Summary of the wildfire workshop held at Jasper Ridge Biological Preserve June 9-10, 2022
Ecological Best Practices for Wildfire Risk Management in California- Jasper Ridge Biological Preserve as a Natural Laboratory

RECOMMENDATIONS FOR MERGING FIRE FUEL MITIGATION WITH STEWARDSHIP PRACTICES TO MAINTAIN BIODIVERSITY AND ECOSYSTEM FUNCTION AT JASPER RIDGE BIOLOGICAL PRESERVE

EXECUTIVE SUMMARY

Jasper Ridge Biological Preserve was established by Stanford University as a natural laboratory for research, education, and conservation. In 2021, the Stanford Wildfire Management Plan (2021 SWMP) was released, which recommends fuel-reduction to reduce wildfire risk throughout the university's lands. This provides the opportunity for Jasper Ridge to balance fuel reduction goals with overall stewardship of its natural ecosystems. To optimize the opportunity, the Preserve hosted a workshop in June 2022 titled, *Ecological Best Practices for Wildfire Risk Management in California- Jasper Ridge Biological Preserve as a Natural Laboratory* with 25 invited experts in the areas of land-management, risk management, wildfire modeling, fire emergency response, research, Indigenous practice, ecology, policymaking, and law.

In recognizing that Jasper Ridge ecological systems provide unique value to Stanford, the workshop had three goals:

- Discuss the risks beyond wildfire modeling efforts from the 2021 SWMP that should be considered in developing appropriate fuel reduction treatments for Jasper Ridge.
- Examine ecological stewardship strategies that balance wildfire risk mitigation through fuel reduction with supporting and enhancing ecosystem integrity.
- Identify opportunities to learn, communicate, and employ best practices of fuel reduction methods at Jasper Ridge, with the aim of informing best practices in similar landscapes.

This white paper provides the summary and outcome of the workshop identifying a set of recommendations to meet the concurrent goals of fuel reduction for wildfire risk mitigation and land stewardship at Jasper Ridge.

Recommendations

1. **Communicating Risk**: Clearly communicate 1) how wildfire risk is modeled, including underlying assumptions and limitations, and 2) that modeling is a first step in developing a fuel reduction strategy that also includes liability, enterprise, and reputational risks.
2. **Ecological Integrity:** Emphasize ecologically sensitive and sustainable fuel reduction treatment designs for Jasper Ridge. These include: 1) developing treatments based on habitat specificity, 2) using herbivory (including domestic species and reintroducing of native elk) for vegetation management, 3) restoring habitats that are fire-tolerant or fire-dependent, and 4) creating a stewardship crew that could be used for year-around management on all Stanford lands, including Jasper Ridge.
3. **Adaptive Management:** Approach fire-risk mitigation through adaptive management that draws on diverse areas of expertise, experience, responsibility, and engagement (including fire agencies, Indigenous partners and practitioners, researchers, educators, local communities, and risk managers), and which incorporates all aspects of Jasper Ridge's mission of research, education, and conservation in its treatment plans.

1. INTRODUCTION

Many of California's natural ecosystems evolved with frequent low-to-moderate intensity fires that naturally occurred (e.g. lightning strikes) or were associated with Indigenous peoples; these regular wildfires provided both periodic fuel reduction and enhanced ecosystem integrity through improved habitat for many species. Yet, the perceived risk posed by fire led twentieth century land managers to prioritize fire suppression activities and avoid managed fire on the landscape. These suppression policies led, in turn, to increased vegetation density and a new focus in the twenty-first century on vegetative fuel reduction techniques intended to mitigate fire risk to people and structures in the event of an unintended ignition. Vegetation management for fuel reduction is designed to modify wildfire behavior and can be accomplished through a variety of treatment approaches. Careful foresight in treatments before fire is ignited can provide land managers options that both mitigate fire risk while supporting ecological integrity.

1.1 Jasper Ridge fuels management within the Stanford Wildfire Management Plan

The initial framing for this workshop was a review of the comprehensive Wildfire Management Plan commissioned by Stanford University (2021 SWMP), which recommends fuel-reduction treatments throughout Stanford's ~8100 acres. The plan emerged after a series of destructive wildfires devastated many parts of California in recent years. Statewide, we are seeing communities, organizations, and municipalities becoming increasingly concerned with the risk related to wildfire, with a large focus on vegetative fuel management to mitigate that risk.[1] The 2021 SWMP focuses on fuel management specifically and exclusively for Stanford lands by assessing wildfire risk to life, property, and other high value resources. However, the fire modeling used in the report is focused only on vegetative fuels (i.e., no structures as fuels) within Stanford boundaries and the suggested treatments do not fully capture the overall stewardship goals of Jasper Ridge, which has been long recognized and lauded for its research, education, and conservation missions. The workshop was premised on achieving the dual goals of managing fire risk through fuel reduction concurrently with stewardship of ecosystem health and supporting biodiversity at the Preserve.

Jasper Ridge Biological Preserve comprises 1193 acres of Stanford's land. It is the University's premier site for education and research on and conservation of naturally operating terrestrial ecosystems, which include ecologically intact oak woodlands, chaparral, and grasslands (Appendix 1a). The preserve, like many natural areas in the Santa Cruz Mountain region, carries a heavy fuel burden, in a large part as a result of the removal of Indigenous people and their fire practices, as well as decades of fire suppression in a system that co-evolved with high-frequency, and characteristically low- to medium intensity fires. Additionally, California has experienced over three degrees of warming in the last century and will see even more warming and drought in the next few decades, which decreases moisture content of vegetation and drives wildfire intensity (Varga et al. 2022). The wildfire modeling exercise of the 2021 SWMP suggested a high fire hazard over much of Jasper Ridge land and recommended fuel reduction on more than 50% of the preserve over the next five years (Appendix 1b).

Jasper Ridge abuts suburban residential areas on two sides with agricultural and open-space lands managed by Stanford surrounding the rest. Situated at the heart of this WUI, Jasper Ridge is Stanford University's core area for biodiversity and ecological integrity, with the mission: **"to**

[1] Examples of initiatives and organizations that include diverse membership: California Wildfire & Forest Resilience Task Force, California Fire Safe Council, California Prescribed Burn Associations

contribute to the understanding of the Earth's natural systems through research, education, and protection of the preserve's resources." The importance of this mission, and Jasper Ridge's success to date in fulfilling that mission has long been recognized not only within Stanford but also in the local, regional, national, and international communities. Evidence of this success includes hundreds of research publications, major awards for education and outreach activities, and development of a strategic plan that emphasizes the role of Jasper Ridge as producing new knowledge for land stewardship locally, regionally, and globally.[2] Beyond its world-renowned research and education programs, Jasper Ridge acts as a regional conservation partner in the Santa Cruz Mountains Stewardship Network and the UNESCO Golden Gate Biosphere Reserve.

In this context, Jasper Ridge emerges as an important research and testing ground for how to combine fire-fuels reduction and ecological stewardship goals. For example, fire history research at Jasper Ridge determined that over the period from about 1650 to 1850, the average fire-return interval was 14.1 years (Stephens and Fry 2005). However, Indigenous community knowledge and other research in oak woodlands and other grass-dominated ecosystems throughout the region suggests shorter fire return intervals. Archaeological evidence of tule elk, pronghorn antelope, and grizzly and black bears indicates that biotic drivers of a moderately open landscape were also present (Bocek and Reese, 1992). Recent studies include a detailed chronology of the changes in vegetation that accompanied various land-use changes over the last 160 years, recorded in the accumulated sediment layers of Searsville Reservoir and Upper Lake Marsh (Stegner et al., 2022), and on comparisons of Jasper Ridge biodiversity with surrounding lands in the face of land-use changes (Blair 1996, Viteri and Hadly, 2022). Such work offers a rare opportunity to delineate the prehistoric to historic baselines that, combined with knowledge of a warmer, drier future, can define appropriate targets for a restorative, sustainable approach to fire fuel management.

Accordingly, the assembled team of experts from the workshop focused on Jasper Ridge to develop practices for ecologically sensitive vegetation management for fuel reduction specifically at the preserve, which could then be informative to the Santa Cruz Mountain region and beyond to meet the mutually important needs of maintaining ecological function, integrity, and biodiversity while at the same time reducing risk of damage from wildfire in the WUI of California.

1.2 Workshop Goals

The participants synthesized information and experience pertinent to achieving the following goals:

- Discuss the risks beyond wildfire modeling efforts from the 2021 SWMP that should be considered in developing appropriate fuel reduction treatments for Jasper Ridge.
- Examine ecological stewardship strategies that balance wildfire risk mitigation through fuel reduction with supporting and enhancing ecosystem integrity.
- Identify opportunities to learn, communicate, and employ best practices of fuel reduction methods at Jasper Ridge, with the aim of informing best practices in similar landscapes.

This white paper summarizes the conclusions and recommendations on which the participants reached consensus.

[2] Notable recognition includes: Global Change Experiment, Organization of Biological Field Stations Human Diversity Award, NSF grant for collaborative avian ecological studies, Inquiry-Based Instruction (IBI) *Science* Prize for undergraduate course focused on faculty research.

2. COMMUNICATING RISKS

RECOMMENDATION 1: COMMUNICATING RISK

Clearly communicate 1) how wildfire risk is modeled, including underlying assumptions and limitations, and 2) that modeling is a first step in developing a fuel reduction strategy that also includes liability, enterprise, and reputational risks.

2.1 Assessing Wildfire Hazard and Risk

Motivators for fuel reduction come from many different directions, influenced by safety, health concerns, social pressures, economics, and legal liability. Fire risk can be both real and perceived when considering hazards. The 2021 SWMP assessed fire hazard at Jasper Ridge as part of an overall analysis that included all of Stanford lands plus a three-mile analysis buffer beyond the boundary. Model inputs included dominant vegetation, terrain and elevation, and various relevant climate parameters (temperature, humidity, wind speed and direction, etc.). Probability and intensity of fire under varying conditions was modeled using the Fire Behavior Fuel Model (FBFM40). Outputs included burn probability (Appendix 1a.2) and conditional flame length (Appendix 1a.3), which when combined express normalized integrated fire hazard (Appendix 1a.4). See the 2021 SWMP for details.

Whereas hazard only looks at what will likely burn, risk considers what the impact of burning would be in terms of what would be lost. In the modeling exercise, risk was assessed by a process that defined high value resource resources and assets (HVRAs) as structures, above-ground utilities, cultural sites that could be affected by fire, established and maintained recreation sites (such as golf courses), and biological resources (strictly defined as areas of known sensitive species that would be deleteriously affected by fire). Generally, an HVRA was defined as a mappable feature, with social value or tangible cost in excess of $10,000, that would be impacted by fire.

2.2 Assumptions, limitations, uncertainties of risk and hazard assessment

The 2021 SWMP has recommendations as to which areas of Stanford lands and what kinds of fuel reduction treatments would minimize risks to the HVRAs included in the model in the event of a possible large, and destructive fire.[3] However, the HVRA definition precluded taking into account additional ecological attributes, beyond sensitive species, that are critical to the mission of Jasper Ridge, notably maintaining natural, healthy ecosystems throughout the preserve. While some ecological values were considered, the rankings of socio-ecological value per square meter placed ecological assemblages at the very bottom by a large margin (2021 SWMP, Fig. 2-7). Also, the process heavily emphasized mitigating the risk to built structures (2021 SWMP, Fig. 2-7) over natural spaces.

There are additional important risks beyond the modeling effort that should be considered when developing appropriate fuel reduction strategies for Jasper Ridge. These include: loss of life, legal liability, enterprise risk, and reputational damage that can arise from disregarding social responsibility and/or cultural considerations. Below, we summarize the workshop participant

[3] The 2021 SWMP does not consider unlikely, catastrophic fires outside historic variability, which are outside the scope of the model and is also outside the scope of this white paper.

discussion considering these additional risks and how it impacts Jasper Ridge specifically, and Stanford broadly.

Property and Life. The risk to property and life is generally weighted most heavily in fire-fuel reduction efforts. In the case of Jasper Ridge, this risk applies mainly to neighboring communities. Within the preserve, building and human density is extremely low. Buildings occupy only about 0.25% of the preserve. Typically, fewer than 50 people are on the 1193-acres during heavy-use times (during business hours when classes are in session during the academic year) and generally they are concentrated in the same areas as the buildings. Just two people live on-site. Normally, no people are in most of the acreage. Similarly, in the Stanford-owned open-spaces to the east of Jasper Ridge, buildings are very few and population density is very low. In contrast, just outside the western and southern boundaries of Jasper Ridge, buildings and associated infrastructure occupy more than 20% of the land, and population density is about 484 people per square mile. To the north are Stanford-owned open-space lands with no regularly occupied buildings, but an important built structure is the Stanford Linear Accelerator that parallels the Jasper Ridge border. Running through the northern part of Jasper Ridge are the SLAC power lines. These considerations indicate that the main risk to structures and people from a wildfire lies outside of the preserve, not within it.

Legal Liability. In California law, liability focuses on human-caused ignition, not on fire fuels. The relevant statutes stipulate criminal liability for fires started by arson; those started by the fault of public utilitity companies (such as electric lines igniting fires); or those started by negligently allowing fire kindled or attended to escape to another property. This focus on ignition and negligence implies a very low liability risk for Stanford as far as Jasper Ridge is concerned.

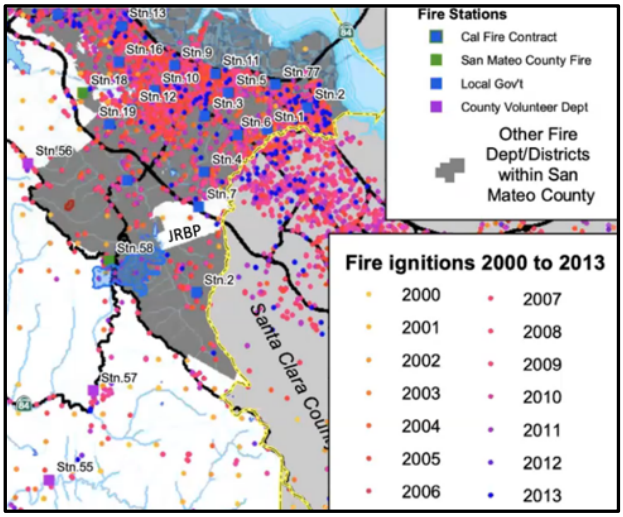

Figure 1. Fire ignition history on Jasper Ridge and surrounding lands.

First, historically the highest probability of ignition is outside of Jasper Ridge. This is because most fires are started by people, and population density and land use are much higher outside the preserve (Fig. 1). A fire ignited outside JRBP that spreads into and through the Preserve and then continues onto other property does not create liability for the University under the current legal regime.

Second, the only utility lines that run through Jasper Ridge are the responsibility of PG&E or the United States Department of Energy (the SLAC transmission lines). This means that fires ignited by mechanical failure of power lines in high winds or by failure to trim trees such that branches or other material strike power lines and ignite fires are not the legal liability of Stanford.

Third, strict protocols are in place to prevent negligent ignition at Jasper Ridge. For example, standard operating procedure allows activities that could accidentally start a fire (such as mowing) only when weather conditions are fire-safe. On average there are fewer than 20 vehicles using the preserve per day. The preserve is closed to general use on red-flag days. Additionally, Jasper Ridge maintains eight outdoor video surveillance cameras that can help detect wildfire ignitions (and to detect trespassers who conceivably could start a fire by carelessness). These cameras have proven useful in detecting possible lightning strikes, allowing Jasper Ridge staff to check those areas for any signs of ignition. Moreover, multiple cameras in the ALERTWildfire South & East Bay region (including one at Jasper Ridge and one at the Stanford Dish) can be trained on the preserve and other university lands to aid in detection of fires, monitor fires during containment, help evacuations through improved situational awareness, and observe contained fires for flare-ups. Finally, Jasper Ridge is regularly patrolled by a resident ranger, who responds quickly to unusual activities, and a volunteer ranger staff regularly monitors the roads and trails.

Enterprise Risk. Enterprise risk refers to the damage that would be caused to the core functions of Jasper Ridge and more generally Stanford University. In the event of a major wildfire within Jasper Ridge, the destruction of Sun Field Station, the Solar Decathlon House, and maintenance equipment (vehicles, tractors, etc.) would set back operations for a period of weeks to months. The burning of various habitats would mandate interruptions and changes in some research and educational activities, and a loss of other research and educational opportunities depending on the location and intensity of fire. Outreach activities (docent-led tours for the public, etc.) would have to be paused. The larger losses would come from destruction of the Solar Decathlon House (loss of housing for the resident ranger) and Sun Field Station, which houses irreplaceable archives and scientific specimens (notably the herbarium).

However, recovery to core functions could be relatively rapid. Administrative functions could be performed off-site (as demonstrated during the COVID-19 pandemic). Maintenance equipment and crews (needed to clear roads and trails, etc.) could be brought in from outside. Some research and educational activities would likely quickly pivot to take advantage of the "natural experiment" that burning—a natural ecological process for the ecosystems within Jasper Ridge—would provide. In these ways the core mission of Jasper Ridge would continue to be fulfilled (albeit in different ways with respect to pre-fire conditions). These considerations suggest that while enterprise risk associated with wildfire is certainly not negligible, neither is it severe for Jasper Ridge, and in fact would likely open up new oppportunities for fulfilling the core research, education, and conservation missions, as has been the case for other field stations that have recently experienced wildfires, notably Pepperwood Preserve near Santa Rosa, CA, and Blue Oak Ranch Reserve, near San Jose, CA.

The flip side of enterprise risk is the damage that could be inflicted by inappropriate treatment design intended to prevent wildfire but negatively impacts biodiversity

and threaten ecosystem function. Ecological risk is a serious concern to Jasper Ridge, as are the likely interruptions to research and educational activities in the event of large wildfire. In these cases, irreparable harm could be induced that would make Jasper Ridge unsuitable to fulfill its core mission indefinitely.

Taking a broader view, wildfire in areas surrounding Jasper Ridge pose significant enterprise risk to Stanford University as a whole. Impacts could include destruction of a large number of faculty, staff, and student-occupied housing; increasing homelessness on or adjacent to the Stanford campus with all of its concomitant challenges; and post-fire, a dramatic increase in housing costs for both purchasing and renting homes for Stanford employees and students. These considerations highlight the need for community cooperation in ignition management, fuels management, and home-hardening to reduce fire movement beyond the border of Stanford lands. Work done to manage fuels at Jasper Ridge can contribute to broader community efforts on lowering fire risk in communities upon which Stanford University depends, thus lowering overall enterprise risk.

Reputational Risk. Less tangible but also critically important are the reputational risks that can increase from insensitivity to the needs and perceptions of community partners. Significant reputational damage can accrue from failing to engage with partners to make decisions, and to adequately communicate how the decision-making process integrates the risks of damage to property and life, legal liability, and institutional enterprise. Among key points to convey are why certain treatments are undertaken (or not), their effectiveness, and the value of setting up treatments to maximize learning opportunities. Vegetation management that does not address overall stewardship goals of Jasper Ridge can damage the reputation of the preserve in the eyes of all of its partners: higher administration at Stanford; decision-makers in LBRE; Indigenous partners involved in stewardship; regional and international conservation networks of which Jasper Ridge is part (Santa Cruz Mountains Stewardship Network, Golden Gate Biosphere Reserve); the broader biological field station community (Organization of Biological Field Stations); Jasper Ridge staff, researchers, students, and docents; and the surrounding communities. These and other Jasper Ridge partners expect high-quality, ecologically sensitive stewardship and protection of the preserve's rare and valuable resources.

It is generally understood that no model is perfect, but that model outputs can still be used to inform land-management decisions. For this reason, it should be clearly articulated that the 2021 SWMP is a first step in wildfire risk mitigation, and that additional risks and considerations will be included in developing the appropriate fuels reduction treatments for individual units of Stanford's lands.

2.3 Specific Recommendations for Mitigating Wildfire Risk at Jasper Ridge

As summarized above, the workshop participants discussed additional wildfire risks and management considerations specifically for Jasper Ridge. Moral, ethical, political, and existential risks were also mentioned and apply to the decision-making process as well. Through this discussion, participants also identified concrete opportunities for mitigating wildfire risk at the Preserve. These suggested recommendations include:

- Fire-harden Sun Field Station, the Solar Decathlon House, and the maintenance facilities (currently the Corp Yard, within five years the new Academic Support Complex). This includes both fuel reduction and fire-hardening of the structures through appropriate building modifications (replacing highly flammable with less flammable siding and roofing, modifications to prevent trapping of embers, etc.).
- Provide an adequate buffer to inhibit spread of flames into Jasper Ridge from ignitions outside the preserve, or outside Jasper Ridge borders if ignition is within the preserve. Particularly important will be treating areas along the border of residential neighborhoods (Appendix 1b). Treatments should be designed to integrate the combined effect of fire-hardening, emergency-responder access and staging, and buffers outside Jasper Ridge borders as well as inside.
- Work with PG&E to evaluate burying existing power lines.
- Evaluate fire hydrant placement at Jasper Ridge.
- Emphasize vegetation management treatments and strategies that reduce fuels while maintaining or enhancing ecosystem health and biodiversity.

3. TREATMENTS AND STRATEGIES FOR VEGETATION MANAGEMENT

RECOMMENDATION 2: ECOLOGICAL INTEGRITY

Emphasize ecologically sensitive and sustainable fuel reduction treatment design for Jasper Ridge: 1) develop treatments based on habitat specificity, 2) consider herbivory (including domestic species and the reintroduction of native herbivores, notably elk) for vegetation management, 3) aim to restore habitats that are fire-tolerant or fire-dependent, and 4) create a stewardship crew that could be used for year-around management on all Stanford lands, including Jasper Ridge.

3.1 Stewardship Goals

The goals of vegetation management for fuel reduction are to modify fire behavior in the event of an ignition to reduce wildfire intensity and rate of spread, protect structures and life, and improve access for emergency fire responders.[4] For Jasper Ridge, fuel reduction is just one component of total land stewardship to meet the mission of research, education, and protection of the preserve's resources. Workshop participants discussed how fuel reduction treatments and strategies at Jasper Ridge must minimize negative impacts to its core mission, and if accomplished appropriately, it can also maintain and enhance ecosystem integrity.

Specific stewardship goals identified by workshop participants included the following:

- Regenerating woodlands with appropriate age structure and species composition
- Maintaining biodiversity—including small vertebrates and native plants
- Minimizing ground disturbance
- Minimizing loss of cover for animal movement through corridors into and through Jasper Ridge
- Avoiding excessive noise
- Preventing spread of invasive species, pathogens, and pests

[4] See CAL FIRE Focus on Fuels Reduction

- Removing non-native “problem” trees (pines, acacias, etc.)
- Retaining habitat features such as snags and downed trees
- Maintaining strategies that anticipate inevitable vegetation adjustments due to climate change
- Protecting species of special concern
- Employing nature-based maintenance approaches where possible—such as reseeding with appropriate species and conservation-oriented herbivore grazing and browsing
- Restoring and enhancing the watershed through the Searsville Watershed Restoration Project

3.2 Place-Based fuels management for Jasper Ridge

Vegetation management can be accomplished through a variety of methods including herbivory, mechanical equipment, and burning. Methods can be used independently or in combination to design specific treatments for a particular vegetation type and area. Treatment design should be based on goals for fuel reduction, long-term maintenance, and overall stewardship. Below is a summary of the workshop participants’ discussion of various treatments based on expertise and on-the-ground experience.

> ***Burning*.** California ecosystems in the WUI, like Jasper Ridge, are typically comprised of annual/perennial grasslands, serpentine grasslands, coast live oak woodland, blue oak woodland, chaparral, redwood forest, and riparian areas with mosaic vegetation patterns historically generated by fire and other disturbances (Pickett et al. 1999). Fire is among the greatest landscape-scale processes to shape these systems, which have evolved to thrive when periodic, low- to moderate-intensity fires move through them (Anderson 2006). The resultant vegetation composition and structures in turn support a great diversity of wildlife (Purcell & Stephens 2005, Livingston et al. 2016, He et al. 2019).
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> Controlled burns are among the most cost-effective approaches to land stewardship, and provides many incomparable benefits. Prescribed and cultural fire can be used to address both stewardship and fuel reduction goals. When applied by practitioners, fire can be controlled to burn at low to medium intensities, which can help enhance biodiversity, while reducing fuel loads, and this benefit can be maximized by varying the time of year for the burn (Knapp et al. 2009, Hankins 2013). It is vital to recognize that Indigenous communities have practiced culturally significant stewardship through traditional fire practices for millennia (Hankins 2015). The realization of fire’s role in these ecosystems is relatively recent from a western science understanding. This oversite has come at a tremendous cost to the integrity of this landscape relative to fire and biodiversity conservation.
>
> Indigenous partners should be recognized in playing a particularly special role in implementing stewardship practices that include fire and fuel reduction. Cultural burns may be planned and carried out at Jasper Ridge, but only in partnership with tribes. Engagement with Indigenous partners such as the Muwekma Ohlone and other indigenous groups is critical to do early and often during the project planning phase to maximize collaborative goals and outcomes. The planning process would include identifying cultural resources prior to treatment, and understanding how

cultural burning can contribute to desired results. The practice of cultural burning on ancestral land not only provides inherent value to Indigenous community members, but the practice also supports the dual goals of fuel reduction and enhancing biodiversity.

***Herbivory*.** Recoupling cultural or prescribed burns with grazing, particularly with wild native ungulates, reduces vegetative fuel loads, while providing nutrient rich forage which attracts herbivores- this is known as pyric herbivory (Starns et al. 2019). Native herbivorous mammals with which California vegetation co-evolved include elk (*Cervus canadensis)*, mule deer (*Odocoileus hemionus californicus*), pronghorn (*Antilocapra americana*), and beaver (*Castor canadensis*). The reintroduction of elk into suitable areas could help meet fuel goals while simultaneously achieving the goal of reintroducing large native ruminants into areas of their historic range. Beavers also have been demonstrated to effectively reduce fire risk by widening riparian gaps in forest and shrub thickets and increasing fire resistance of riparian vegetation by raising the water table with beaver ponds. Domestic animals are commonly used as substitutes for native herbivores with goats functioning predominantly as browsers, sheep as intermediate foragers, and cattle as grazers. The type of animal has a big effect on what types of vegetation will be removed (see Appendix 3).

***Mechanical*.** Overall, workshop participants largely recommend using burning and herbivory treatments for fuel-reduction to mimic natural ecological processes or reintroduce natural methods when possible and appropriate. However, in some areas, mechanical methods might be utilized for initial or routine treatment depending on the setting. Mechanical methods include crews with hand tools thinning vegetation, and using tracked or wheeled heavy equipment to mow or masticate fuels, which would be hauled, chipped or burned. Mechanical treatments can be highly variable and can be nuanced in designing the appropriate approach for Jasper Ridge. For example, while generally costly, hand-crews can be used to work on steep slopes and sensitive areas like riparian habitats. Appropriately trained crews can be highly selective when removing vegetation around sensitive species. They can also be used for preparing burn unit perimeters prior to prescribed burning. When using machinery, small equipment with rubber tracking can reduce ground disturbance, or larger equipment with greater reach used only on existing roads and trails can also avoid excessive ground disturbance. Specialty equipment and treatment design can be used in combination for highly selective fuel reduction to retain valuable habitat features, remove invasive plants, foster mix-aged tree stands, and create mosaic vegetation patterns in the landscape. Where appropriate, mechanical treatments can be used as a transitionary measure to set the stage for more sustainable follow up maintenance.

3.3 Addressing implementation and capacity concerns: Creating an in-house ecological stewardship crew

A key factor in achieving ecologically sensitive vegetation management is to work with a trusted contractor. Prior to hiring a contractor, written strategies should be created which include explicit details about treatment design and expectation of vegetation management. This ensures that the

contractor is willing to understand and respect ecological sensitivities and is equipped to meet those goals. Once a contractor is hired, modifications can be made, but specific expectations should be made up-front.

In the case of prescribed burns, partners such as Indigenous practitioners, state and federally certified burn bosses, prescribed burn NGOs, consultants, and fire agencies will also be involved and should be invited at the earliest planning stages to develop a mutual understanding of expectations and ensure shared goals are achieved.

In previous years, contractors amenable to ecological sensitive practices may have been rare, but in recent years, contractors have increased their skillset and contracting outfits have grown. Nevertheless, workforce capacity, cost, and control issues suggest that vegetation management at Jasper Ridge may best be supported by an in-house ecological stewardship crew. This crew would be modeled after existing crews seen at other preserves, reserves, state and county parks, and open spaces. We envision a seasonal or year-around crew of 6-8 employees and/or students who would be trained in vegetation management for fuel reduction, invasive species, and monitoring. An additional in-house option is a Stanford goat, sheep, and/or cattle herd to be used for vegetation management across university lands. This could also be modeled after existing operations. Annual costs for an approximately 120 head cattle herd is $200,000, which includes all cattle, veterinarian care, and two full-time staff.[5] A goat herd would be a similar cost or less.

4. ADAPTIVE MANAGEMENT FOR LONG-TERM STEWARDSHIP

RECOMMENDATION 3: ADAPTIVE MANAGEMENT

Approach fire-risk mitigation through adaptive management that draws on diverse areas of expertise, experience, responsibility, and engagement, and which incorporates all aspects of Jasper Ridge's mission of research, education, and conservation in its treatment plans.

- *Work with fire agencies, Indigenous partners and practitioners, researchers, educators, local communities, and risk managers as partners to identify fire-risk reduction strategies with clearly articulated management goals, objectives, and performance standards best suited to meet the goals of the preserve's mission.*
- *Use the defined management goals, objectives, and performance standards to guide implementation, monitoring, and interpretation of results for adaptive management.*
- *Create and foster collaborations with organizations and academic programs that focus on fire with the goal to become a hub for information, training, experiments, and local outreach about wildfire.*
- *Incorporate all aspects of the Jasper Ridge mission: research, education, outreach, conservation, and stewardship into treatment plans.*

4.1 Monitoring, Assessment, and Collaboration

The disturbances caused by fuels reduction offer ideal opportunities for monitoring outcomes and adaptive management towards defined goals (Sample et al. 2022). These monitoring efforts should then be used to adapt fuel management and stewardship strategies. Adapting strategies should be

[5] Estimates from Santa Lucia Conservancy, which runs a 120-head cattle herd with two staff primarily for vegetation management

done with input from fire agencies, Indigenous partners, researchers, local communities, and risk managers.

To support adaptive management, a suite of data should be collected by uniform methodology before and for several years following treatments and be assessed regularly. At a minimum these should include twice-yearly assessment along appropriate transects for vertebrate presence and abundance, plant species presence, abundance, cover, and structure, soil chemistry and microbiota, and associated environmental data (temperature, humidity, etc.). Workshop participants suggested that assessment techniques should include:

- Camera traps: Install camera traps per treatment area at strategic locations to monitor large-animal use
- eDNA sampling of soils: Establish permanent sampling locations per treatment area for annual sampling to assess both microbial diversity and wildlife census
- Small-mammal and herptile trapping: Establish 2 strategic transects per treatment area for twice-annual assessment. Approximately 100 traps per transect, cover boards for herps, etc.
- Transect and point counts for birds: Monthly transects following Jasper Ridge established protocols
- Transect and point counts, vegetation height for plants: Establish 2 transects per treatment area, plus areas flagged for species of concern, for each treatment area, to be assessed twice per year. Should include areas of disturbed ground and re-seeded areas to monitor invasives
- Annual BioBlitz in the treatment areas, involving citizen scientists
- Erosion monitoring. On steep slopes set up erosion monitoring transects
- Drone imagery to assess canopy cover and animal trackways: Drone flights over established transects once per year to assess development of animal movement between patches via trails
- Continue monitoring previously established woody plant plots to track population dynamics, stand structure, biomass, and carbon
- Acoustic monitoring for bats, birds, insects, and human-associated noise (audiomoths and other instrumentation): 5 audiomoths per treatment area
- Weather station and phenocam strategically located within each treatment area
- Photospheres to record vegetation changes
- Indigenous-centered research or monitoring
- Analysis of all of above to guide adaptive management

Costs, collecting, and analyzing these data would cost ~$20,000 the first year followed by annual monitoring costs of ~$15,000 per year for each treatment area (Appendix 4). In addition to the essential monitoring list above, ideal data would include the following:

- Remote sensing: terrestrial LiDAR, thermal imagining, hyperspectral imaging
- Instrumentation: air quality, water quality and runoff
- Field Collection/Experimentation: seed bank analysis (genetics), diet analysis (genetics), native vs. non-native species proportions, soil macro-biota
- Modeling: carbon sequestration.

A long-term goal would be to share monitoring protocols and compare data with collaborative land managers throughout the region, such as through the Santa Cruz Mountains Stewardship Network and Golden Gate Biosphere Network. Doing so would position Stanford as a sustainability leader

and model for fire risk reduction in the region. Sharing and disbursement of Jasper Ridge monitoring data would inform adaptive management strategies and best practices for ecologically sensitive fuel reduction and land stewardship across the Santa Cruz Mountains network of land managers and local governments.

4.2 Education and Outreach Goals

Stanford University is a research and educational institution; thus research and educational goals should inherently be included with ongoing fuel reduction activities, particularly at Jasper Ridge which serves as a natural laboratory. Jasper Ridge provides an exceptional opportunity to actively study the before, during and after effects of fire fuel risk reduction in an academic setting that fosters dissemination of that knowledge. Below is a list of examples of how workshop participants envisioned this could be accomplished. It is expected that more opportunities will arise as fuel reduction activities are developed, implemented, and adaptively managed.

- Keep research sites with ongoing experiments and outdoor laboratory activities intact as much as possible
- Consider how access for boundary or interior work can coincide with other goals such as re-opening old trails to facilitate visitor access and maintenance, while minimizing harm to wildlife corridors
- Engage students in monitoring, stewardship, and adaptive management
- Engage community in related activities and outreach
- Use the education, outreach, and networking structure of Jasper Ridge to broadly communicate outcomes and engage with partners to enhance ecological sustainability of fire-fuel reduction treatments more broadly

Beyond Stanford's internal network, it is necessary to engage a wider collaborative approach to fire management. Fire knows no borders, and one property alone cannot be the sole focus of fuel management where fire can spread throughout the landscape to direct neighbors or from further away as a result of flying embers. Landscape-level efforts must be made through shared communication with all participants, which include land users, land managers, neighbors, fire agency personnel, and Indigenous partners. Additional support can come through local Fire Safe Councils and Prescribed Burn Associations.

5. WORKSHOP OUTCOMES AND BROADER IMPLICATIONS

The workshop was an excellent opportunity to learn from a broad network of experts in land-management, risk management, wildfire modeling, fire emergency response, Indigenous practice, ecology, policymaking, and law who shared their deep understanding of research and on-the-ground experience in fuels management.

Over the course of two days, the participants achieved the three goals of: 1) discussing risks beyond the wildfire modeling efforts of the 2021 SWMP, 2) examining ecological stewardship strategies that balance fuel reduction and enhancing ecosystem integrity, and 3) identifying opportunities to learn, communicate and employ best practices for fuel reduction. We produced three recommendations to be used by Stanford's team of decision makers in creating appropriate treatments for Jasper Ridge under the University's Wildfire Management Plan.

Our approach was place-based, meaning it was focused on identifying scientifically-grounded strategies and recommendations that are specific in addressing the values and mission of Jasper Ridge within Stanford's lands. These recommendations will help integrate fuels management into the overall stewardship goals of Jasper Ridge focused on ecological integrity.

We envision this approach and the outcomes we learn through monitoring these fuel reduction treatments will support other sites that face similar conditions and challenges. We expect that as ecologically sensitive treatments are applied to the preserve and modified through adaptive management, that lessons can be shared and recommendations be applied to many other areas whose mission involves maintenance of naturally operating ecosystems to sustain high biodiversity, in no small part because the preserve contains every vegetation habitat found in central California and most habitats common in the state. Moreover, Jasper Ridge has at its core education, communication, and collaboration as well as research. Therefore, the practices undertaken at Jasper Ridge, if properly developed, monitored, and communicated, can provide needed guidance for how best to accomplish fire-fuel reduction in ecologically sound ways, can distribute and highlight the lessons learned, and significantly advance effective land stewardship practices in these changing times.

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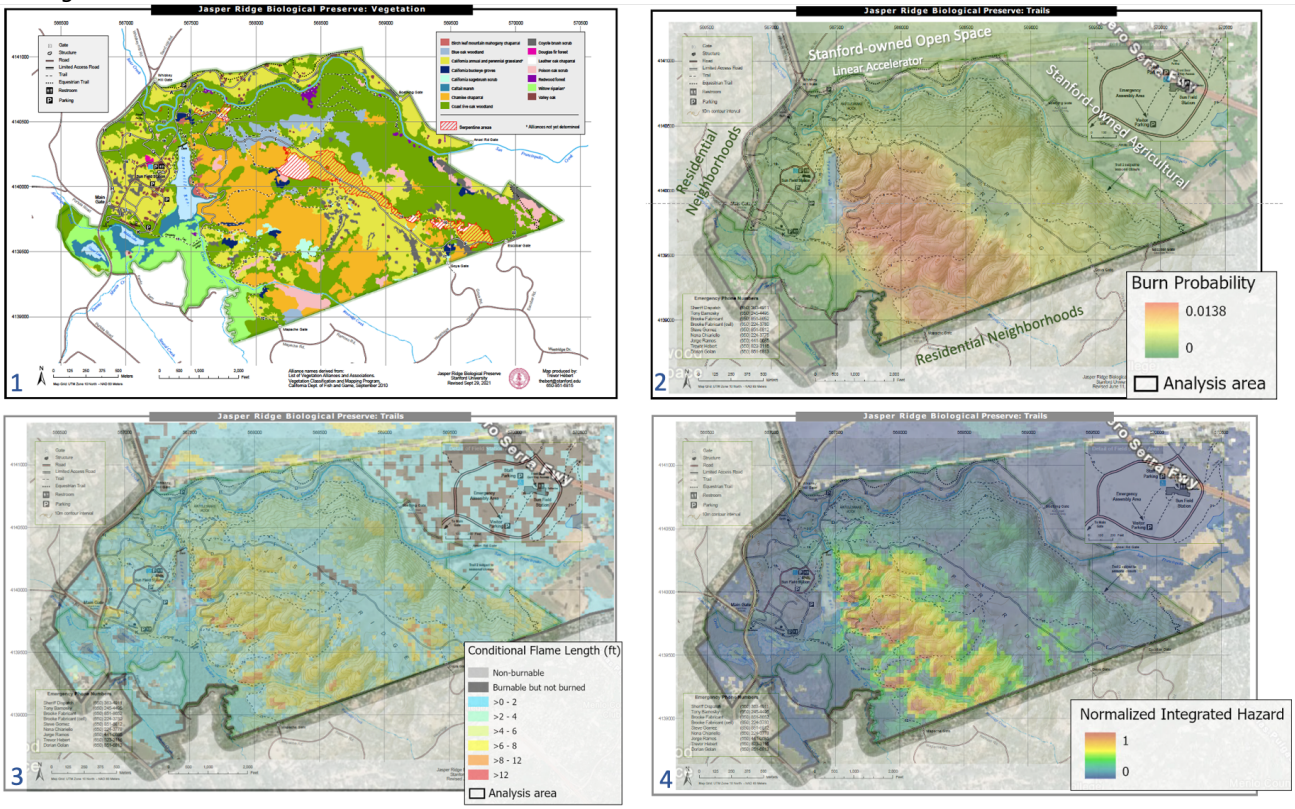
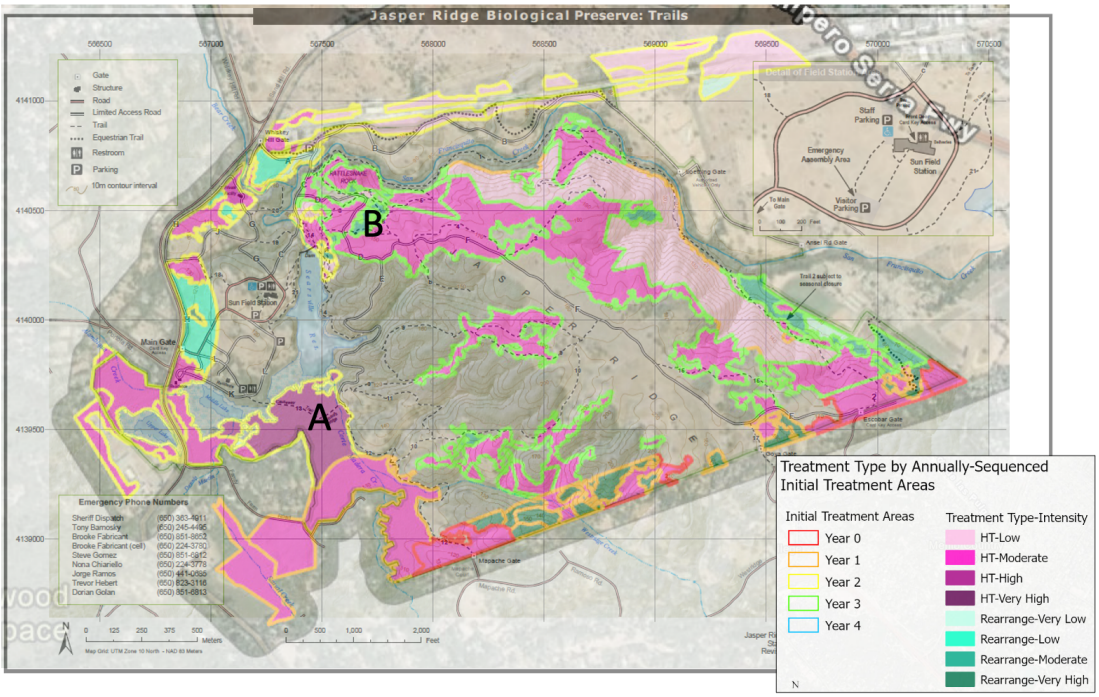
Summary of the wildfire workshop held at Jasper Ridge Biological Preserve June 9-10, 2022

Ecological Best Practices for Wildfire Risk Management in California- Jasper Ridge Biological Preserve as a Natural Laboratory

Appendix 1a: Vegetation, risk and hazard maps for Jasper Ridge. (1) Vegetation within Jasper Ridge, (2) Burn Probability map for Jasper Ridge (bordered in dark green) and adjacent Stanford-owned lands, (3) Conditional Flame Length for Jasper Ridge, (4) Normalized Integrated Fire Hazard. Maps 2-4 are outputs from the 2021 Stanford Wildfire Management Plan.



Appendix 1b. Treatment areas, treatment types, and sequencing recommended by the fire modeling process. A and B indicate areas suggested as the only interior areas of Jasper Ridge critical to treat, based on information presented in this white paper. Treating these areas and a ~200-foot buffer along the JRBP's southern and western borders can achieve the goals of mitigating fire risk to functions of JRBP and to neighbors.



Appendix 2. Summary of workshop participant discussion examining potential concerns with various fuel reduction methods.

Treatment	~Cost/acre	Ecological Concerns and Limitations	Solutions
Hand crews	High	• Invasive species/pathogens (SOD) • Ground disturbance • Alter forest structure by removing young trees/vegetation • Destroy small-animal habitat • Nutrients removed if cut vegetation is hauled off	• Clean equipment • Minimize access routes for crews and equipment • Pile burning rather than dragging and chipping • Selected removal of trees of varied ages • Mosaic that leaves adequate small-animal habitat in appropriate number of patches.
Mowing	Low	• Ground disturbance • Invasive species	• Time mowing activities to avoid/preclude spreading seeds of invasive species
Discing	Low	• Significant ground disturbance • Erosion • Invasive species	• Re-seeding from native stock?
Masticator	Moderate	• Ground disturbance • Erosion • Limited by steep slopes or remote areas • Invasive species/pathogens • Wildlife disturbance • May leads to vegetation-type conversion	• Use smallest equipment possible • Rubber treads rather than metal tracks • Stay on existing roads • “Precision” mastication methods
Domestic Livestock	Low -to-Moderate	• Can degrade water quality in riparian areas • Introduce invasive species (seeds in fur/wool or passing through digestive system) • May not eat enough • May not eat the vegetation desired • Goats may girdle certain kinds of trees • Potential over utilization of forage and soil compaction • Antibiotic use and dewormers can significantly alter soil biota	• Fencing (temporary or permanent) • Pre-treatment quarantine for 24-48 hours to allow seeds from previous site to pass through digestive system. • Do not use livestock that have previously been in areas with high density of invasive species • Monitor frequently to move livestock once they have consumed vegetation to the state desired • Do not use livestock that have been recently treated with antibiotics or dewormers
Elk	Low	• May not stay in areas where treatment is desired • May not eat the desired vegetation • Potential for overgrazing if population densities get too high Competition for grazing/browsing resources in areas where cattle grazing exists • Human/wildlife conflict	• Focus on areas where natural water sources will cause them to congregate • Soft release of pregnant females to establish calving grounds • Keep population densities low enough to avoid competition with domestic livestock
Prescribed Burn	Low to moderate, depending on acreage	• Potential to exhaust the seedbank (if burn is too hot) • Not appropriate for all vegetation types or areas (chaparral, areas of high population density) • Perceived and potentially real risk • Permitting	• Control burns adequately • Use only in appropriate places • Engage experienced burn bosses

Appendix 3a. Herbivory and burning potentials for reducing fuels in different habitats based on workshop participant experience.

Habitat	Domestic Livestock	Elk	Controlled Burns
Chaparral	Not as effective, except possibly along margins; generally difficult to break through chapparal.	Elk utilize chaparral and are big enough to break through it.	Effective, but burns hot and fast, which makes prescribed burning complicated
Coast Live Oak	Cattle, goats and sheep effective in reducing density of understory; may overly impact oak seedlings	Probably effective based on their known habitat and food preferences. Has not been tried or studied.	Effective
Blue Oak	Cattle, goats and sheep effective in reducing density of understory; may overly impact oak seedlings	Same as above	Effective
Poison Oak Scrub	Goats effective in certain seasons (spring)	Same as above	Effective
Annual/Perennial Grassland	Cattle, goats, sheep effective	Same as above	Effective
Serpentine Grassland	Cattle, goats, sheep effective	Same as above	Effective
Redwood Forest	Goats may be effective in the understory	Same as above	Effective
Riparian Areas	Cattle, goats, sheep may be effective, but may also be destructive of these sensitive areas	Same as above	Effective

Appendix 3b. Comparison of different animals for use in reducing fire-fuels at Jasper Ridge. (Modified from information provided by Hannes Boehning and Tule Horton as part of Earthsys 182B, 2021.)

	Elk	Goat	Sheep	Cattle
Effectiveness at thinning ladder fuel	Moderate - primarily consume grasses, will knock down and trample woody mass, will take brush when ground vegetation becomes desiccated in fall	Best - will eat grass, leaves, brush + strip bark from brush. Consume poison oak prolifically in some seasons.	Good – help reduce grasses and forbs but do not reach up to eat leaves and branches as goats do.	Moderate - primarily Eat grass, not brush and woody material. Will break through woody material.
Eating patterns	Both a grazer and a browser. Likes native and non-native grasses, oaks (blue oaks especially, leaves and acorns). Effective in raising the browse line.	Browsers. Prefer to eat weeds, thistles, brush, leaves, small woody pieces, bark. Can eat material up to 6 feet high. Will girdle some trees (notably olives, but also natives).	Intermediate grazer and browser. Concentrate on grasses and forbs.	Grazers. Prefers to eat grasses, but will also eat forbs
Movement patterns	Non-migratory and have high home range fidelity to locations with optimal forage, although sub-alpha bulls are prone to disperse. Will migrate, but with sufficient resources, prefer to stay in one location. Will concentrate near water. Habitats include grasslands, valley floors, riparian areas, oak woodland, oak savanna, and chaparral: all found within Jasper Ridge.	For fire resilience purposes, goats are penned by electric fences in designated areas, and moved as vegetation reaches the desired state.	Same as goats.	Prefer low-slope grasslands in proximity to water — however this varies by class. Several methods exist to aid in distribution, including: placement of water, nutrients, and fences; and use of herding.

Impact on Jasper Ridge Ecosystem (in addition to fire-fuel reduction)	Potential support/restoration of native grasses, bring back native flagship species of in its historic ecosystem. Hooves and heavy body weight churn and aerate soil, potentially making it more productive in combination with fertilization from dung and urine.	Pilot projects are in place to assess the effect on vegetation and soils. Initial observations include raising the browse line, girdling some trees, reducing poison oak foliage, reducing ladder fuels by at least 50%, leaving intact and occupied ~50% of the woodrat nests monitored, fertilizing the soil with abundant dung and urine but long-term tracking will be required to fully assess ecological impacts on vegetation re-growth, soil chemistry and fertility, etc.	Unknown, but likely to stimulate new growth of grasses and forbs. Pilot project demonstrated significant reduction in low vegetation. Fertilize soil with dung and urine.	Without careful management, risk of overgrazing native grasses. Judging from other areas where regenerative ranching techniques are employed, potential for increased water retention, biodiversity, carbon sequestration, and soil fertility. Hooves and heavy body weight churn and aerate soil.
Suitability of Jasper Ridge for health of the animal	Preliminary analyses indicate suitable habitat through much of Jasper Ridge, including marshy areas and permanent water. A detailed habitat suitability analysis would be required before releasing elk at Jasper Ridge.	Not suitable for free-ranging animals. A few goats will likely be killed by mountain lions. Suitable for short-term rentals.	Similar to goats. Sheep generally need shelter from rain.	Grassland areas are suitable. Densely forested areas less so.
Financial Considerations	If fencing was required, considerable for enclosing unfenced parts of Jasper Ridge with a 9-foot elk-proof fence. However, the better option would be free to range in and out of Jasper Ridge, into adjacent Stanford-owned agricultural and protected lands, in which case the main expense would be additional fencing to prevent collisions on Interstate 280 and elk crossing signs on Alpine Road.	$800-$1300 per acre. Could be lessened by Stanford acquiring their own herd of goats and herders for use in fire-fuel reduction.	$800-$1300 per acre. Could be lessened by Stanford acquiring their own herd of sheep and herders for use in fire-fuel reduction.	Leasing to ranchers following conservation practices; ranchers could generate profit. Acquiring and caring for cattle confined to Jasper Ridge would probably be prohibitively expensive.
Human/Labor Considerations	Free-ranging elk at Jasper Ridge would likely be enjoyed by neighbors. Conflicts with cattle-grazing operations have occurred elsewhere, although the only nearby ranches are on Stanford-managed lands. Elk-vehicle collisions the primary challenge. High value	Herders and animal care included in rental contract. Educational value.	Herders and animal care included in rental contract. Educational value.	Requires ranchers knowledgeable in conservation-oriented grazing plus livestock tenders (likely about 1-3 full-time staff). Educational value.

	research opportunity to evaluate elk effects on vegetation community, fire fuel loads, and ecological interactions (puma, condor, etc.). Crossing Highway 280 is a concern. Educational value.			

Appendix 4. Ecological Monitoring and Analysis Budget for Units 2, 3, and 4 at Jasper Ridge (e.g., the treatment units along the Jasper Ridge southern border)

Item	Comments	1-time cost	Annual Cost	Total for First Year
Camera traps: Install 2 camera traps per treatment area at strategic locations to monitor large-animal use	Main cost is initial purchase and installation. 6 cameras x $1000 each, 3 base stations @ $675. Analysis done via AI and collaboration between Jasper Ridge staff and CI students at no cost.	$8,500	-	$8,500
eDNA sampling of soils: Establish 5 permanent sampling locations per treatment area for annual sampling to assess both microbial diversity and wildlife census	Sampling can be done at no cost by existing staff / students. Analysis is $250 per sample x 15 samples = $3750	-	$3750	$3750
Small-mammal and herptile trapping: Establish 2 strategic transects per treatment area for twice-annual assessment. Approximately 100 traps per transect, cover boards for herps, etc.	Traps already available. Main cost is student help. Three nights of trapping for each of the three sites, three student crew. With follow-up data recording etc., 10 8-hour days of work for 3 students @ $25/hour = $6000. Materials and supplies $500 annually.	-	$6500	$6500
Transect and point counts for birds: Monthly transects following Jasper Ridge established protocols	Probably can be done by volunteers already participating in bird surveys. 40 hours of student help for data entry and analysis @ $25/hour = $1000	-	$1000	$1000
Transect and point counts, vegetation height for plants: Establish 2 transects per treatment area, plus areas flagged for species of concern, for each treatment area, to be assessed twice per year. Should include areas of disturbed ground and re-seeded areas to monitor invasives.	Probably can be done by combination of docent herbarium crew plus 2 student helpers. 10 8-hour days of work for 2 students @ $25/hour = $4000. Materials and supplies $500 annually.	-	$4500	$4500
Annual bioblitz in the treatment areas, involving citizen scientists	Snacks, drinks for participants. $500	-	$500	$500
Erosion monitoring. On steep slopes set up erosion monitoring transects: 3 transects per treatment area. Monitor 1 time per year	5 8-hour days of work for 2 students @ $25/hour =$2000 Materials and supplies $500 annually.	-	$2500	$2500
Drone imagery to assess canopy cover and animal trackways: Drone flights over established transects once per year to assess development of animal movement between patches via trails.	Can be done by existing Jasper Ridge staff	-	$2500	$2500
Acoustic monitoring for bats, birds, insects (audiomoths and other instrumentation): 5 audiomoths per treatment area	15 audiomoths--already available at no cost. Consultant to extract and process acoustic data = $10,000		$10,000	$10000
Weather station	20 iButtons @$175 each	$3500	-	-
Phenocam photo series located within each treatment area	3 cameras @ $1500 each; student help to monitor and process	$1200	$1000	$2200
Analysis of all of above to guide adaptive management	Quarter-time student position (guideded by faculty and staff). 520 hours x $25/hour	-	$13000	$13000
TOTALS		$13,200	$45,250	$58,450