SEQUOIA
Ecological Consulting, Inc.

Marin Wildfire Prevention Authority
Marin County, California

Evaluation of Potential Impacts of Livestock Grazing on Special-Status Plants and Sensitive Natural Communities

January 2022 (Updated August 2025)

Prepared for:

Anne Crealock
Marin Wildfire Prevention Authority
1600 Los Gamos Drive, Suite 345
San Rafael, California 94903

Prepared by:

Sequoia Ecological Consulting, Inc.
1342 Creekside Drive
Walnut Creek, California 94596
(925) 855-5500

CONTENTS

1.0 INTRODUCTION

Sequoia Ecological Consulting, Inc. (Sequoia) provides biological support to the Marin Wildfire Prevention Authority (Marin Wildfire) on fuel reduction efforts throughout Marin County, California. Marin Wildfire is a coalition of local fire agencies, emergency service providers, cities, towns, and county government formed to support the development and implementation of a comprehensive wildfire prevention and emergency preparedness initiative. Together with its member agencies, Marin Wildfire works to fund and implement ecologically sustainable vegetation management practices to reduce hazards and achieve measurable fuel reduction consistent with recommendations outlined in the Community Wildfire Protection Plan (Fire Safe Marin 2020). According to this plan, livestock grazing may be used in tandem with other treatment methods to reduce vegetation along emergency evacuation routes and create fuel breaks or fuel reduction zones in Marin County. Grazing provides more rapid and cost-effective implementation than other vegetation management techniques and results in lower greenhouse gas emissions than traditional methods that require the use of mechanical equipment (LD Ford 2018).

2.0 BACKGROUND

2.1. Brief History

The Northern California coastline is home to a diverse mosaic of land cover types and habitats formed by varying geology and soils, elevation, slope and aspect, climate, and land use. Historically, California ecosystems were actively stewarded with fire by indigenous communities and grazed by herds of large ungulates, such as California mule deer (*Odocoileus hemionus californicus*) and tule elk (*Cervus canadensis nannodes*). The open grasslands, woodlands, and adjacent forests of historical Marin County furnished ideal foraging and refugia for these ungulate species that provided natural methods of vegetation management and seed dispersal (Amme 2008). The dynamic of cultural burning and grazing from native herds shaped the plant communities in Marin, contributing to the unique and biodiverse habitats whose ecological health is linked to these vegetation management regimes.

In the early nineteenth century, ranching became a common land use practice, and ranchers introduced cattle, sheep, and horses to the landscape (Amme 2008). Introduced livestock, non-native seeds, and an intensive grazing regime led to the overgrazing of native grasses and establishment of invasive, non-native species and subsequently resulted in a drastic shift of habitats from a native, fire-adapted landscape to a non-native, degraded, and wildfire-prone landscape. The depletion of natural resources such as native grasslands led to the eventual decline of species such as California mule deer and tule elk due to lack of sufficient foraging habitat. Additionally, the establishment of exotic and invasive plant species significantly reduced native plant cover and biodiversity.

By the late twentieth century, grazing by livestock, specifically goats and sheep, became more widely recognized for strategic reduction of fuel loads and invasive species control. Prescribed herbivory, or the intentional use of grazing livestock for vegetation management for wildfire mitigation, differs from earlier ranching practices and offers reduced impacts with increased benefit to native habitats when implemented with careful consideration. Presently, foresters and land managers, such as the California Department of Forestry and Fire Protection, implement grazing practices for fuel reduction and invasive species management projects. Locally, agencies such as East Bay Regional Park District, Midpeninsula Regional Open Space District, John Muir Land Trust, and others utilize grazing for fuel reduction and ecological benefit. With careful consideration, this practice can effectively be employed in Marin County.

2.2. Fuel Reduction Treatments for Wildfire Prevention

Wildfire frequency, intensity, size, and duration is increasing throughout the western United States (Nader et al. 2007). Previously, wildfire prevention efforts actively suppressed cultural burning practices by Indigenous communities, leading to a buildup of flammable vegetative material, fuel load. The unintended result is a landscape at higher risk of intense wildfire, requiring careful planning and management to implement fire-wise communities today. This includes efforts to improve ingress and egress along evacuation routes, protect infrastructure, improve fire detection systems, and implement fuel reduction programs. Modern fuel reduction focuses on preventing small ground-based fires from spreading into the tree canopy and growing into larger, more destructive, and uncontrollable fires (Lovreglio et al. 2014). Fuel reduction entails removing dead and low-growing vegetation under the larger tree canopy and removing the lower limbs of large trees to reduce the likelihood of fire entering the canopy.

Fuel reduction methods include use of heavy mechanical equipment, hand removal, treatment with herbicide, prescribed fire, or prescribed herbivory. Mechanical treatments can be ideal for areas with a high volume of dead biomass or along existing roads; however, this methodology is relatively expensive and poses considerable risks to sensitive plants and wildlife as it is highly disruptive to natural habitats, non-discriminatory, and often challenging to implement within settings where sensitive resources are present. Limitations of mechanical treatment include fire risk and incidental combustion, pollution, spilling of hazardous materials from damaged or leaking equipment, and safety risk to operators. Hand removal is labor-intensive and ineffective for large treatment areas. Prescribed fire is another effective fuel reduction method; however, this treatment is most effective for reducing fuels in areas with vegetation less than three inches in diameter. Limitations of prescribed fire include air quality concerns and specific conditions required for management. Prescribed fire is not appropriate for all plant communities, such as sagebrush scrub, and can pose challenges in areas close to human habitation (Nader et al. 2007). Prescribed herbivory, or targeted grazing, is an effective fuel reduction technique in grassland, scrub, or woodland

habitat and when planned according to specific site conditions, may improve ecological health of the treatment area (Bartolome et al. 2014; Beck et al. 2015; Startin 2022).

Marin County is home to a wide variety of special-status plants and sensitive natural communities, and the consideration of these resources in fuel reduction planning efforts is integral to their conservation and maintenance of biological diversity (CDFW 2018). The potential impacts of livestock grazing on these sensitive resources, both positive and negative, may vary based on multiple environmental, site, and implementation factors. Sequoia prepared this report to provide an evaluation of grazing impacts on special-status plants, their habitats, and sensitive natural communities. Additionally, this report provides recommended Project Design and Implementation Features (PDIFs) developed by Marin Wildfire to avoid and minimize potential impacts on these resources that could result from proposed treatment activities (i.e., implementation of grazing regimes for fuel reduction).

2.3. Special-Status Plants and Sensitive Natural Communities in Marin County

Numerous special-status (i.e., threatened, endangered, rare) plant species and sensitive natural communities are known to occur in Marin County. Serpentine grasslands present near Mount Tamalpais and the surrounding watershed (NRCS 2021) support a diversity of special-status plant species, such as Marin dwarf flax (*Hesperolinon congestum*), jewelflowers (*Streptanthus* sp.), and paintbrushes (*Castilleja* sp.), which are the host plants for the federally threatened Bay checkerspot butterfly (*Euphydryas editha bayensis*; Inman 2020; Weiss 1999). Serpentine soils—nutrient-poor soils that support low-growing native vegetation while excluding non-native, invasive species—are the foundation of serpentine grassland habitat and are notably susceptible to disturbance. Potential threats to this sensitive natural community type include agriculture, high-intensity fire, air pollution, and various human activities. Serpentine-adapted plants may experience elevated levels of nitrogen pollution from agricultural runoff and vehicle emissions, as well as other anthropogenic sources. This pollution changes the soil chemistry, degrades the habitat quality for serpentine-adapted plant species, and, furthermore, creates opportunity for intrusion of non-native annual grasses and weeds (Hernández et al. 2016; Samojedny et al. 2022).

Non-serpentine annual and perennial grasslands of Marin County are considered sensitive natural communities, support special-status plant species, and are also characterized by high native plant diversity (Stein et al. 2000). Annual and perennial grasslands occur throughout the county but are more concentrated along the Point Reyes Peninsula east of Tomales Bay toward Bodega Bay, where they are recognized as coastal prairie habitat. One of the largest coastal prairie habitats in California is located along the 8-mile expanse between Tomales Bay and Bodega Bay (Amme 2008). These native grasslands historically have high rates of invasion by non-native, invasive plant species due to the low competitive ability of native species, high levels of human disturbance, and limited dispersal ability (Sage

Environmental Group 2020; Corbin and D'Antonio 2010; Seabloom et al. 2003). Encroachment of coyote brush (*Baccharis pilularis*), a native shrub species found in coastal scrub habitat in California, also poses a threat to grasslands as its establishment causes habitat type conversion. In the absence of the fire and grazing regimes that shaped Marin's sensitive natural grassland communities, adjacent coyote brush plants encroached over the last 200 years and continue to be a threat to sensitive annual and perennial grasslands today. Over the last 70 years, the encroachment of woody species such as coyote brush decreased remnant coastal grassland habitat in Marin County by 62 percent (Startin 2022).

Coastal scrub and maritime chaparral, once extensive along the Northern California coastline, were significantly reduced, and their ranges, increasingly fragmented, largely due to urbanization (Davis and Borchert 2006). In Marin County, these habitats are found in small patches within the fog belt. Coastal scrub habitat supports dozens of special-status plant and animal species, and maritime chaparral alone habitat hosts over 40 species of endemic manzanita, making these some of the most diverse woody communities in California (Vasey and Parker 2014; Sawyer et al. 2009). In the absence of regular low-intensity fire and/or grazing regimes that maintain ecological health of these communities, coastal scrub and maritime chaparral habitats are more vulnerable to invasion by non-native species (D'Antonio et al. 1993). Invasive species within chaparral and coastal scrub communities also begin to encroach upon adjacent grassland and woodland habitats if left untreated (Ford and Hayes 2007). Of these two habitat types, the less dense coastal scrub is considered more vulnerable to exotic invasion than chaparral; however, factors such as climate change and lack of fire and/or grazing regimes impact scrub and chaparral similarly (Lambrinos 2002; Cornwell et al. 2012).

Other habitat types known to occur in Marin County, such as wetlands and coastal dunes, also support special-status plants and sensitive resources. However, these habitats are not at risk of high-intensity wildfire and are not targeted by prescribed herbivory for fuel reduction efforts. Similarly, conifer forest and hardwood forest habitats support sensitive resources, but grazing is not considered an effective treatment strategy in these habitat types unless the target vegetation is small-diameter fuels or shrubs and brush (RMAC 2015).

3.0 NEGATIVE IMPACTS OF GRAZING

Studies show that improperly managed grazing may result in soil compaction and erosion, nutrient deposition, introduction of pathogens, physical damage to plants via herbivory and trampling, increased turbidity in wetlands, and changes in the water regime and nutrient cycling. These potential impacts are expanded upon below.

3.1. Soil Compaction and Erosion

Soil compaction and erosion impacts may vary based on the site conditions and the grazing species utilized. Steep slopes and sensitives natural communities are more susceptible to soil compaction and erosion, and cattle may be more likely to cause damage in these ways. Cattle grazing may denude the substrate of vegetation and create exposed, loose soils that are more susceptible to erosion, in turn causing sedimentation of adjacent aquatic features (Morris and Reich 2013; Bush 2006). Additionally, trampling that occurs during cattle grazing results in the compaction of soils, which may lead to an overall increase in annual plant cover, including cover by invasive annual species, which are better adapted to this type of disturbance than native species. The duration of grazing also significantly affects the intensity of soil compaction—areas that experience long-term grazing exhibit higher levels of soil compaction and recover significantly slower than areas exposed to short-term grazing (Morris and Reich 2013). However, areas exposed to intensive, long-term grazing can recover from soil compaction as quickly as 2 years after excluding livestock (Sharrow 2007).

3.2. Nutrient Deposition and Introduction of Pathogens

Grazing animals deposit urine and feces as they move across the landscape. This deposition may degrade water quality; introduce excess nutrients and pathogens, such as disease-causing bacteria or viruses; and increase nutrient loading in nearby waterways (Morris and Reich 2013). In sensitive serpentine outcrops, naturally high levels of heavy metals and low levels of essential nutrients aid the exclusion of invasive species, but the addition of nutrients from animal feces may negatively impact these inherently sensitive systems by altering the soil chemistry (Hernández et al. 2016). Additionally, studies suggest that increased atmospheric nitrogen deposition from air pollution poses a greater risk of nutrient intrusion into serpentine systems (Bush 2006). In wetland and riparian systems, a measurable increase in nutrient levels of directly grazed waterways is observed compared to waterways that are excluded from grazing by means of fencing (Morris and Reich 2013). However, in areas where historic fertilizer use is already high, there is no observable change in nutrient levels. The addition of nitrogen, either from anthropogenic activity or grazing animal deposition, negatively impacts sensitive natural communities and reduces ecosystem resilience.

Despite the potential for nutrient deposition, grazing is recognized as an essential tool for invasive species management within serpentine grasslands and wetlands when implemented with appropriate consideration (Morris and Reich 2013; Sage Environmental Group 2020; LD Ford 2018; Huntsinger et al. 2007). Excessive nutrient and pathogen pollution from animal waste that may cause health risk to aquatic habitats and sensitive plant and animal species within them typically occurs when livestock are confined and waste is concentrated near waterways. Thus, intentional exclusion of grazing livestock from waterways can reduce the impact of nutrient and pathogen introduction (Bush 2006).

3.3. Direct Herbivory and Trampling

Grazing may impact sensitive plants by direct physical damage (e.g., herbivory and trampling). Unfavorable impacts of herbivory and trampling vary by habitat type, grazing intensity, duration of grazing, type of grazing livestock, and topography. Grazing pressure, or the impact that grazing will have on a landscape, also varies by the grazing species. The direct herbivory impact of one cow is approximately equivalent to eight sheep or eleven goats. Furthermore, goats have a lower trampling impact than cattle. In consideration of the lower direct herbivory and reduced trampling impact, the use of goats for grazing eases grazing pressure (Burritt and Frost 2006). Direct herbivory and trampling may also cause damage to special-status plants if grazing occurs during the blooming period (CDFW 2018).

Sensitive natural communities that evolved under the influence of grazing by large ungulates are better adapted to the impacts of trampling; therefore, in these environments, grazing is less likely to eliminate a particular species or negatively affect overall plant diversity (Morris and Reich 2013). Historical exposure of a sensitive community to grazing likely influenced that habitat to be more resilient under grazing pressure (Lunt et al. 2007). Prescribed herbivory may benefit environments that co-evolved with ungulates if grazing is carefully planned to mimic the impacts of trampling and direct herbivory that occurred during the evolutionary history of that system.

3.4. Non-native Seed Dispersal

Invasive plant seeds are often dispersed by methods such as physical attachment to fur, consumption and excretion, or spread by vehicles used to tend and transport livestock when those vehicles become contaminated with feces and dirt. Dispersal of non-native, invasive seeds is more detrimental when utilizing cattle as compared to sheep or goats for grazing. Cattle feces provide suitable conditions for germination of seeds, but the small fecal pellets produced by sheep and goats do not create conditions as conducive to seed germination and establishment. In either case, there is a risk of mechanical dispersal of non-native seeds via fur or hooves (Morris and Reich 2013).

In a study on goat consumption, 10 percent of ingested seeds survived the passage through the digestive system and were still viable after excretion (Karrington et al. 2011). Viability after excretion varied by plant species consumed, and all seeds passed through the goats within 72 hours. Therefore, goats consuming the seeds of invasive species may spread viable seed if they are moved between grazing locations within three days. Goats prefer immature seed heads, reducing the likelihood of viable seeds surviving the gut of goats and germinating after excretion (Huntsinger et al. 2007). The risk of invasive species spreading between sites via goat consumption and subsequent defecation of seeds is relatively low due to the herbivory preference and function of goat digestive systems (Harrington et al. 2011; Holst et al. 2004).

4.0 BENEFITS OF PRESCRIBED HERBIVORY

4.1. Native Plant Community Diversity

Grazing benefits native plant diversity and the general health of systems evolved in the presence of megaherbivores and ungulate herbivores, such as native California grasslands (Bartolome 2014). When planned appropriately, grazing can deliver ecological benefits such as invasive species management, prevention of habitat type conversion by adjacent scrub and chaparral communities, and promotion of serpentine grassland diversity (Beck et al 2015). Presently, land managers in California carefully consider timing, duration, grazing species, and frequency of grazing to steward landscapes with the goal of increased native diversity (Sage Environmental Group 2020). Goats preferentially consume shrubs and can reduce shrub encroachment into grasslands and improve diversity and density of native species compared to ungrazed areas (Huntsinger 2007; Bartolome et al. 2014; D'Antonio 2015; Startin 2022).

Exclusion of sensitive natural communities and resou from grazing will reduce negative impacts (Bush 2006; Sage Environmental Group 2020). Additionally, different grazing species may naturally exclude areas that are not preferential, such as how sheep tend to avoid grazing in wet areas even without fencing (Burritt and Frost 2006). Fencing can effectively exclude grazing goats from wet areas prone to compaction, serpentine or riparian areas sensitive to nutrient disturbance, or habitats containing sen ve plants.

Under well-managed timelines and treatment regimes, grazing may be beneficial to serpentine grasslands (LD Ford 2018). In this sensitive natural community, grazing leads to reduced s cover, increased native species richness, and greater native forb cover compared to ungrazed communities (Beck et al. 2015). If managed with short-duration grazing at a low to moderate intensity and timed to avoid sensitive species blooming periods, grazing in serpentine grasslands may mediate the effects of nitrogen deposition from smog by reducing the abundance of exotic annual grasses and favoring native perennial grasses and endemic forbs (LD Ford 2018; Pasari 2014). However, grazing in serpentine grasslands is limited by availability of suitable forage for livestock, tripping hazards to grazing livestock, and presence of woody species that do not recover quickly from defoliation and trampling.

4.2. Wildfire Fuel Reduction

Prescribed herbivory reduces fine, herbaceous fuel loads and can be used to establish strategic fuel breaks in areas where mec cal treatment is not feasible, such as in steep terrain inaccessible to mechanized equipment (Schachtschneider et al. 2024; Lovreglio et al. 2014). Grazing reduces combustible biomass and fine fuels, resulting in shorter flame length and decreased fire intensity and spread (Ratcliff et al. 2022; Lovreglio et al. 2024). Goat grazing is the most environmentally friendly, cost effective, non-toxic, and non-polluting solution to fuel reduction (Lovreglio et al. 2014). Grazing, in combination with mechanical and

manual treatments, may be the most effective and feasible technique available for fuel break maintenance and, if carefully planned and implemented, could be useful in habitat enhancement of grassland communities, including rare and native plant species (LD Ford 2018). Limitations of grazing on wildfire fuel reduction include manual removal of dead biomass and less effectiveness in reducing ignition risk (Fire Safe Marin 2021; Lovreglio et al. 2014).

Furthermore, the combination of prescribed burns and prescribed herbivory is an efficient management practice for maintaining native plant communities while reducing non-native species (Hernández et al. 2021). This combination of treatments mimics historical evolutionary conditions and contributes to ecological health of these sensitive natural communities by elimination of non-native biomass and increased native forb recruitment from the native seed bank awaiting suitable environmental conditions (Hernández et al. 2021). Once treated, regular prescribed herbivory offers low cost and minimal impact maintenance of fuel reduction zones (Huntsinger et al. 2007).

4.3. Control of Invasive Species

Aside from habitat loss, invasive plants are the most significant threat to native plant species, special-status plant species, and sensitive natural communities. Prescribed herbivory, either utilized independently or in combination with other methods, can be an effective tool to reduce invasive species, prevent the continued spread of non-native and invasive plants, and protect known sensitive plant populations in California grassland and scrub communities (CDFW 2021). The Bureau of Land Management, the National Park Service, and private landowners use livestock grazing to achieve fuel reduction, control invasive species, improve rangeland health, and promote biodiversity (Huntsinger et al. 2007). Additionally, timed grazing of cattle, sheep, and goats reduced populations of yellow starthistle (*Centaurea solstitialis*) and the cover and height of invasive shrubs (Thomsen 1993; Rathfon et al. 2021). Since its introduction to California in the mid-1800s, yellow star thistle has spread throughout the state and now infests over 8 million acres (Thomsen et al. 1993). This spiny, noxious weed is categorized as “Highly Invasive” on the California Invasive Plant Council’s Invasive Plant Inventory (Cal IPC 2022). Yellow star thistle germinates in the fall with seasonal rains but does not become spiny and inedible to goats until late May or June. Therefore, targeted goat grazing treatments in areas infested with yellow star thistle are most effective when timed between September and May (Thomsen et al. 1993).

Chosen livestock species, existing vegetation community, grazing timing, and grazing intensity determine the effectiveness of grazing for non-native and invasive plant species. French broom (*Genista monspessulana*)—a woody invasive plant with the potential to cause habitat type conversion and increase the intensity and severity of wildfires—is unpalatable to most livestock but readily consumed by goats (Cal-IPC 2021; Holst et al. 2004; Oneto et al. 2020). Goats reduce the size, vigor, and seed dispersal of broom due to defoliation of shoots and removal of bark and should be utilized during the flowering period

of these woody shrubs, which typically occurs between March and May (LD Ford 2018; Holst et al. 2004). As versatile foragers, goats are particularly effective livestock for invasive species control. They consume invasive annual species, including artichoke thistle (*Cynara cardunculus*), black mustard (*Brassica nigra*), ripgut brome (*Bromus diandrus*), wild oat (*Avena barbata*, *A. fatua*), and wild radish (*Raphanus* spp.), all of which may be unpalatable to other livestock (Sage Environmental Group 2020). Goats preferentially consume seedlings, preventing invasive species from reaching maturity, seeding, and spreading (Huntsinger et al. 2015). Degraded native grasslands and bunchgrasses, such as purple needlegrass (*Stipa pulchra*), are threatened by encroachment of invasive species, such as Italian rye grass (*Festuca perennis*), wild oat, and ripgut brome. Grazing can be used to reduce these commonly encountered invasive species and increase native cover (Gennet et al. 2017).

Limited and carefully timed grazing can be utilized to help restore non-native grassland and increase native plant diversity (Bartolome 2013; Menke 1992). In Carmel, California, a long-term grazing study conducted within coastal grasslands revealed a 6 percent decrease in ripgut brome and an increase in native annual forb cover when compared to similar ungrazed plots (Evans et al. 2023). Properly applied grazing pressure better suits native plants that historically evolved with similar pressure and may increase native species cover by reducing competitive ability of non-native species. When planned with consideration to site specifics, target vegetation, goals, and limitations, grazing may be beneficial for native vegetation communities and special-status plant species.

5.0 PLANNING A GRAZING PROJECT

Site conditions, sensitive resources, composition of existing vegetation, plant palatability, and seasonal growth patterns are considered when planning prescribed herbivory as a fuel reduction treatment. Additionally, timing of grazing activity; duration of grazing; grazing intensity; site selection; and herd exclusion, containment, and movement are important considerations prior to implementation. These considerations are explored further below.

5.1. Seasonal Timing of Grazing

Appropriate timing of grazing implementation can maximize effectiveness of biomass reduction and prevention of invasive species spread. Mid-spring or mid-fall is the optimal season for grazing as annual grasses are green, flowering, and palatable to goats, but this timing is species-specific and must be considered for your target species (Freese and Cope 2019). If grazing is implemented too early in the plant's blooming cycle, target forage plant species may resprout, flower, and seed, while grazing too late may may miss the opportune window to prevent seeding. Another consideration is the frequency of grazing within a season and across multiple seasons. To reduce invasive annual grass seeding in coastal California grasslands, grazing is best utilized during the months of March–May, should consist of several

rotations during the spring, and should be repeated annually (Daines 2006). Seasonal timing of grazing must also be considered in conjunction with the species selected for grazing treatment.

5.2. Livestock Selection, Diet, and Limitations of Grazing Effectiveness

Planners assess the presence of invasive plant populations in a targeted treatment site and consider and desired biodiversity outcomes when selecting livestock for a fuel reduction project. Goats, sheep, and cattle can all be effective in fuel reduction, but managers should be careful to select the appropriate livestock species to produce the desired result. Goats and sheep are less selective than larger livestock when it comes to forage of grasses, forbs, and woody plants, and goats consume more woody plants, shrubs, and leaves than sheep or cattle (Daines 2006). If grazing activities are planned for the fall, goats are preferable over sheep and cattle because their diversified diets and strong digestive systems allow them to target non-native annual grasses, as well as invasive forbs, such as yellow star thistle (Daines 2006; Thomsen et al. 1993). Cattle and horses primarily consume grass and are not effective browsers of plant species typically found within scrub and forest communities (Burritt and Frost 2006). Sheep eat a relatively higher diversity of plants, including grass species that are unpalatable to cattle and forbs, including yellow star thistle and leafy spurge (*Euphorbia virgata*). In addition, sheep can graze in steeper topography than cattle and avoid marshy or wet areas without fencing. Goats have the greatest adaptability of diet as their strong jaws and digestive systems are designed for chewing and digesting tough, woody plants, including blackberry (*Rubus* spp.), poison oak (*Toxicodendron diversilobum*), and coyote brush.

While sheep tend to graze on forbs and cattle typically prefer grasses, goats are versatile feeders who will graze on woody plants, grasses, and plants with chemical defenses (Burritt and Frost 2006; Morris and Reich 2013). Goat browsing prevents plants from reaching maturity, leading to the reduction of seed banks of exotic weeds and grasses (Hart 2001). Goats feed on a variety of shrubs, some of which are not consumed by other grazing species, and are more likely to graze plants that are considered hazardous fuels due to their preference for woody plants (Lovreglio et al. 2014). Furthermore, goats are the most agile of common grazing livestock species and are better able to access steep slopes than cattle or sheep (Burritt and Frost 2006). For these reasons, goats are most frequently selected for fuel reduction grazing practices.

However, goat grazing is not feasible or practical in all habitat types, such as dense conifer forests with little understory browse, or in cold, wet environments where goats may become susceptible to illness (Bush 2006). Grazing with goats, especially at moderate intensity levels, may reduce the likelihood of quickly spreading wildfire, shorten flame length, and reduce fire intensity by decreasing the presence of fine fuels, but it does not reduce the risk of fire ignition (Lovreglio et al. 2014). Generally, no livestock, regardless of species, consume dead vegetation. Therefore, areas with heavy accumulation of dead biomass likely require manual removal of these fuels to ensure that the treatment area is cleared of hazardous dead vegetation (Fire Safe Marin 2021).

5.3. Grazing Intensity

The stocking rate (number of animals grazing) and grazing period are considered in conjunction to achieve the desired grazing intensity of the prescribed grazing regime. Grazing intensity is measured by light, moderate, or high intensity, and the ideal intensity for treatment is determined by the site characteristics, existing vegetation, and desired outcomes. High-intensity, short-term grazing can be very effective in selective weed control, but this method of treatment is not as effective in long-term invasive species control as compared to low-intensity, longer-duration grazing. Alternatively, low-intensity, long-term grazing occurs in a less controlled environment than short-term grazing and therefore can lead to unintended consequences, such as consumption of desired or special-status plant species (Thomsen et al. 1993). When planning prescribed herbivory treatment, land managers consider the costs and benefits of weed control versus the risk of direct impact to existing sensitive resources. Methods to control grazing intensity for increased benefits and reduced risk of harmful impacts are employed, such as temporary exclusion to protect sensitive resources, including special-status species populations, sensitive natural communities, and areas designated as critical habitat for protected species (Freese and Cope 2019).

6.0 GRAZING TO SUPPORT MARIN WILDFIRE FUEL REDUCTION ACTIVITIES

Marin Wildfire prepared the following PDIFs to avoid and minimize potential impacts on sensitive plant species and natural communities because of treatment activities, particularly grazing. These measures were developed in collaboration with a team of experts, stakeholders, and members of the public and continue to undergo revision as new information and research improves understanding of design and implementation. Projects are reviewed on a case-by-case basis, and PDIFs are incorporated into planning as relevant. The following PDIFs may not be applicable to all projects involving grazing, nor do they represent all measures that may be applicable to a fuel reduction project. Please refer to the project-specific environmental documents to review measures specific to each individual project. Relevant measures related to prescribed herbivory and protection for sensitive plant species are provided below.

ET-1: Environmental Training for Biological Resources

All crew members and contractors will receive training from a qualified registered professional forester (RPF) or biologist prior to beginning a treatment project where sensitive biological resources could occur in the work areas. The training will describe the appropriate work practices necessary to effectively implement the appropriate project design and implementation features and to comply with the applicable environmental laws and regulations. The training will include the identification, relevant life history information, and avoidance of potentially present special-status species with potential to occur; identification and avoidance of sensitive natural communities and habitats with the potential to occur in the treatment area; best management

practices; and reporting requirements. As appropriate, the training will include protocols for work, such as specific trimming methods, where applicable. The training will instruct workers when it is appropriate to stop work and allow wildlife encountered during treatment activities to leave the area unharmed and when it is necessary to report encounters to a qualified RPF or biologist. The qualified RPF or biologist will immediately contact the California Department of Fish and Wildlife (CDFW) or United States Fish and Wildlife Service (USFWS), as appropriate, if any wildlife protected by the CE Species Act (CESA) or Federal Endangered Species Act (ESA) is encountered and cannot leave the site on its own (without being handled).

ES-1: Environmental Surveys for Rare Plants:

Within areas where rare and special-status plants have a moderate to high potential to occur, based on desktop data of habitat types, known site-specific information, and the professional judgment of qualified biologists, surveys will be conducted prior to any activity that has the potential to damage perennial plants or is proposed to occur during the flowering season for the specific annual plant species that has the potential to damage the flowering body and seeds of these plant species. Activities that have the potential to damage the flowering body may include but may not be limited to mowing, weed whacking, off-road vehicle and heavy equipment use, discing, and prescribed burning.

Surveys for rare plants will occur for these species across the entire project footprint. Surveys will occur during the blooming period, if feasible, and will occur prior to work for the specified special-status plant. If blooming period surveys are not feasible and the sensitive plant in question can be keyed to genus outside of the blooming period, surveys will be conducted for all members of the genus. Individuals will be flagged for avoidance or modified methods. Physical avoidance will include flagging, fencing, stakes, or clear, existing landscape demarcations (e.g., edge of a roadway) to delineate the boundary of the avoidance area around the suitable habitat and removal after completion. For physical avoidance, a buffer may be implemented as determined necessary by the biologist. Sensitive species damage or loss avoidance may include implementation of appropriate species-specific no-activity buffers around sensitive resources. Temporary fencing will also be implemented, as and where determined necessary based on the species tolerance, if grazing is prescribed in the area of flagged individuals for avoidance or modified methods (WILD-1).

IP-1: Clean Equipment

All crew members, surveyors, and other personnel on site related to project activities will clean clothing, footwear, and equipment used during treatments of soil, seeds, vegetative matter, other debris or seed-bearing material, or water (e.g., rivers, streams, creeks, lakes) before entering the

treatment area or when leaving an area with infestations of invasive plants, noxious weeds, known plant pathogens, or invasive wildlife.

IP-2: Prevent the Spread of Invasive Species and Plant Pathogens

Segregate and treat soils and vegetation contaminated with invasive plant seeds and propagules. Treat, as appropriate, to prevent the spread of invasive plants. Treatment may include disposal on site within already infested areas, chipping or pile burning and mulching to eliminate viable seeds, or disposal at an approved cogeneration plant or green waste facility. Minimize soil disturbance to the greatest extent possible to reduce the potential for introducing or spreading invasive plants or plant pathogens, to protect topsoil resources, and to reduce available habitat for the establishment of new invasive plants.

IP-3: Treat Invasive Plants Prior to Seeding

Schedule activities to maximize the effectiveness of control efforts and minimize introduction and spread of invasive plants as feasible, with consideration for project objectives and location (e.g., install and maintain fuel breaks, disc lines, and other work before non-native plants set seeds).

IP-4: Retain Native Plants

When removing vegetation, focus first on removing invasive and highly flammable species, and dead or diseased vegetation. Retain beneficial, low-fire risk, healthy native plant species whenever possible, except where the historic disturbance regime for the vegetation community has not been maintained or the vegetation poses a hazard to the public.

GEO-1: Erosion and Soils Loss Stabilization Measures

Soils will be stabilized if a vegetation management activity may leave less than 70 percent groundcover or native mulch/organic material.

For areas between 50 percent and 70 percent ground cover left:

- Sow native grasses and other suitable native vegetation on denuded areas where natural colonization or other replanting will not occur rapidly; use slash or chips to prevent erosion on such areas.
- Use surface mounds, depressions, logs, rocks, trees and stumps, slash and brush, the litter layer, and native herbaceous vegetation downslope of denuded areas to reduce sedimentation and erosion, as necessary to prevent erosion or slope destabilization.
- Install approved, biodegradable erosion-control measures and non-filament-based geotextiles (e.g., coir, jute) when:

- Conducting substantial ground-disturbing work (e.g., use of heavy equipment, pulling large vegetation) within 100 feet and upslope of currently flowing or wet wetlands, streams, lakes, and riparian areas;
- Causing soil disturbance on moderate to steep (10 percent slope and greater) slopes; and
- Removing invasive plants from stream banks to prevent sediment movement into watercourses and to protect bank stability.

- Sediment-control devices, if installed, will be certified weed-free, as appropriate. Sediment control devices will be inspected daily during active work to ensure that they are repaired and working as needed to prevent sediment transport into the waterbodies.

For areas with less than 50 percent ground cover:

- Any of the above measures
- Stabilize with mulch or equivalent immediately after project activities to the maximum extent practicable.
- If project activities could result in substantial sediment discharge from soil disturbance, as determined by the qualified personnel (e.g., RPF), organic material from mastication or mulch will be incorporated onto at least 75 percent of the disturbed soil surface where the soil erosion hazard is moderate or high, and 50 percent of the disturbed soil surface where soil erosion hazard is low to help prevent erosion.
- Where slash mulch is used, it will be packed into the ground surface with heavy equipment so that it is sufficiently in contact with the soil surface.
- Once work is completed, the areas will be inspected at least annually if accessible, until groundcover exceeds 70 percent or slopes have stabilized, as determined by a qualified professional. At that time, erosion-control and slope-stability devices may be removed.

GEO-1: Erosion and Soils Loss Stabilization Measures

Methods will be implemented to reduce the potential creation of prescribed herbivory trails and erosional features, including the following:

- Implement methods, which could include rotating or providing multiple feeding areas and providing multiple watering stations to minimize excessive congregation of animals in any one location for too long, as determined by a qualified professional.
- If prescribed herbivory trails or damaged areas form, the bare area will be remediated by decompacting the soil and discontinuing prescribed herbivory in the area until the trails are revegetated, as determined by a qualified professional.
- Manage livestock grazing on steep slopes (generally slopes with more than 35 percent grade) to reduce potential for erosion. Management can include (but is not limited to)

reducing or limiting the number of animals or duration on slopes above 35% (using stocking equation) to avoid erosion and avoid placing water and feeding troughs on steep slopes.
- Grazing will not occur during a storm event or under muddy conditions, when hooves may sink into the ground.

HYD-1: Prescribed Herbivory Treatments

The following water quality protections will apply for all prescribed herbivory treatments:

- Limit the duration of prescribed herbivory within 50 feet of lakes/reservoirs, creeks, streams, riparian corridors, and wetlands to prevent soil erosion that could affect water quality (see SH-1)
- Water will be provided for grazing animals in the form of an on-site stock pond or a portable water source located outside of environmentally sensitive areas.
- Treatment prescriptions will be designed to protect soil stability. Grazing animals will be herded out of an area if accelerated soil erosion is observed.

WILD-1: Temporary Fencing

If temporary fencing is required for prescribed herbivory treatment, a wildlife-friendly recyclable fencing design will be used. The design should consider the following:

- Minimize the chance of wildlife entanglement by minimizing barbed wire, loose or broken wires.
- If feasible, keep electric netting-type fencing electrified at all times or laid down while not in use.
- Charge temporary electric fencing with intermittent pulse energizers.
- Allow wildlife to jump over easily without injury by installing fencing that can flex as non-target animals pass over it and installing the top wire low enough (no more than approximately 40 inches high on flat ground) to allow adult ungulates to jump over it, while keeping grazing animals safely within the fence. The determination of appropriate fence height will consider slope, as steep slopes are more difficult for wildlife to pass.
- Fences should be highly visible to birds and mammals by using high-visibility tape or wire, flagging, or other markers.

SH-2: Grazing and Sensitive Habitats

Avoid grazing in sensitive habitats, including serpentine-associated communities, chaparral, and across waterways, and within a 50-foot buffer if there is a need for protection of riparian vegetation from grazing. Limited grazing may be allowed if it would be beneficial to plant and

wetland communities, including serpentine-associated communities, without causing harm (e.g., removal of invasive species) or resulting in erosion.

7.0 CONCLUSION

Livestock grazing can be a powerful tool for fuel reduction and provides a cost-effective and efficient strategy for the reduction of fuels in the urban-wildland interface. While there are limitations to prescribed herbivory and grazing in sensitive natural communities, the relatively fast speed, low cost, and low environmental risk of this treatment poises this method as a preferred approach to manual or mechanical methods in many grassland habitats. Additionally, prescribed herbivory offers land managers another method that can be used in conjunction with other treatment methods to improve desired outcomes. When implemented in consideration of treatment site conditions and sensitive resources, grazing can effectively reduce accumulated fuel loads to aid in wildfire risk reduction and prevention, control the establishment and spread of non-native and invasive species populations, and support reestablishment and protection of native plant species and sensitive natural communities.

8.0 REFERENCES

Amme, David. 2008. The Grasses and Grasslands of Marin and Sonoma Counties. Grasslands: Winter 2008. https://cnga.org/resources/Documents/Grasslands%20Journal/Grasslands%20Articles/Amme_Grass%20of%20Marin%20and%20Sonoma_Grasslands%20Winter%202008.pdf.

Bartolome, J.W., B.H. Allen-Diaz, S. Barry, L.D. Ford, M. Hammond, P. Hopkinson, F. Ratcliff, S. Spiegal, and M.D. White. 2014. Grazing for Biodiversity in California Mediterranean Grasslands. Rangelands 36(5):36–43.

Beck, Jared J., D.L. Hernández, J.R. Pasari, and E.S. Zavaleta. 2015. Grazing Maintains Native Plant Diversity and Promotes Community Stability in an Annual Grassland. Ecological Society of America 25(5):1259–1270. https://www.jstor.org/stable/24432127.

Burritt, E., and R. Frost. 2006. Animal Behavior, Principles and Practices. In, Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement, K. Launchbaugh (ed.). American Sheep Industry Association (ASI). Centennial, CO.

Bush, Lisa. 2006. Grazing Handbook: A Guide for Resource Managers in Coastal California. Sotoyome Resource Conservation District, California State Coastal Conservancy.

California Department of Fish and Wildlife (CDFW). 2018. Protocols for Surveying and Evaluating Impacts to Special-Status Native Plant Populations and Sensitive Natural Communities. State of California. California Natural Resources Agency. Department of Fish and Wildlife. March 20, 2018. 12 pps.

California Invasive Plant Council (Cal-IPC). 2022. Inventory of invasive, non-native plants that threaten natural areas in California. http://www.cal-ipc.org/ip/inventory.

Corbin, Jeffrey D., and Carla D'Antonio. 2010. Not Novel, Just Better: Competition Between Native and Non-Native Plants in California Grasslands that Share Species Traits. Plant Ecology 209:71–81.

Cornwell, W.K., S. Stuart, A. Ramirez, C.R. Dolanc, J.H. Thorne, and D.D. Ackerly. 2012. Climate Change Impacts on California Vegetation: Physiology, Life History, and Ecosystem Change (California Energy Commission Publication No. CEC-500-2012-023). Retrieved from California Energy Commission website: http://www.energy.ca.gov/2012publications/CEC-500-2012-023/CEC-500-2012-023.pdf.

Daines, Ron. 2006. Reader's Guide to the Targeted Grazing Handbook. https://www.webpages.uidaho.edu/rx-grazing/handbook/Reader's_Guide.pdf.

D'Antonio, C.M., D.C. Odion, and C.M. Tyler. 1993. Invasion of Maritime Chaparral by the Introduced Succulent Carpobrotus edulis. Oecologia 95:14–21.

Davis, F.W., and M.I. Borchert. 2006. Central Coast Bioregion. In, Fire in California's Ecosystems, N.G. Sugihara, J.W. van Wagtendonk, K.E. Shaffer, J. Fites-Kaufman, and A.E. Thode (eds.). University of California Press, Berkeley.

Evans, A.W., B.D. Woodward, A.C. Wyckoff, D. Toledo, S. Duke, C. Fischer, C. Núñez, and R. Sierra-Corona. 2023. Livestock grazing is an effective conservation tool for Californian coastal grassland ecology: An eight-year study on vegetation dynamics. *Applied Vegetation Science*, 26, e12736. https://doi.org/10.1111/avsc.12736.

Fire Safe Marin. 2020. Community Wildlife Protection Plan. December 2020. https://firesafemarin.org/resources/marin-community-wildfire-protection-plan/.

———. 2021. Adapt to Wildfire. November 19, 2021. https://firesafemarin.org/.

Ford, L.D., and G.F. Hayes. 2007. Northern Coastal Scrub and Coastal Prairie. In, Terrestrial Vegetation of California, Third Edition, M.G. Barbour, T. Keeler-Wolf, and A.A. Shoenherr (eds). University of California Press, Berkeley.

Freese, R., and A. Cope. 2019. Grazing for Wildland Management. California Invasive Plant Council Symposium presentation slides.

Gennet, Sasha, Erica Spotswood, M. Hammond, and J.W. Bartolome. 2017. Livestock Grazing Supports Native Plants and Songbirds in a California Annual Grassland. PLoS ONE 12:e0176367. https://doi.org/10.1371/journal.pone.0176367.

Harrington, K.C., W.B. Beskow, and J. Hodgson. 2011. Recovery and viability of seeds ingested by goats. New Zealand Plant Protection. 64:75–80.

Hart, S.P. 2001. Recent Perspectives in Using Goats for Vegetation Management in the USA. Journal of Dairy Science 84:E170-E176.

Hernández, Daniel L., D.M. Vallano, E.S. Zavaleta, Z. Tzankova, J.R. Pasari, S. Weiss, P.C. Selmants, and C. Morozumi. 2016. Nitrogen Pollution is Linked to U.S. Listed Species Declines. BioScience 66(3):213222.

Hernández, Eliza, E.A. Shaw, L. Aoyama, A. Brambila, C. Niederer, S.B. Weiss, and L.M. Hallett. 2021. Fire Versus Grazing as Tools to Restore Serpentine Grasslands Under Global Change. Society for Ecological Restoration. Restoration Ecology.

Holst, P.J., C.J. Campbell, M.H. Campbell, and A.R. Gilmour. 2004. Grazing of pasture weeds by goats and sheep. 2. Scotch broom (Cystisus scoparius L.) Australian Journal of Experimental Agriculture. 44(6) 553–557.

Huntsinger, Lynn, J.W. Bartolome, and C.M. D'Antonio. 2007. Grazing Management on California's Mediterranean Grasslands. In, California Grasslands: Ecology and Management, M. Stromberg (ed.). Pp. 233–253.

Inman, John. 2020. Native Species Response to Goat Foraging in a Shrub-Invaded California Coastal Grassland. AES Theses.

Karrington, K.C., W.B. Beskow, and J. Hodgson. 2011. Recovery and Viability of Seeds Ingested by Goats. Institute of Natural Resources, Massey University, PB 11-222, Palmerston North, New Zealand.

Lambrinos, J.G. 2002. The Variable Invasive Success of Cortaderia Species in a Complex Landscape. Ecology 83(2): 518–529. https://www.jstor.org/stable/2680032?seq=1#page_scan_tab_contents.

LD Ford Rangeland Conservation Science (LD Ford). 2018. Grazing Feasibility Study for the Mt. Tamalpais Watershed. Marin Municipal Water District, California. Prepared for Marin Municipal Water District.

Lovreglio, Raffela, Ouahiba Meddour-Sahar, and Vittorio Leone. 2014. Goat Grazing as a Wildfire Prevention Tool: A Basic Review. iForest – Biogeosciences and Forestry. Technical Notes – doi: 10.3831-ifor1112-007.

Lovreglio, R., J. Lovreglio, G.G.A. Satta, M. Mura, and A. Pulina. 2024. Assessing the Role of Forest Grazing in Reducing Fire Severity: A Mitigation Strategy. *Fire*, *7*(11), 409. https://doi.org/10.3390/fire7110409.

Lunt, Ian D., David J. Eldridge, John W. Morgan, and Bradd G. Witt. 2007. A Framework to Predict the Effects of Livestock Grazing and Grazing Exclusion on Conservation Values in Natural Ecosystems in Australia. Australian Journal of Botany 55:401–415.

Morris, K., and P. Reich. 2013. Understanding the Relationship Between Livestock Grazing and Wetland Condition. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria. Technical Report Series No. 252.

Nader, G., Z. Henkin, E. Smith, R. Ingram, and N. Narvaez. 2007. Planned herbivory in the management of wildfire fuels. Rangelands 29:18–24.

Natural Resources Conservation Service (NRCS). 2021. Soil Survey Staff. Gridded National Soil Survey Geographic (gNATSGO) Database for the Conterminous United States. U.S. Department of Agriculture, Natural Resources Conservation Service. https://nrcs.app.box.com/v/soils.

Oneto, S.R., J.M. DiTomaso, and G.B. Kyser. 2020. UC IPM Pest Notes: Brooms. UC ANR Publication 74147. Oakland, CA.

Pasari, Jae R. 2014. Interactive Effects of Nitrogen Deposition and Grazing on Plant Species Competition in a Serpentine Grassland. Rangeland Ecology Management 67:693–700.

Rangeland Management Advisory Committee (RMAC). 2015. Prescribed Herbivory for Vegetation Treatment Projects. Board of Forestry and Fire Protection. https://bof.fire.ca.gov/media/7208/white-paper.pdf.

Ratcliff, F., D.R. Rao, S.J. Barry, S. Dewees, L. Macaulay, R. Larsen, M Shapero, R. Peterson, M/ Moritz and L. Forero. 2022. Cattle grazing reduces fuel and leads to more manageable fire behavior. *California Agriculture*, 76(2–3). http://dx.doi.org/10.3733/ca.2022a0011 Retrieved from https://escholarship.org/uc/item/3cf6r40v.

Sage Environmental Group. 2020. Prescribed Goat Grazing for Wildland Management. YouTube, uploaded by Sage Environmental Group. November 16, 2020. https://www.youtube.com/watch?v=peiJCW80E44.

Samojedny, T.J., M. Devlin, R. Shane, and N. Rajakaruna. 2022. The Effects of Nitrogen Enrichment on Low-Nutrient Environments: Insights from Studies of Serpentine Soil-Plant Relations. In: Naeem, M., Bremont, J.F.J., Ansari, A.A., Gill, S.S. (eds) Agrochemicals in Soil and Environment. Springer, Singapore. https://doi.org/10.1007/978-981-16-9310-6_13.

Sawyer, J.O., T. Keeler-Wolf, and J. Evens. 2009. Manual of California Vegetation. Sacramento, CA: California Native Plant Society Press. http://www.cnps.org/cnps/vegetation/manual.php.

Schachtschneider, C.L., E.K. Strand, K.L. Launchbaugh, and S. Jensen. 2024. Targeted Cattle Grazing to Alter Fuels and Reduce Fire Behavior Metrics in Shrub-Grasslands. Rangeland Ecology and Management.

Seabloom, Eric W., W. Stanley Harpole, O.J. Reichman, and David Tilman. 2003. Invasion, Competitive Dominance, and Resource Use by Exotic and Native California Grassland Species. PNAS 100(23):13384–13389.

Sharrow, Steven. 2007. Soil Compaction by Grazing Livestock in Silvopastures as Evidenced by Changes in Soil Physical Properties. Agroforestry Systems 71:215-223. 10.1007/s10457-007-9083-4.

Startin, C.R. 2022. Assessing Woody Plant Encroachment in Marin County, California, 1952–2018. University of Southern California.

Stein, B.A., L.S. Kutner, and J.S. Adams. 2000. Precious Heritage: The Status of Biodiversity in the United States. New York, Oxford University Press.

Thomsen, Craig D., W.A. Williams, M. Vayssiéres, F.L. Bell, and M.R. George. 1993. Controlled Grazing on Annual Grasslands Decreases Yellow Star Thistle. California Agriculture 47(6):36–40.

Vasey, M.C., and V.T. Parker. 2014. Drivers of Diversity in Woody Plant Lineages Experiencing Canopy Fire Regimes in Mediterranean Type Climates. In Plant Ecology and Evolution in Harsh Environments, N. Rajakaruna, R. S. Boyd, and T. B. Harris (eds.). Hauppauge, NY, Nova Publishers. Pp. 179–200.

Weiss, Stuart B. 1999. Cars, Cows, and Checkerspot Butterflies: Nitrogen Deposition and Management of Nutrient-Poor Grasslands for a Threatened Species. Conservation Biology 13(6):1476–1486.