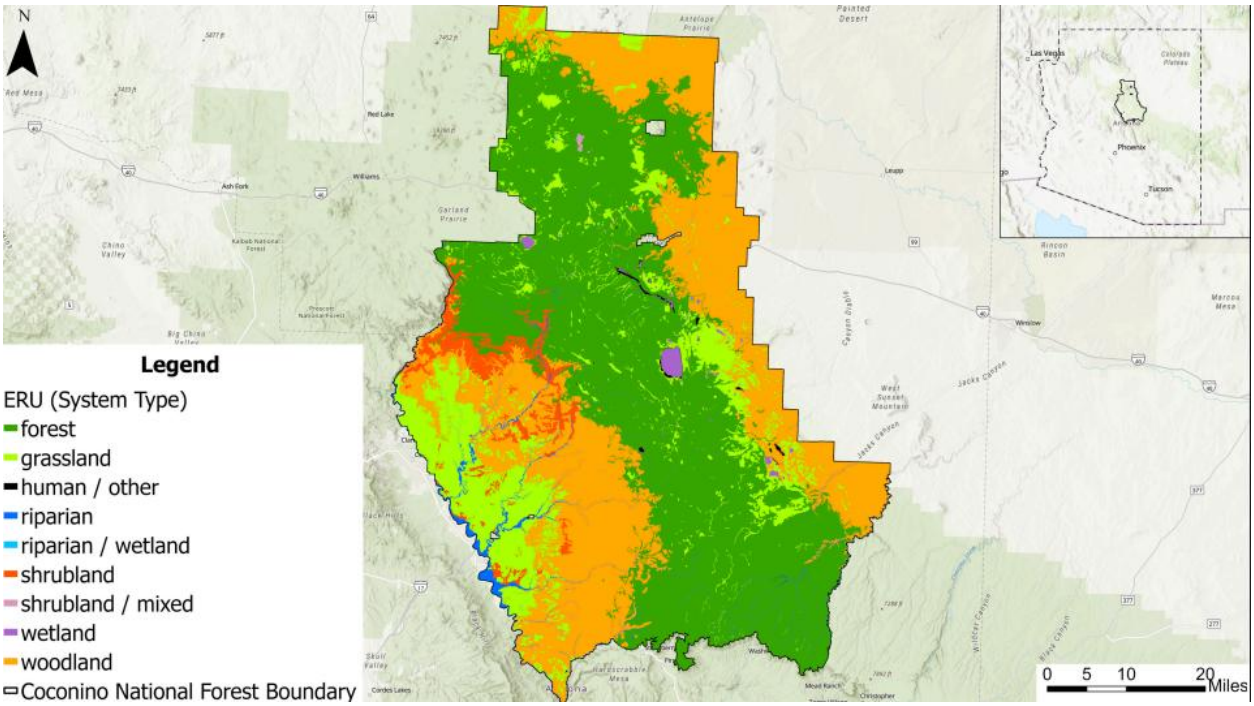
Team 5

Colette Pansini, Jillian Bennett, Chad Smith

Introduction

Coconino National Forest

- Vast size
- Unique complexity of ecosystems
- Diverse group of stakeholders
- Plentiful management opportunities and needs

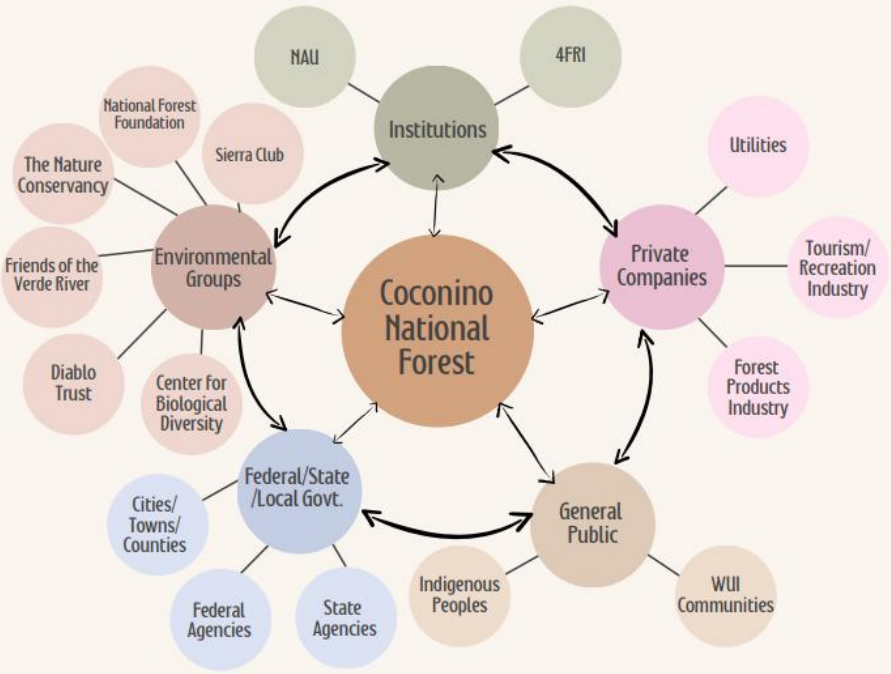


Stakeholder Analysis

Identified 5 main stakeholder groups

Key concerns shared among most stakeholder groups:

- Increased frequency and scale of high-severity wildfire
- Forest resilience to climate change
- Overall forest health and function
- Support of local economies and industries



Interview Takaways

Amy Waliz
ERI

- Supportive of collaborative efforts of the Coconino
- For the benefit of ERI (and all other stakeholders) the forest managers should consider inclusion of all different people

John Pelak & Travis Aldrich
AZ DFFM

- Collaborative on fuels reduction projects is critical
- Reduction of stand-replacing wildfire & increasing forest resilience to climate change is top priority

Hannah Buchanan & Elvy Barion
SRP

- Management decisions impact downstream water users and critical infrastructure
- Strong support for fuels reduction activities and watershed level management

Resource Objectives Matrix

			Economic Objectives			
			Maximize timber use and production by collaboration with stakeholders and identifying additional areas to support commercial permits, personal use paid permits, and free use permits to the general public		Engage with stakeholders to increase the pace and scale of thinning projects through partnerships including the Good Neighbor Authority	
		Weight	Rating	Score	Rating	Score
Evaluation Criteria	Feasibility	30.00%	4	1.2	4	1.2
	Benefit to Forest Resiliency	50.00%	3	1.5	4	2
	Low Effort/Resources Required	20.00%	3	0.6	3	0.6
Weighted Total				**3.3**		**3.8**

Scale: 1=low, 5=high

Resource Objectives Matrix

			Social/Cultural Objectives			
			Enhance recreation opportunities on the forest by improving existing facilities and providing new dispersed and developed recreation opportunities		Survey, identify and document cultural resources and take appropriate actions to preserve at-risk sites	
		Weight	Rating	Score	Rating	Score
Evaluation Criteria	Feasibility	30.00%	3	0.9	4	1.2
	Benefit to Forest Resiliency	50.00%	1	0.5	2	1
	Low Effort/Resources Required	20.00%	1	0.2	3	0.6
Weighted Total				**1.6**		**2.8**

Scale: 1=low, 5=high

Resource Objectives Matrix

			Environmental Objectives					
			Reduce the risk of high-severity wildfire through increased fuels reduciton activites (thinning + prescribed fire) to reduce vegetation density and support low-severity fire		Improve and protect habitat for threatened & endangered species by prioritizing surveys, research, and restoration.		Survey, identify, and document invasive plant and animal species and prevent, slow, or eradicate invasions where possible to minimize impacts to native species	
		Weight	Rating	Score	Rating	Score	Rating	Score
Evaluation Criteria	Feasibility	30.00%	5	1.5	4	1.2	4	1.2
	Benefit to Forest Resiliency	50.00%	5	2.5	5	2.5	5	2.5
	Low Effort/Resources Required	20.00%	2	0.4	3	0.6	3	0.6
	Weighted Total			**4.4**		**4.3**		**4.3**

Scale: 1=low, 5=high

Matrix Results

Synergies:

- Thinning / economy / forest products industry
- Thinning & prescribed fire / wildlife
- Recreation / economy
- Cultural resources / Indigenous communities
- Invasives management / forest health

Trade-Offs:

- Timber production / T&E habitat / environmental groups
- Thinning / Invasive species
- Cultural resources / recreation / thinning
- Prescribed fire / WUI communities

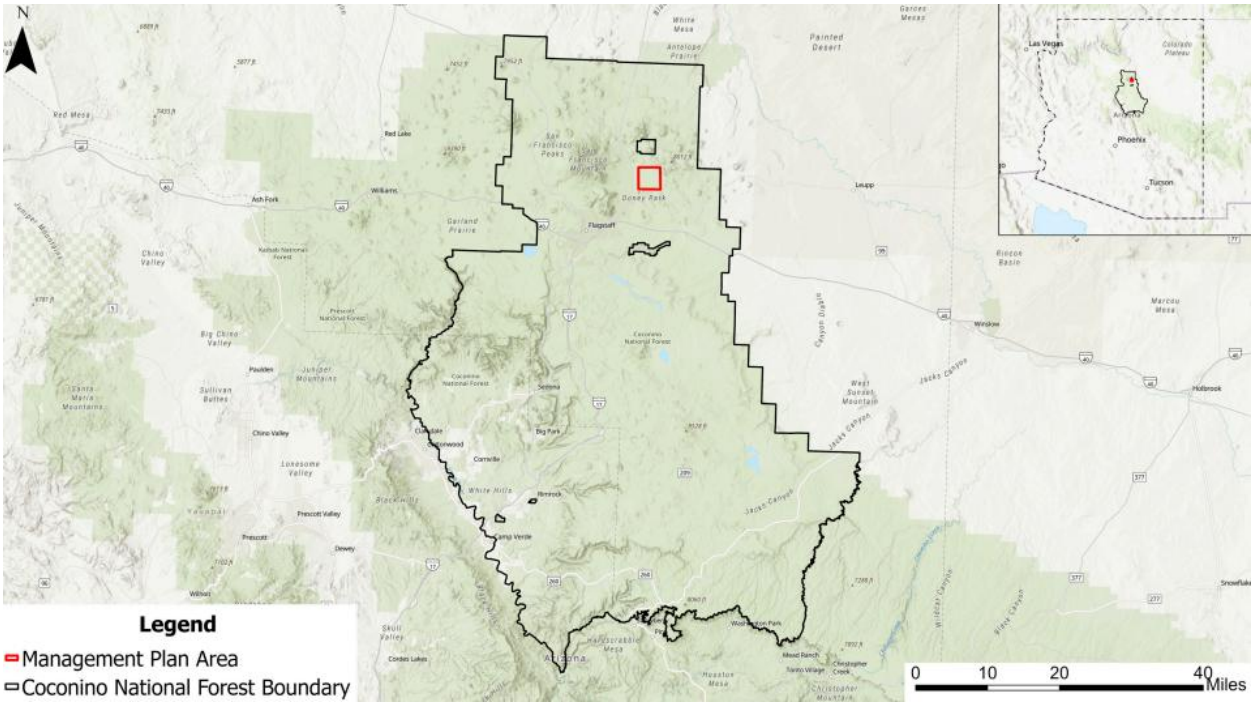
Resource Objectives

Objective 1:

Reduce the risk of high-severity wildfire through fuels reduction activities

Objective 2:

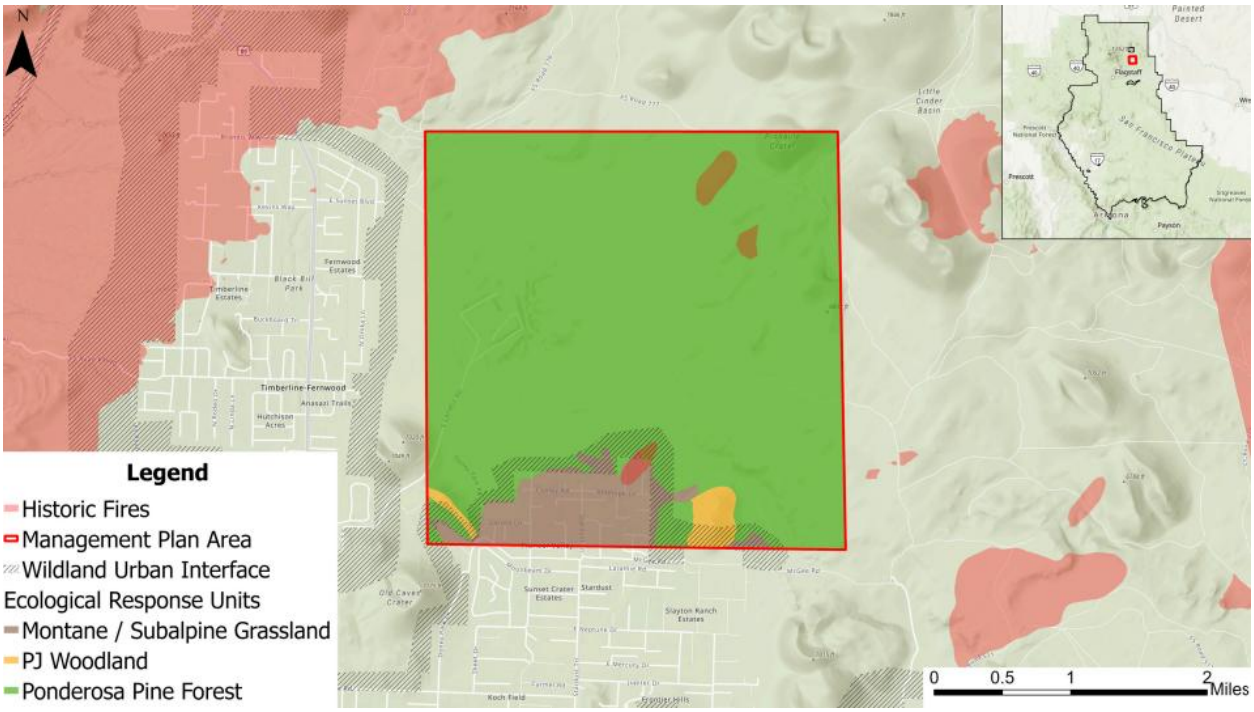
Survey, document, and treat *Bromus tectorum* to prevent or mitigate invasions of non-native species

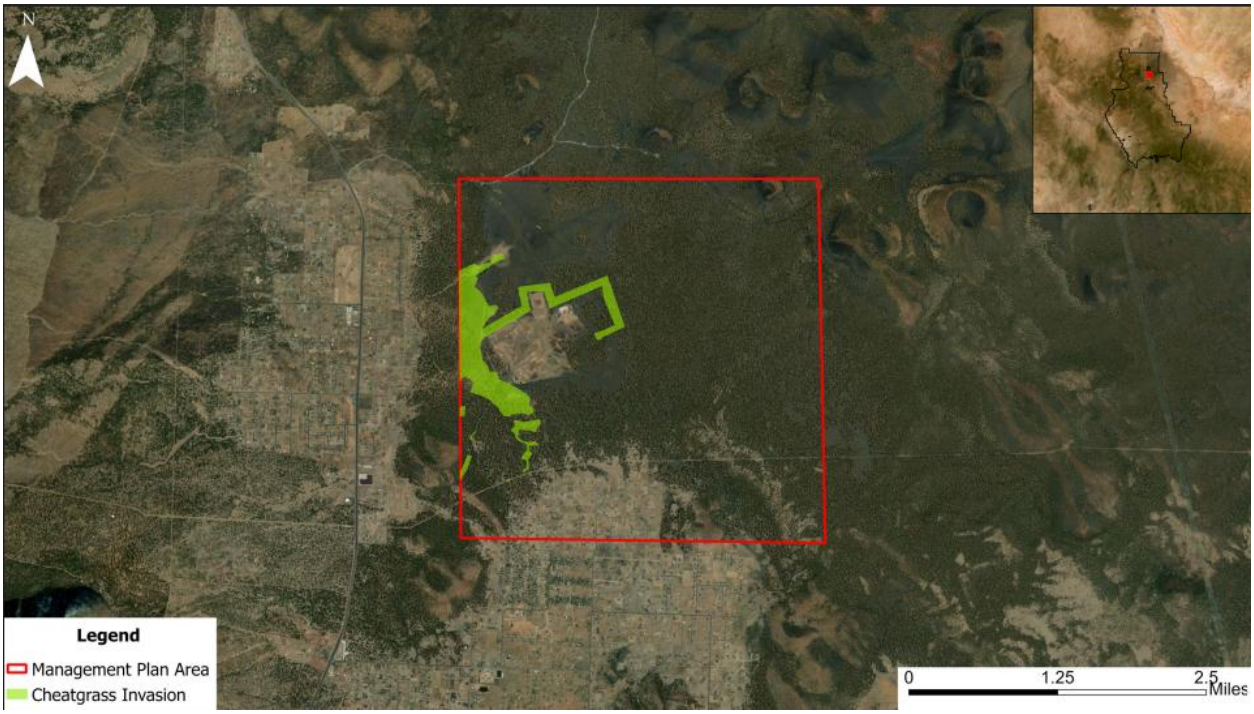


Zoning Plan

Management plan area is 6,000 acres

- 5,300 acres of ponderosa pine forest
- 290 acres of known cheatgrass invasion
- Majority of project area could benefit from prescribed fire





Management Strategies

- Monitoring of project area to decide best course of action
  - Pre- and Post- treatment
- Utilization of adaptive management strategies
  - Analyze efficacy of treatment
- Inclusion of stakeholders in all processes of the treatment
  - Input before and after treatment
  - Posting of management design to webpages

Implementation

- In ponderosa pine habitat:
  - Conduct thinning to reduce the density of trees, reduce fuel loading, and open the canopy
  - Conduct subsequent prescribed fire and support managed wildfire to reduce surface fuel loading

Goal: heterogeneity, habitat diversity, different age classes

- In cheatgrass invaded habitat:
  - Conduct mechanical treatment to physically remove the grass
  - Chemical treatment will be limited to extreme circumstances
  - Conduct prescribed fire to help mitigate spread

Goal: protect native species, mitigate spread

Monitoring Framework

Objective 1: Reduce the risk of high-severity wildfire through fuels reduction activities

Thinning:

1. Establish fixed-radius 1/10th-acre monitoring plots
2. Conduct pre-treatment data collection to determine baseline conditions
3. Conduct post-treatment data collection and determine if objectives were met
4. Continue annual data collection to monitor regrowth and success of subsequent treatments

Prescribed fire:

1. Establish fixed 10x10 meter monitoring quadrants
2. Conduct pre-treatment data collection to determine baseline conditions
3. Conduct post-treatment data collection and determine if objectives were met
4. Continue annual data collection to monitor regrowth and success of subsequent treatments

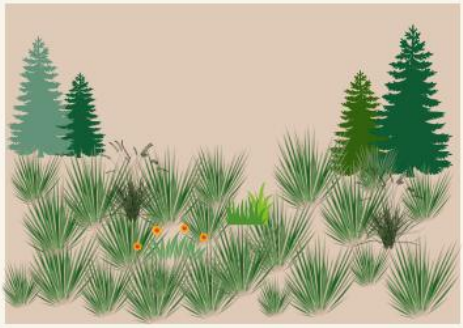
Objective 2: Survey, document, and treat Bromus tectorum to prevent or mitigate invasions of non-native species

1. Establish fixed 10x10 meter monitoring quadrants
2. Conduct pre-treatment data collection to verify and corrections to the delineation of the species' extent
3. Conduct post-treatment data collection and determine if objectives were met
4. Continue annual data collection in entire management plan area to monitor new invasion areas to inform adaptive management

Visual Representation of Monitoring Framework

Ponderosa Pine

Cheatgrass



Pre- Treatment

Visual Representation of Monitoring Framework

Ponderosa Pine

Cheatgrass

During Treatment

Visual Representation of Monitoring Framework

Ponderosa Pine

Cheatgrass

Post- Treatment

Timeline

2025
Publish management plan

2026
Conduct baseline surveys, determine treatment areas

2027
Begin treatment in phased approach

2028
Conduct post-treatment data collection

2029
Implement adaptive management in future phases of treatment

2030
Continue post-treatment data collection, re-assess management goals for next 5 years

Recommendations

- Continue long-term monitoring and adaptive management
- Expand treatments outside of project area
- Continue active collaborative efforts with stakeholders

Conclusions

- Stakeholder involvement is critical
- Ideal management regime can be cost prohibitive
- Success hinges on federal budget, general stakeholder approval, and potential implementation challenges


Thank
You