*sustainability*

MDPI

*Article*

# Rangeland Land-Sharing, Livestock Grazing's Role in the Conservation of Imperiled Species

**Sheila Barry [1,2,*] and Lynn Huntsinger [2,*]**

[1] University of California Agriculture and Natural Resources, San Jose, CA 95112, USA
[2] Environmental Science, Policy and Management, University of California Berkeley, Berkeley, CA 94720, USA
* Correspondence: sbarry@ucanr.edu (S.B.); huntsinger@berkeley.edu (L.H.); Tel.: +1-408-282-3106 (S.B.)

**Abstract:** Land sharing, conserving biodiversity on productive lands, is globally promoted. Much of the land highest in California's biodiversity is used for livestock production, providing an opportunity to understand land sharing and species conservation. A review of United States Fish and Wildlife Service listing documents for 282 threatened and endangered species in California reveals a complex and varied relationship between grazing and conservation. According to these documents, 51% or 143 of the federally listed animal and plant species are found in habitats with grazing. While livestock grazing is a stated threat to 73% (104) of the species sharing habitat with livestock, 59% (85) of the species are said to be positively influenced, with considerable overlap between species both threatened and benefitting from grazing. Grazing is credited with benefiting flowering plants, mammals, insects, reptiles, amphibians, fish, crustaceans, and bird species by managing the state's novel vegetation and providing and maintaining habitat structure and ecosystem functions. Benefits are noted for species across all of California's terrestrial habitats, except alpine, and for some aquatic habitats, including riparian, wetlands, and temporary pools. Managed grazing can combat anthropomorphic threats, such as invasive species and nitrogen deposition, supporting conservation-reliant species as part of land sharing.

**Keywords:** livestock grazing; species conservation; land-sharing; invasive species; nitrogen deposition; conservation-reliant species



**Citation:** Barry, S.; Huntsinger, L. Rangeland Land-Sharing, Livestock Grazing's Role in the Conservation of Imperiled Species. *Sustainability* **2021**, *13*, 4466. https://doi.org/10.3390/su13084466

Academic Editors: Iain J. Gordon, Pablo Gregorini and Fred Provenza

Received: 31 March 2021
Accepted: 13 April 2021
Published: 16 April 2021



## 1. Introduction

Livestock grazing is the widespread agricultural use of natural and seminatural landscapes throughout the world. Although estimates vary, as much as 50 percent of the world's land area is grazed by domestic livestock [1]. People have relied on grazing livestock as a source of high-quality protein for thousands of years, especially in ecosystems not usable for cultivation due to a lack of water, poor soils, harsh climate, rough topography, or high elevation. Throughout their history, grazing domestic livestock have generally shared grasslands with wild grazers and a host of other wild animals. Traditionally taking place on lands that are not arable, livestock producers are adapted to rearing animals on lands in a seminatural condition, sometimes with natural or anthropogenic fire, and other land management practices to keep woody vegetation in check and improve the forage for both wild and domestic grazers.

Despite technological and production shifts initiated in the twentieth century, the life cycle of commercial beef cattle in the United States still most often includes a significant period on grazing lands [2,3]. Such lands have been promoted for conservation through land sharing under the rubric of "working landscapes" [4,5]. Land sharing, which encompasses wildlife-friendly farming practices, integrates biodiversity conservation with agricultural production on the same land [6,7]. To better understand the relationship between livestock grazing and species conservation from land sharing, this study assesses the current impacts of livestock grazing, detrimental and beneficial, on the conservation of federally listed plant

and animal species in California as stated in listing documents published in the United States Federal Register.

Listing documents used to implement the US Endangered Species Act of 1973 (ESA) identify plants and animals vulnerable to extinction, designate their critical habitat, and inform their recovery, including recognizing threats to the species and their habitats. The United States Fish and Wildlife Service (USFWS) administers and enforces the ESA for terrestrial species. The USFWS is required to use scientifically valid information to describe reasons for a species' demise and recommend actions for its recovery. The descriptions as outlined in Section 4 (a) (1) of the ESA consider five factors: (A) habitat loss, (B) overutilization, (C) disease or predation, (D) inadequate regulatory mechanisms, and (E) other natural or human-made factors affecting a species' survival. The impact of livestock grazing on a listed species and its associated habitat is included in the USFWS's analysis of the five factors when livestock grazing occurs with the species or within its habitat. The information provided is the current state of knowledge and continually changing; when new information is learned about a species' needs and survival, the five-factor information is updated through 5-year reviews and recovery plans.

A previous highly cited study, Wilcove et al. [8], used ESA listing information published in the US Federal Register to quantify threats to listed species. They found 22% of all US-listed endangered, threatened, or candidate species (n = 1207) were impacted by habitat degradation or destruction resulting from livestock grazing. This finding is similar to Czech et al. [9], which compared Federal Register documents and World Wildlife Fund compendium data for causes of the endangerment of 877 species. They found 16.0% were threatened by livestock grazing and 20.8% of the species by ranching, respective of the data source.

Both Wilcove et al. and Czech et al. provided little explanation of livestock grazing's role in species decline. Wilcove et al. [8] categorized grazing as an extractive land use along with logging and mining. Czech et al. [9] found a strong relationship between grazing threats and non-native species, which they noted was at least, in part, explained by grazing's modification of plant and animal community composition. However, there is a growing body of research from grazed lands worldwide that recognize the potential of domestic animal grazing to modify or maintain habitat in ways that benefit certain species [10–16]. In recent reviews, for example, positive impacts from livestock grazing maintaining open habitats were found for amphibian [10] and small mammal [11] species.

Livestock grazing affects biota and their ecological systems in varied and complex ways. Through consumption, physical impact, and nutrient redistribution, grazing livestock can change vegetation, soils, and habitats [17]. Although these effects of grazing are well-known, whether they have negative or positive impacts in a particular ecosystem and on a specific plant or animals species depends on the species, the ecosystem, the current environmental conditions, as well as the management of the livestock and their grazing [18–20]. In terms of livestock's influences on ecosystems and threatened and endangered species, herbivory should not be treated as a "black box".

Despite the varied and contrasting impacts of grazing, to date, there is no assessment of threats to imperiled species that considers livestock grazing's varied impacts on specific species and their habitats, positive as well as detrimental. If nothing else, Wilcove's concerns with the importance of conservation on private lands and the need for active management [21] calls for such an assessment since so much land in a natural and seminatural state is owned by ranchers, who rely on grazing for income and use it as a tool of active habitat management.

California is well suited for such an assessment. First, with a varied climate and topography and a growing population, the California Floristic Province, which includes most of the state and small parts of adjacent areas in Oregon, Nevada, and Baja California, Mexico, is one of the world's most biologically rich and endangered ecoregions; it is a globally recognized biodiversity hotspot [22]. Six thousand one hundred forty-three plant species are native to the province; 42% of these species are endemic [23]. California has

more federally listed species (282 in 2017) than any other state in the continental United States. With so much biodiversity at risk, threats to species and recovery activities have been identified for a large number of plants and animals across many species groups.

Second, despite California's rich biodiversity, non-native annual grasses and forbs or broad-leaved plants are widely established and dominant across most of California's rangelands. These annuals are part of a novel ecosystem with large numbers of species from Mediterranean environments worldwide, many originating in the "Fertile Crescent", a domestication hearth [24–26]. Biological introductions, both intentional and unintentional, are pervasive, impacting native species and ecosystems in California and throughout the world [27].

Third, like much of the western United States, livestock grazing across the state is extensively managed, with about 40% grazed by livestock to some extent [28]. While California's Mediterranean climatic zone, which includes grasslands, hardwood woodlands, and chaparral, provides most of the forage consumed by livestock, two other zones also support extensive livestock production. The cold desert steppe, which is characterized by sagebrush grassland and pinyon-juniper woodlands, and the warm desert, which includes barren lands and, at higher elevations, montane meadows and conifer forest, provide seasonal grazing, primarily for cattle [29].

Another reason that California is well suited for an assessment of grazing impacts on listed species and associated habitats is that it is a natural laboratory to study land sharing. Although livestock grazing in the western United States has a relatively short history (<300 years) compared to Europe and Asia, native species found on California's rangelands evolved with herbivory by now-extinct megafauna, including medium to large herbivores, such as ground sloth, bison, camel, horse, mammoth, mastodon, and ox [30]. Like in other parts of the world, conservation efforts in California increasingly consider livestock grazing a way to maintain extensive natural landscapes and their native diversity [31], expanding available habitat well beyond the possibility for nature reserves. Land sharing provides an income to landowners through livestock production and reduces the risk of development or land-use conversion [28,32]. While land sparing strategies emphasize separating nature conservation and agriculture, relying on intensification of agriculture on smaller areas to "spare" conservation areas, land sharing strategies seek to accomplish both biodiversity conservation and agriculture within the same landscape [33]. This strategy is often presented as requiring trade-offs, where either agricultural yields or species conserved are reduced [34]. For instance, Butsic and Kuemmerle [35] have suggested considering land-sharing and land-sparing across a spectrum where agricultural yields and species conservation are optimized depending on the ecosystems and species. Given the limited feasibility of intensifying agricultural production on many grazing lands [36], including California's rangelands, livestock grazing may provide a decisive land-sharing opportunity where conservation is not compromised for agricultural production and species conservation and recovery for some species is enhanced.

A quantitative assessment from USFWS listing documents for multiple species across a wide variety of habitats grazed by domestic livestock allows detection of patterns that may explain the varied and sometimes contradictory responses from livestock grazing observed and often reported in the literature. This assessment of all federally listed species in California addresses the following questions (i) What is the role of grazing in the conservation of federally listed species? (ii) Does grazing's role in species conservation differ by taxonomic groups and across different ecosystems? Moreover, (iii) What are the specific reasons that plants or animals are threatened by or benefit from grazing? These three questions allow us to understand better land sharing's potential for conservation on livestock grazing lands in California. It is important to keep in mind that "grazing" occurs on all rangelands, by everything from caterpillars to elephants depending on location. However, in this paper, the term grazing refers to the agricultural pursuit of managed livestock grazing unless otherwise stated.

## 2. Materials and Methods

Federal Register documents published by the USFWS for all federally listed threatened or endangered species (182 plants and 100 animals) in California as of 1 December 2017, were reviewed. A searchable database of ESA documents developed by the Center for Conservation Innovation of the Defenders of Wildlife [37] was initially used to identify species associated with grazing. ESA listing documents search through the database included the final rule for listing, 5-year reviews, and recovery plans.

Federally listed species were determined to be associated with grazing if "graz*", "overgraz*", or "trampl*" appeared in the text of at least one of the listing documents associated with an imperiled species in California (Table 1). Mentions of "grazing" and "trampling" were verified as being related to domestic livestock versus wild or feral animals. The term "livestock" was searched, but it did not yield additional species affected by grazing livestock or ranching. Other terms for herbivory, "browsing" and "foraging", were also searched but were not found to be used in the USFWS documents reviewed to describe interactions with livestock.

From the search results, an Excel database was developed with the document's title, type, date, web URL, and the associated listed species, as well as statements from the text regarding grazing (Data S1). The data were sorted by species and date, and the newest listing document associated with each species with a grazing interaction identified. The complete listing documents were accessed from the Environmental Conservation Online System (ECOS), managed by the USFWS [38]. The most recent listing document was typically a 5-year review, but a recovery plan or the final rule was the latest in some cases. From listing documents, species type (plant or animal), animal species group, plant guild, and date of the latest listing document were recorded for each species. Information on the species' terrestrial and aquatic habitat was obtained from NatureServe Explorer Species reports under ecological and life history [39]. NatureServe Explorer Species reports, a product of NatureServe in collaboration with the Natural Heritage Network, are referenced on the USFWS ECOS website as an authoritative source of additional species information. NatureServe reports terrestrial habitat for species based on US National Vegetation Classifications at the formation level [40]. Some species are found in multiple terrestrial or aquatic habitats, and all habitats were recorded for each species. From the NatureServe listing, the primary terrestrial and aquatic habitats, if applicable, were recorded for each listed species and included in the Excel database (Data S1).

The USFWS uses various statements to describe the effects of livestock grazing on listed species and their habitats (Table 1). Statements on grazing were coded and categorized. A category for a grazing benefit and a grazing threat was independently assigned for each listed plant and animal species. Stated threats from "grazing", "overgrazing", or "trampling" were categorized as grazing threats. The threat of "loss or cessation of grazing" was considered to indicate a benefit from grazing. In USFWS documents, this threat results from lack of grazing leading to habitat degradation because grazing is acting to maintain habitat structure or function. "Inappropriate grazing" was typically categorized as both an indication of potential threat and benefit from grazing. The USFWS generally uses inappropriate grazing to mean that grazing at the wrong time or intensity is detrimental to the species or its habitat, while grazing at the right time and intensity may be beneficial. The benefit of appropriate grazing is indicated by statements like, "too little grazing is detrimental to the species or its habitat".

For species with mentions of grazing in initial listing documents but no statement on grazing's threat or benefit in the newest listing document, the categories, "no grazing threat" and "no grazing benefit" were used. The category "no grazing threat" also includes species where the USFWS states that "grazing is not a threat". The statement "grazing is a not threat" typically reflects a change in the USFWS's understanding of grazing's effect on a listed species, where previous listing documents had mentioned grazing as a threat to the imperiled species or its habitat.

**Table 1.** Categorization of grazing impacts on species conservation stated in the most recent United States Fish and Wildlife Service (USFWS) listing documents (5-year reviews or recovery plans) from 2000 to 2016 for each listed species in California where grazing is mentioned.

| Categories for Grazing's Mention | Impact Statements or Category Descriptions |
| --- | --- |
| Livestock grazing current | • Livestock grazing has a current relationship with listed species |
| No longer a factor | • "Grazing is no longer a threat" because livestock is not present, or the habitat has been protected, and livestock has been excluded. |
| No current threat | • Grazing was listed as present or threatening in previous listing documents, but there is no current mention of grazing. |
| Other grazing threatens | • "Wild or feral animals, including burros, deer, gophers or rabbits, are a threat". This category was used only when grazing threats were limited to feral or wild animals. |
| Island species | • Species and their habitat on the Channel Islands have been impacted by uncontrolled grazing of non-native feral and wild species, including cattle, sheep, goats, deer, elk, bison, and pigs. Most of these animals have been removed, but historical impacts persist. |
| **Categories of grazing's current threats** | |
| Grazing or overgrazing threatens | • "Grazing or trampling by livestock is a threat".<br>• "Overgrazing, severe, heavy, intensive, improper, inappropriate, poor or unmanaged grazing or trampling is a threat".<br>• "Goat grazing for fuels breaks is a threat". |
| Unknown grazing threat | • The impact of grazing on the species is unknown. |
| No grazing threat | • "Grazing is not a threat".<br>• No grazing threat is stated. |
| **Categories of grazing's current benefit** | |
| Grazing benefits | • "Appropriate, managed, controlled, optimal, moderate or light grazing benefits, enhances, restores or maintains".<br>• "Loss of grazing or cessation of grazing is detrimental or a threat".<br>• "Inappropriate grazing (which includes too little grazing) is a threat". |
| Unknown grazing benefit | • "Grazing's benefit is unknown". |
| No grazing benefit | • No benefit is stated. |

"No longer a factor", "other grazing threat", "no current grazing threat", and "island species" are additional categories used in this study that describe the stated relationship between grazing and a listed species in listing documents (Table 1). The USFWS states that grazing is no longer a threat when grazing no longer occurs within the species' habitat, often due to protections that restrict grazing, e.g., reserve status. "Other grazing threatens" was used when listed plants or animals are not known to be impacted by domestic livestock, but the stated threat is from wild or feral herbivores, horses, or burros. "No current grazing threat" was assigned to species where the presence of livestock grazing was noted as a threat in early listing documents, e.g., USFWS final listing rule, but in the most recent documents, e.g., five-year reviews, livestock grazing was not mentioned.

Both "no longer a factor" and "other grazing threat" describe the threat of grazing to listed species endemic to the Channel Islands off the coast of California, but because of the unique grazing history of these islands, the 21 plants and three animals found only on the islands are categorized as "island species". Grazing threats were primarily from uncontrolled grazing by feral sheep and goats, deer, bison and elk. These animals were introduced to the islands and were generally not managed; they have now been nearly entirely removed.

Although initial results identified 209 species or 74 percent of the listed species in California where grazing is mentioned, the review of most recent documents found a current livestock grazing relationship with 143 species or 51 percent of the listed species (Table 2). Further analysis of grazing threats and benefits for this assessment was only considered for species with a current livestock grazing relationship.

**Table 2.** Number of listed animal and plant species in California with grazing mentioned in USFWS listing documents, oldest and current.

| Livestock Grazing Mentions | # of Animal Species | % of Listed Species | # of Plant Species | % of Listed Species | Total | % of Listed Species |
|---|---|---|---|---|---|---|
| Other grazers (feral, wild) | 1 | | 7 | | 8 | 3% |
| Island species (historic, feral) | 3 | | 21 | | 24 | 9% |
| No Longer (historic) | 2 | | 17 | | 13 | 5% |
| No Current | 6 | | 9 | | 14 | 5% |
| Livestock grazing current | 56 | 56% | 87 | 48% | 143 | 51% |
| Total grazing mentions | 68 | 68% | 141 | 78% | 209 | 74% |
| Total listed species | 100 | | 182 | | 282 | |

The association between grazing's role on listed species and species attributes, including type, i.e., animal versus plant, animal species groups, plant guilds, and habitat types within terrestrial and aquatic systems, was determined using Pearson's chi-squared tests. Calculating the chi-squared statistic and comparing it against the chi-squared distribution indicates whether the observed pattern of responses is significantly different from expected if the variables were truly independent of each other [41]. In this case, Pearson's chi-squared allows us to determine if grazing's role as a threat or benefit is independent of species' type, animal group, plant guild and habitat type.

To illuminate the specific assertions about the nature of grazing impacts beyond the broad categories of threats and benefit, reasons for grazing's stated role in the newest listing documents were coded and categorized and included in the database (Data S1). Multiple reasons for grazing's benefit or threat are recorded for some species. Direct threats to an individual animal or plant or its natal site were differentiated from indirect impacts to habitat or ecological processes, e.g., plant succession, impacts to soil and water quality. All benefits were identified as indirect impacts.

## 3. Results

Grazing was considered an impact in listing documents for most of California's federally listed species (74%, 209 species). However, based on the most recent listing documents, the impact of livestock grazing on federally listed species is currently considered for 143 species or 51% of federally listed species in California (Table 2). The United States Fish and Wildlife Service (USFWS) updated listing documents based on the review of new information, including research findings, expert opinion and reports, and in some cases, the presence or absence of grazing animals. Among federally listed species with a current grazing relationship, the USFWS states threats from livestock grazing for 73% (104) species but recognizes benefits from grazing for 59% (85) of the listed species occurring in the state (Table 3). Since a grazing benefit and threat were independently assigned for each species, there is considerable overlap. Both negative and positive impacts from grazing are reported for 65 species with a current grazing mention (Figure 1). Threats

and benefits to federally listed species from livestock grazing in California are primarily attributed to cattle, although the USFWS notes impacts from sheep and goat grazing for some species' populations.

**Table 3.** Number of listed animal and plant species in California (2017) with current grazing mention, percent of species threatened and benefiting.

| Livestock Grazing Current (Threats and Benefits) | # of Animal Species n = 56 | % of Current Animals | # of Plant Species n = 87 | % of Current Plants | Total | % of Listed Species |
|---|---|---|---|---|---|---|
| Grazing threat | 47 | 84% | 57 | 66% | 104 | 37% |
| Unknown grazing threat | 2 | 4% | 5 | 6% | 7 | 2% |
| No grazing threat | 7 | 13% | 25 | 29% | 32 | 11% |
| Grazing benefit | 36 | 64% | 49 | 56% | 85 | 30% |
| Unknown grazing benefit | 0 | | 4 | 5% | 4 | 1% |
| No grazing benefit | 20 | 36% | 34 | 39% | 54 | 19% |
| Both grazing threat and benefit | 30 | 53% | 35 | 40% | 65 | 23% |

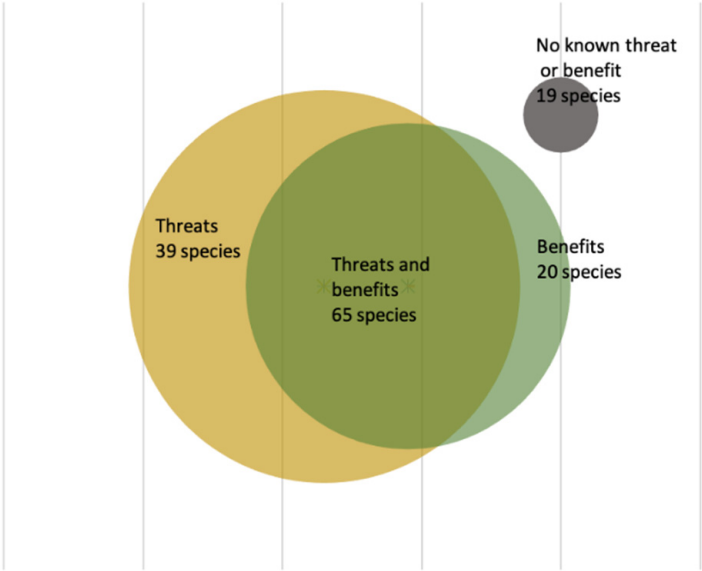


**Figure 1.** Number of federally listed species with threats or benefits from grazing in most recent listing documents, including all federally listed species in California occurring with livestock grazing or in habitats grazed by livestock (n = 143 species).

### *3.1. Grazing's Impact by Species Type*

Similar numbers of federally listed flowering plant and animal species in California occur in conjunction with livestock grazing, 56% (56) of animal and 48% (87) of flowering plant species; however, the USFWS more often states a threat to animal species from livestock grazing than to plant species. Grazing threatens 84% of the animal species and 66% of the flowering plant species with a current livestock grazing mention (Figure 2, Table 4). In contrast, there is no relationship in grazing's stated benefits to species type, with 64% and 56% of the animal and flowering plant species benefitting, respectively (Figure 2, Table 4).

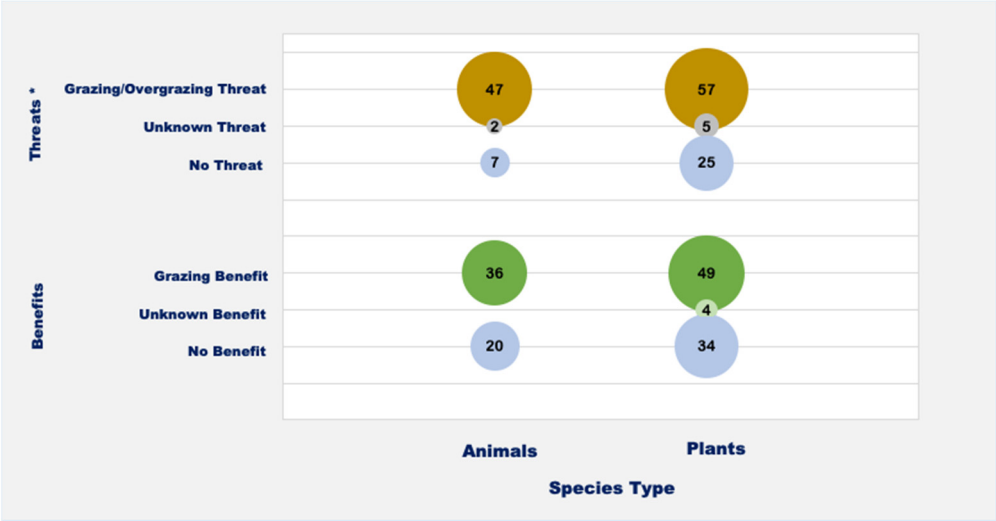


**Figure 2.** Livestock grazing's impacts, threats, and benefits for federally listed species in California by species type. The size of the circle is relative to the number of species. Pearson's chi-squared test level of significance represented as * $p \leq 0.05$ for threats and no significance for benefits between species type $p > 0.05$.

**Table 4.** Summary of statistical analysis of differences in grazing's role as a threat and benefit concerning listed species in California. Level of significance represented as * $p \leq 0.05$ and ** $p \leq 0.01$.

| | | Threat | | | | Benefit | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Difference in Grazing's Role for Each** | **n** | **Pearson's $X^2$** | **df** | ***p*-Value** | | **Pearson's $X^2$** | **df** | ***p*-Value** | |
| Animals vs. plants | 143 | 5.931 | 2 | 0.05 | * | 3.04 | 2 | 0.22 | |
| Animal species group | 56 | 10.385 | 12 | 0.58 | | 17.07 | 6 | 0.01 | ** |
| Plant guild | 87 | 10.001 | 10 | 0.44 | | 17.396 | 10 | 0.07 | |
| Terrestrial habitat | 105 | 25.835 | 16 | 0.06 | | 29.161 | 16 | 0.02 | * |
| Aquatic habitat | 73 | 20.126 | 12 | 0.07 | | 18.473 | 12 | 0.10 | |

### *3.2. Grazing's Impact by Animal Species Group and Plant Guild*

All California animal and plant species groups with federally listed species have species that may be threatened or may benefit from livestock grazing except "conifers and cycads". Among animal species groups, there is no association between groups and threats from grazing (Table 4). Threats to animal species are widespread across all species groups, with at least 75% of the species within each species group being stated as threatened by grazing (Figure 3). In contrast, the potential benefit from grazing varies by animal species group (Table 4). Amphibians, crustaceans, insects, mammals, and reptiles all have more species that benefit from grazing than species that do not benefit. Fishes and bird species are not likely to have a stated grazing benefit. Of listed California species, only one bird species (California Condor, *Gymnogyps californianus*) and one fish species (desert pupfish, *Cyprinodon macularius*) are noted to benefit from livestock grazing.

Plant species with federally listed species are in the "flowering plants" and "conifers and cycads" groups. All the federally listed plant species in California impacted by livestock grazing are in the flowering plant species group. This group includes both annual and perennial species in the forb, grass, and grass-like plant guilds. However, most of the listed plant species (84%) impacted by grazing are forbs or broad-leaf plants (Figure 4). There is no association between plant guilds and the stated likelihood of threat or benefit (Table 4).

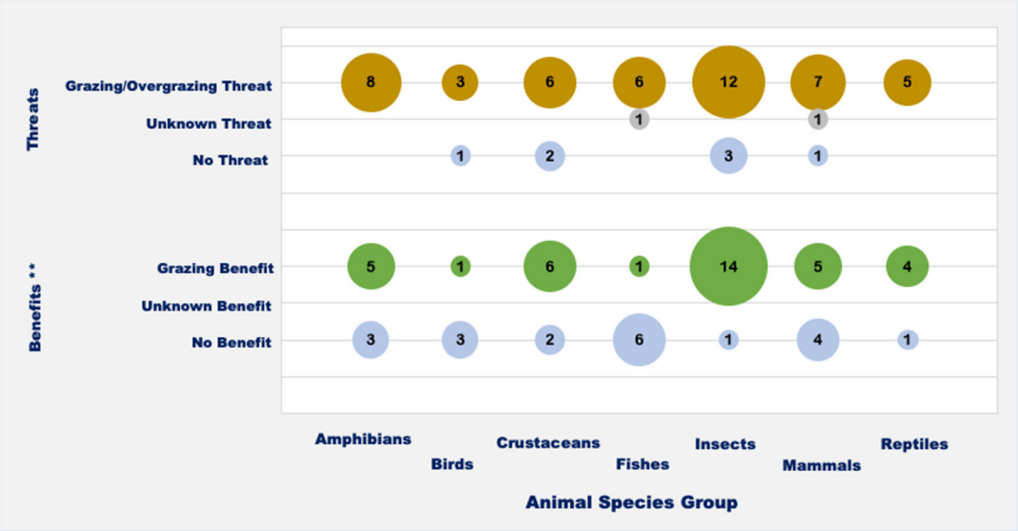


**Figure 3.** Livestock grazing's impact, threat and benefit for federally listed animals in California by species group. The size of the circle is relative to the number of species. Pearson's chi-squared test no significance for threats $p > 0.05$ and level of significance represented as ** $p < 0.01$ for benefits.

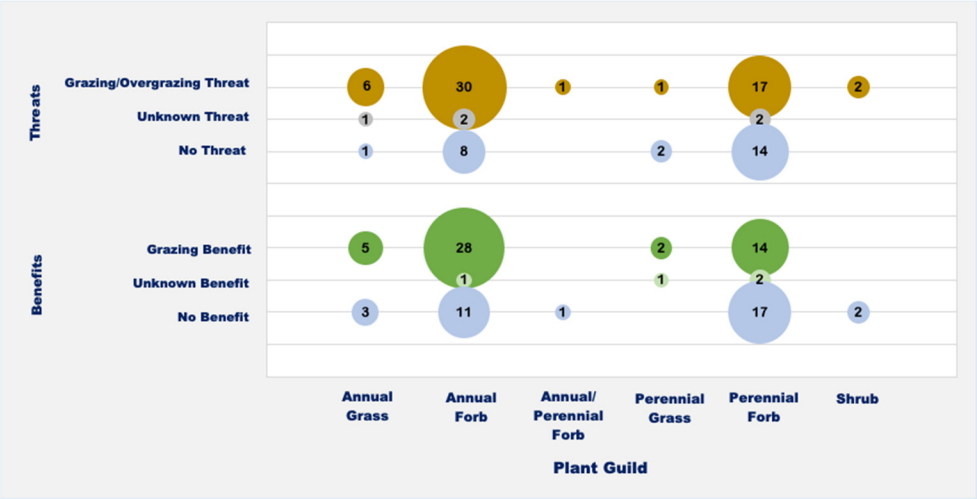


**Figure 4.** Livestock grazing's impact, threat and benefit for federally listed species in California by plant guild. The size of the circle is relative to the number of species. No significance for Pearson's chi-squared test for threats or benefits by plant guild $p > 0.05$.

### *3.3. Grazing's Impact by Ecosystem*

Impacts from livestock grazing to listed species are found across a diversity of ecosystems in California. Plant and animal species may be found in or complete their lifecycle in multiple types of terrestrial or aquatic habitats. Of those species with a grazing relationship, 52% are found only in terrestrial habitats, 25% are found only in aquatic habitats, and the remainder, 23%, may use or spend different parts of their lifecycle in both terrestrial and aquatic habitats.

Some species are threatened, and some benefit from grazing in every terrestrial habitat type with livestock grazing in California except alpine, where Sierra Nevada bighorn sheep may contract a disease from domestic sheep [42] (USFWS 2008), but no benefits from grazing are noted. Although 60% of the species that benefit from grazing in terrestrial habitats are found in grasslands (Figure 5), there are more species with a stated grazing benefit than with no benefit in grasslands, barren land, and woodlands. There was no

association between terrestrial habitat types and the number of species threatened by grazing (Table 4).


**Figure 5.** Livestock grazing's impact, threat and benefit for federally listed species by terrestrial habitat type. The size of the circle is relative to the number of species. Pearson's chi-squared test no significance for threats $p > 0.05$ and level of significance represented as * $p \leq 0.05$ for benefits.

Listed species impacted by livestock grazing are also found in various aquatic habitats, but most are found in temporary or vernal pools, 62% (Figure 6). On California grasslands, federally listed species using temporary pools for all or part of their lifecycle include 21 plant species, annuals and perennials, and 12 animal species, amphibians, crustaceans, fish, and insects. While grazing threats are stated for some species in every aquatic habitat type with listed species impacted by grazing, benefits from grazing are found for some federally listed species in temporary pools (including vernal pools), wetlands, riparian, and springs (Figure 6). There is no association between the likelihood of stated grazing benefits or threats for a particular species from grazing with aquatic habitat types.

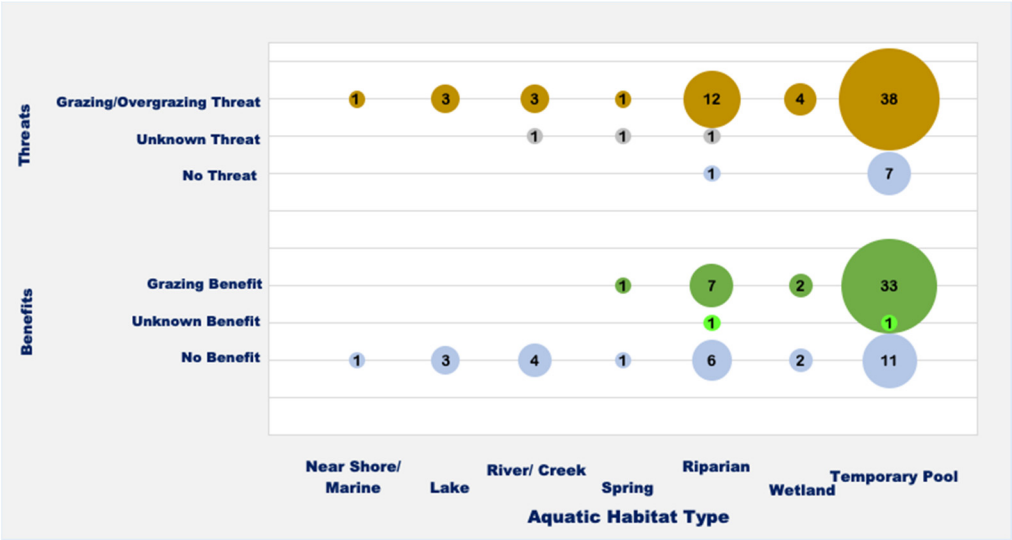


**Figure 6.** Livestock grazing's impact, threat and benefit for federally listed species by aquatic habitat type. The size of the circle is relative to the number of species. No significance for Pearson's chi-squared test for threats or benefits by aquatic habitat type.

In summary, this assessment considered the number of federally listed species in California by species type, animal species group, plant guild, terrestrial habitat, and aquatic habitat that is threatened by or benefit from livestock grazing. The number of species stated as threatened by grazing in California only differs significantly by whether they are an animal or flowering plant, not among animal species groups, plant guilds or habitat type. In contrast, the number of species found to benefit from grazing is related to animal species group and type of terrestrial habitat (Table 4).

### *3.4. The Reasons Livestock Grazing Threatens Species*

The primary reasons stated for grazing's threat differ between federally listed plant and animal species. Direct impacts, including the potential for a plant or part of a plant to be consumed or trampled by livestock, is the most frequently stated threat to plant species; 58% of the listed flowering plant species occurring in grazed habitats were reported to be threatened by direct impacts (Figure 7). Evidence of direct impact from grazing and trampling is mostly anecdotal, although sometimes it is reported with observations, including description or data.

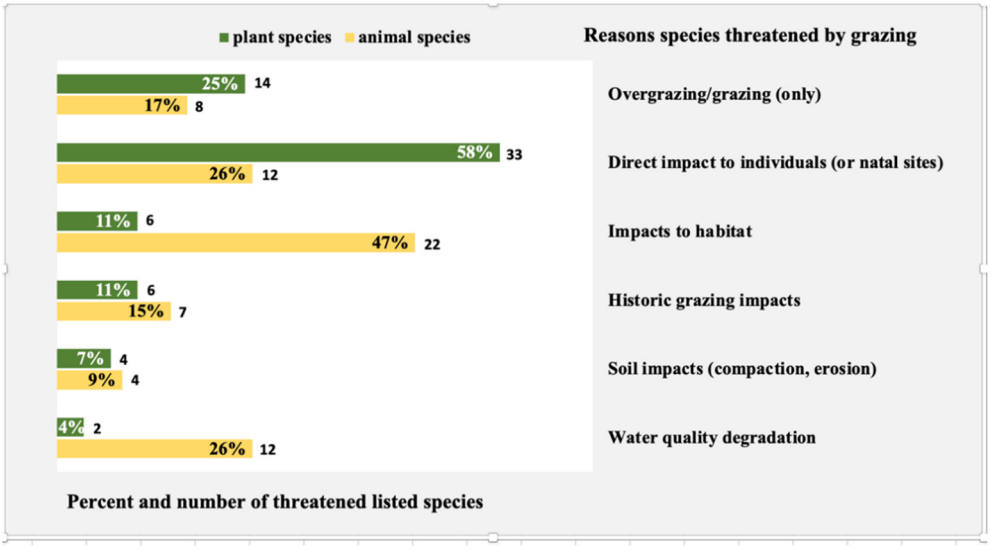


**Figure 7.** Reasons for livestock grazing's threat to federally listed plant and animal species in California.

In reporting the threat from direct impact from grazing and trampling, the USFWS recognizes that grazing threats to individuals do not necessarily result in species decline or drive a plant species to extinction. For example, in describing grazing impacts on the annual forb, Sidalcea keckii, the USFWS reported that cattle were observed causing damage by eating the plants, but the damage was barely noticeable a week later [43]. Similarly, the USFWS [44] reported cattle herbivory and trampling impacts to the perennial forb, Cirsium fontinale var. obispoense, but cites a 1998 study where researchers determined that grazing impacts, which were to mature plants, were offset by an increase in juvenile plants.

There are, however, a couple of examples where direct impacts of grazing were reported to have facilitated extirpation in listing documents. A population of the shrub, Arctostaphylos pallida, already weakened by a root fungus and shading, was considered extirpated by goats grazing at intensities designated to reduce fuel loads [45]. Trampling by cattle was reported to have extirpated a population of Cordylanthus mollis spp. mollis. This annual forb is supported by fragile underground connections, haustoria that were considered to have been damaged by trampling [46]. The USFWS in listing documents often states that direct impacts are primarily a risk to species under situations of overgrazing or heavy grazing, and when listed, species have small or isolated populations that are vulnerable to stochastic expiration.

After threats from direct impacts, "grazing", or more often "overgrazing", with no specific explanation, is the most frequently stated reason livestock grazing threatens a flowering plant species. As described in Table 1, "overgrazing" as a threat includes severe, heavy, intensive, improper, inappropriate, poor, or unmanaged grazing or trampling. Overall, 83% of listed flowering plant species occurring in habitats with livestock are stated to be threatened by grazing or trampling's direct impact on a plant, or grazing or overgrazing (Figure 7).

On the other hand, federally listed animal species are primarily threatened by indirect impacts from habitat loss or degradation, which is the stated reason that grazing threatens 47% of federally listed animal species (Figure 7). Impacts to habitat from livestock grazing include introductions and increases in invasive species and loss of riparian vegetation. Water quality degradation, which includes livestock grazing causing excess sediment and nutrients or higher stream temperatures, is a stated impact on 26% of the federally listed animal species found in grazed habitats in California. In addition, 26% of the animal species are threatened by direct impacts to individuals or natal sites, e.g., burrows or nests. Other less frequently stated threats to listed species plant and animal species from grazing and trampling include other indirect impacts to hydrologic functions and soil condition, e.g., erosion and compaction (Figure 7).

While threat reasons to listed species from grazing were individually identified for analysis in this assessment, the impacts are not necessarily independent. The USFWS describes the cascading effects of livestock's impact on ecosystem processes leading to habitat degradation and diminishing survival or recovery for some species. For example, livestock impacts to water quality, stream channels, and riparian vegetation threaten the Little Kern golden trout, Oncorhynchus mykiss whitei, and Paiute cutthroat trout Oncorhynchus clarkii seleniris [47,48] (USFWS 2011, 2013c). As described in the listing documents for these fish species, livestock may concentrate in riparian areas due to water availability, green vegetation, and shade. Fish habitat is degraded by the reduction in water holding areas, shade, and cover, resulting in increased water temperatures and decreased water quality from excess sediment and nutrients. However, the USFWS listing also notes that grazing has occurred in the drainage of the Little Kern golden trout for more than 100 years, and it is known that controlling the timing and intensity of grazing can minimize impacts [47]. Similarly, the USFWS states that grazing threats to Paiute cutthroat trout have been reduced because grazing has either been eliminated from their habitat or conservative grazing management objectives have been put in place [48].

### *3.5. The Reasons Livestock Grazing Benefits Species*

Benefits from livestock grazing to the survival or recovery of federally listed species all result from indirect impacts. For plant and animal species in California, species benefit from grazing that maintains or enhances habitat by controlling non-native annual plants (biomass, cover, and height), reducing thatch (buildup of dead vegetation), maintaining hydrologic functions (inundation period), mitigating dry atmospheric nitrogen deposition, preventing land-use change, providing disturbance creating some bare ground, or preventing woody plant invasion from maintaining grassland (Figure 8). Controlling non-native species, mostly non-native annual plants, is the most frequent reason stated that grazing benefits both federally listed flowering plant and animal species in California; 89% of species positively impacted by livestock grazing benefit from control of non-native species. For example, in the USFWS listing documents for several insects (ten butterflies and one moth), controlling non-native annual grasses is stated to favor native forb or broad-leaf plant populations supporting the conservation of these species, which rely on forbs for nectar and larvae food. Similar to grazing threats, grazing benefits were individually recognized for this assessment, but many are related to one another.

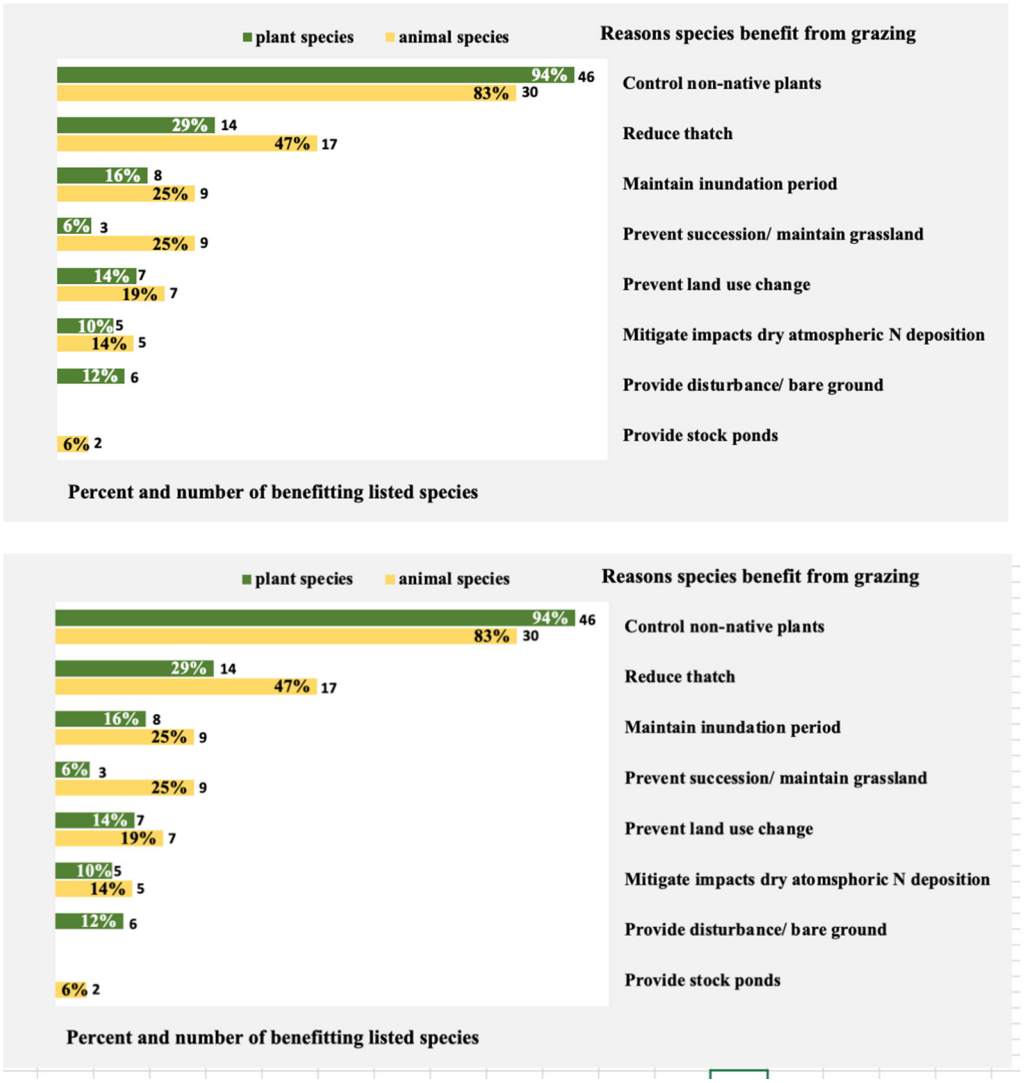


**Figure 8.** Reasons for livestock grazing's benefit to federally listed plant and animal species in California.

In addition to controlling non-native plants to favor certain species, grazing is stated to benefit some listed species by controlling vegetation that alters habitat, including thatch (Figure 8). In the grasslands and shrublands of the San Joaquin Valley of California, for example, maintaining habitat with sparse vegetation supports various listed species, including Kern mallow (Eremalche parryi ssp. Kernesis) [49], blunt-nosed leopard lizard (Gambelia silus) [50], giant kangaroo rat (Diposdomys ingens) [51], and San Joaquin kit fox (Vulpes macrotis) [52]. For the small ground-dwelling native vertebrates, annual grass and thatch can create an impenetrable thicket [50]. For the larger native vertebrate, San Joaquin kit fox, taller, dense vegetation can obscure their visibility of predators [52]. Habitat with sparse vegetation is also necessary for both listed plant and animal species in coastal grasslands, including the Santa Cruz tarplant (Holocarpha macradenia) [53] and Ohlone tiger beetle (Cicindela ohlone) [54].

Some species (five plants, annual and perennial forbs; five animals, insects and a reptile, Figure 8) benefit from grazing that controls vegetation associated with air pollution. The USFWS cites research that shows air pollution, specifically dry atmospheric nitrogen deposition, creates a fertilizer load that alters plant communities and habitat, and livestock grazing can maintain habitat by removing excess vegetation and nitrogen [16,55]. Grazing's control of vegetation is also associated with maintaining grasslands by preventing succession or invasion by brush to benefit some animal and plant species (Figure 8). For listed

plants like the Western Lily, Lilium occidentale that are threatened by loss of grassland, the USFWS [56] has stated that the benefits of grazing seem to outweigh the potential threat from these plants being grazed or trampled.

Within aquatic habitats, species benefitting from grazing, which includes flowering plants, amphibians, and invertebrates, are primarily found in temporary or vernal pools, where livestock help maintain an adequate inundation period, for example, [57,58]. Listing documents for species in temporary pools cite research by Marty [59] and Pyke and Marty [15] that describe increased grass cover in and around ungrazed vernal pools leading to increased evapotranspiration and decreased pond duration. Other benefits stated for listed species in aquatic habitats include a couple of animal species that benefit from the presence and maintenance of stock ponds associated with livestock grazing. Livestock grazing is also credited with maintaining a compatible land use for six animals and four plants (Figure 8), despite development pressure—a direct link to the land-sharing concept.

## 4. Discussion

Livestock grazing is a widespread land use in California and has often been considered a threat to conservation (see [8,9]), regardless of whether or not confirming research has been conducted [60,61]. Despite this, this assessment from the USFWS listings shows a complex and varied response to grazing among imperiled species and their habitats. Beginning in 1769 with the arrival of Spaniards in California, livestock grazing, among other things, contributed to introducing and spreading non-native species [62,63], resulting in habitat loss and a novel ecosystem. Now, as documented in this assessment, grazing is credited with controlling non-native plants and thatch buildup and maintaining specific habitat structures and functions for many listed plant and animal species. The fact that USFWS identifies grazing as a threat and a benefit to many species indicates that how grazing is done matters. Grazing management certainly affects the conservation outcome for the listed species in California that are either negatively or positively affected by grazing (n = 65).

### *4.1. Value and Limitations of Best Available Science and the USFWS Listings*

In fulfilling ESA requirements to identify threats that put species at risk of extinction, the USFWS documents indicate the relationship between livestock grazing for every threatened and endangered species based on the "best scientific and commercial data available". In many cases, the studies needed to understand better how species and habitat respond to grazing over time or to a particular grazing pattern have not been done. In the absence of published research for many species, applying the best available science means that threat information may be based on expert opinion, including observations and unpublished data, or may be extrapolated from research findings for similar species or ecosystems [64]. For example, in some cases, threats to species are based on assessments of grazing's impact on western rangelands or aquatic habitats, including Fleischner [60] and Belsky et al. [65]. Often as not, grazing benefits are identified when grazing exclusion leads to loss of the species targeted for protection [16,66,67], and these research findings may be applied to similar species in similar habitats.

While the use of the best available science allows for thorough coverage of all listed species potentially impacted by livestock grazing or other threats, it also means that some statements of effects are amplified as findings are repeated. In this assessment, using the best available science from the USFWS listings may limit our assessment of patterns relative to grazing's impact across species types, groups, or ecosystems. It should also be recognized that the USFWS listing documents are not always up to date, and just like California ecosystem conditions, things are continually changing. The full picture of grazing impacts over time and with variation in conditions is seldom fully known [11,68]. The analysis here adds more depth and detail to the complexities of the situation in considering the role of livestock grazing in land sharing based on the diversity of species and their habitats that are threatened by or benefit from grazing.

### *4.2. Proper Management to Minimize Threats*

Terms, including severe, heavy, intense, improper, unmanaged, uncontrolled, or overgrazing, have all been used by the USFWS to describe grazing and trampling impacts that threaten listed species. Generally interchangeable with "overgrazing", these terms are not consistently defined or applied in listing documents or in the scientific literature [69]. Overgrazing implies that grazing is in excess of management goals [70] or has described any grazing that results in negative impacts [69]. Whether or not a species is at risk from "overgrazing" depends on the severity and frequency of the grazing impact, the ecosystem, and adaptations of the plant or animal to grazing or its outcomes [11,71].

In this assessment, the likelihood of threat to listed species from livestock grazing was not associated with ecosystems, plant guilds, or animal species groups (Table 4). Instead, grazing was found to threaten numerous species across all species groups and habitat types, suggesting that some grazing level, typically unmanaged or excessive, can impact any habitat and affect the survival of most species on grazed lands. There is evidence in the published literature that grazing managed inappropriately can change species composition, cause erosion and decrease productivity and fail to meet habitat conservation goals [65,72–74]; however, grazing can also be managed so that negative impacts are mitigated and minimized. From a comprehensive review of literature on grazing systems and impacts, Briske et al. [68] concluded that grazing intensity, a function of stocking rate and livestock distribution is the single most important management factor influencing conservation outcomes and livestock production in grazed systems. Controlling grazing intensity with proper stocking rates coupled with livestock distribution practices, including water distribution, supplement placement, herding, and fencing, have been found to reduce impacts of livestock on rangelands, including impacts in riparian areas [68,75–79].

### *4.3. Grazing Supports Conservation Reliant Species*

Managed grazing can reduce threats from grazing to listed species and meet livestock production needs [68,80], but it is grazing's benefit to species conservation that defines a role for land-sharing and counters arguments that suggest land-sharing requires trade-offs between species conservation and agricultural production. Ranching's benefit in protecting rangelands from development has been valued across the western US and throughout much of the world where land is at risk for development [31,81]. Between 1984 and 2008, over 195,000 hectares of California's rangeland habitats were converted to residential development or intensive agriculture [82]. In this assessment, the benefit of maintaining ranching as compatible land use was recognized for a few listed species (seven animals, eight plants, Figure 7), but the value of grazing as a process was recognized for many more animals and plants.

Grazing has been described as a natural or even keystone process in ecosystems that have evolved with grazing [83]. The plants and animals in these systems are considered to have co-evolved with herbivores and exhibit adaptations that support their success while being grazed [19]. In systems with ecological and evolutionary grazing histories, livestock grazing can replace some of the functions provided by native herbivores, which may be extirpated, or incompatible with current land uses. However, the benefits to listed species from grazing in California are often indifferent from local evolution and grazing history because the native flora has been largely replaced. Instead, livestock grazing is playing a pivotal role in mitigating the environmental consequences of anthropomorphic-driven change, including invasive and naturalized non-native species and nitrogen deposition, and in fact, the management of a novel ecosystem comprised of plants from other places.

This value of grazing for species conservation is explained, at least in part, by the concept of "conservation reliant" species [84,85]. Due to anthropomorphic activities' impacts on a species or its habitat, many species require ongoing conservation management actions to recover or even persist, becoming conservation reliant. Scott et al. [86] examined the management actions required by recovery plans for species listed under the ESA and found that 84% of 1136 species are conservation reliant. The most common management

actions reported for conservation-reliant species were control of other species, active habitat management, and artificial recruitment.

Invasive plants are a major challenge to the conservation of native species throughout the world and a leading driver of extinction [87], and several researchers have concluded that California has some of the most heavily invaded ecosystems [88–90]. Non-native annual grasses are naturalized across California's grasslands, shrublands, and woodlands [91]. They have also colonized areas in California that were once sparse with vegetation like dunes [92] and desert [93] or areas once dominated by low-growing broad-leaved plants [94]. They are larger statured than most native broad-leaved plants, highly resilient to grazing and drought, and reproduce with vigor from high seed production and fertility. The ubiquitous presence and impact of naturalized non-native grasses underlie livestock grazing's benefits for many species across various ecosystems. While stated benefits were more common for listed species in grasslands than in other habitats, species benefitting from grazing's control of non-native species and habitat management, in general, are found on barren lands, desert, sand, playa or salt flats, shrublands, woodlands, and conifer forest as well as temporary pools, wetlands, and riparian zones. A decline and extirpation of native species are evident when livestock grazing is removed from ecosystems that are naturally open and barren but now crowded by invasive species and thatch [13,14,16].

While this study focused on grazing's impacts on threatened and endangered species, the effects identified are also related to species, not a risk, e.g., forage and pollinator plants for listed insects [16,55], and may apply to other species on grazed lands. The value of some level of grazing to support biodiversity in grasslands has been demonstrated in many locations worldwide [95–99]. When livestock are managed to prevent over utilization and habitat degradation, grazing can impact rangeland vegetation, increasing heterogeneity or patchiness and creating habitat for a greater diversity of species [98,100,101]. In California, the continued and growing impact of non-native species driven by anthropomorphic activities, including climate change, inadvertent species introductions, and air pollution [16,102,103], extends the value of grazing to support listed species across all terrestrial habitats and in some aquatic habitats.

Lunt et al. [104] proposed a framework to assess grazing's value for achieving conservation objectives in different ecosystems in Australia. Like stated reasons for grazing's benefit to species conservation in this assessment, they found grazing to be beneficial when it either (1) controls the biomass of potentially dominant, grazing-sensitive plants, (2) prevents encroachment by undesirable, grazing-sensitive, potential dominants, (3) provides required disturbance niches (4) maintains habitat structure or (5) enhances the diversity of species and vegetation structures across the landscape. This framework could be used to evaluate the role of grazing and rangeland livestock production in land sharing in many ecosystems.

## 5. Conclusions

This review of the USFWS listings documents concludes that many federally listed species in California are conservation reliant, requiring continued interventions to support their lifecycle or maintenance of habitat and that sharing land with livestock grazing will continue to be an important conservation strategy. Most, if not all, ecosystems on the planet have been altered by land use and other anthropomorphic effects. Threats to biodiversity stemming from pervasive non-native species, climate change, and the disruption of essential ecosystem processes and disturbance regimes may not be overcome simply by preserving land, improving regulatory protections, and removing threats [105]. Livestock grazing is perhaps the only ongoing land use that can be feasibly manipulated to manage vegetation and habitats at the landscape scale.

**Supplementary Materials:** The following are available online at https://www.mdpi.com/article/10.3390/su13084466/s1, Data S1: Species Data.

**Author Contributions:** Conceptualization, S.B. and L.H.; methodology, S.B.; formal analysis, S.B.; data curation, S.B.; writing—original draft preparation, S.B.; writing—review and editing, S.B. and L.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was supported by the University of California Agriculture and Natural Resources and the University of California Berkeley, Department of Environmental Science, Policy and Management.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Data is in Supplementary Material Data S1: Species Data.

**Acknowledgments:** The authors would like to acknowledge Elisa Mineo, Anh Thi Phuong Pham, and Theresa Becchetti, who assisted in developing the data set, James Bartolome and Sheri Spiegal for their review, and Chamali Dharmasiri and Lee Ann Ray for their assistance with the charts.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Holechek, J.L.; Piper, R.D.; Herbel, C.H. *Range Management: Principles and Practices*, 6th ed.; Prentice-Hall: Upper Saddle River, NJ, USA, 2011.
2. Sayre, N.F.; Carlisle, L.; Huntsinger, L.; Fisher, G.; Shattuck, A. The role of rangelands in diversified farming systems: Innovations, obstacles, and opportunities in the USA. *Ecol. Soc.* **2012**, *17*, 4. [CrossRef]
3. Galyean, M.L.; Ponce, C.; Schutz, J. The future of beef production in North America. *Anim. Front.* **2011**, *1*, 29–36. [CrossRef]
4. Plieninger, T.; Ferranto, S.; Huntsinger, L.; Kelly, M.; Getz, C. Appreciation, use, and management of biodiversity and ecosystem services in California's working landscapes. *Environ. Manag.* **2012**, *50*, 427–440. [CrossRef] [PubMed]
5. Charnley, S.; Sheridan, T.E.; Nabhan, G.P. (Eds.) *Stitching the West Back Together: Conservation of Working Landscapes*; University of Chicago Press: Chicago, IL, USA, 2014.
6. Green, R.E.; Cornell, S.J.; Scharlemann, J.P.; Balmford, A. Farming and the fate of wild nature. *Science* **2005**, *307*, 550–555. [CrossRef] [PubMed]
7. Fischer, J.; Abson, D.J.; Butsic, V.; Chappell, M.J.; Ekroos, J.; Hanspach, J.; Kuemmerle, T.; Smith, H.G.; von Wehrden, H. Land sparing versus land sharing: Moving forward. *Conserv. Lett.* **2014**, *7*, 149–157. [CrossRef]
8. Wilcove, D.S.; Rothstein, D.; Dubow, J.; Phillips, A.; Losos, E. Quantifying threats to imperiled species in the United States. *BioScience* **1998**, *48*, 607–615. [CrossRef]
9. Czech, B.; Krausman, P.R.; Devers, P.K. Economic associations among causes of species endangerment in the United States: Associations among causes of species endangerment in the United States reflect the integration of economic sectors, supporting the theory and evidence that economic growth proceeds at the competitive exclusion of nonhuman species in the aggregate. *AIBS Bull.* **2000**, *50*, 593–601.
10. Howell, H.J.; Mothes, C.C.; Clements, S.L.; Catania, S.V.; Rothermel, B.B.; Searcy, C.A. Amphibian responses to livestock use of wetlands: New empirical data and a global review. *Ecol. Appl.* **2019**, *29*, e01976. [CrossRef]
11. Schieltz, J.M.; Rubenstein, D.I. Evidence based review: Positive versus negative effects of livestock grazing on wildlife. What do we really know? *Environ. Res. Lett.* **2016**, *11*, 113003. [CrossRef]
12. Bartolome, J.W.; Allen-Diaz, B.H.; Barry, S.; Ford, L.D.; Hammond, M.; Hopkinson, P.; Ratcliff, F.; Spiegal, S.; White, M.D. Grazing for biodiversity in Californian Mediterranean grasslands. *Rangelands* **2014**, *36*, 36–43. [CrossRef]
13. Germano, D.J.; Rathbun, G.B.; Saslaw, L.R. Effects of grazing and invasive grasses on desert vertebrates in California. *J. Wildl. Manag.* **2012**, *76*, 670–682. [CrossRef]
14. Marty, J.T. Loss of biodiversity and hydrologic function in seasonal wetlands persists over 10 years of livestock grazing removal. *Restor. Ecol.* **2015**, *23*, 548–554. [CrossRef]
15. Pyke, C.R.; Marty, J. Cattle grazing mediates climate change impacts on ephemeral wetlands. *Conserv. Biol.* **2005**, *19*, 1619–1625. [CrossRef]
16. Weiss, S. Cars, cows, and checkerspot butterflies: Nitrogen deposition and management of nutrient poor grasslands for a threatened species. *Conserv. Biol.* **1999**, *13*, 1476–1486. [CrossRef]
17. Heitschmidt, R.; Stuth, J. *Grazing Management: An Ecological Perspective*; Timber Press: Portland, OR, USA, 1991; p. 259.
18. Koerner, S.E.; Smith, M.D.; Burkepile, D.E.; Hanan, N.P.; Avolio, M.L.; Collins, S.L.; Knapp, A.K.; Lemoine, N.P.; Forrestel, E.J.; Eby, S.; et al. Change in dominance determines herbivore effects on plant biodiversity. *Nat. Ecol. Evol.* **2018**, *2*, 1925–1932. [CrossRef] [PubMed]
19. Milchunas, D.G. *Responses of Plant Communities to Grazing in the Southwestern United States*; Gen. Tech. Rep. RMRS-FTR-169; US Department of Agriculture, Forest Service, Rocky Mountain Research Station: Fort Collins, CO, USA, 2006.
20. Augustine, D.J.; McNaughton, S.J. Ungulate effects on the functional species composition of plant communities: Herbivore selectivity and plant tolerance. *J. Wildl. Manag.* **1998**, *62*, 1165–1183. [CrossRef]

21. Wilcove, D.S.; Bean, M.J.; Long, B.; Snape, W.J.; Beehler, B.M.; Eisenberg, J. The private side of conservation. *Front. Ecol. Environ.* **2004**, *2*, 326–331. [CrossRef]
22. Myers, N.; Mittermeier, R.A.; Mittermeier, C.G.; Da Fonseca, G.A.; Kent, J. Biodiversity hotspots for conservation priorities. *Nature* **2000**, *403*, 853. [CrossRef] [PubMed]
23. Burge, D.O.; Thorne, J.H.; Harrison, S.P.; O'Brien, B.C.; Rebman, J.P.; Shevock, J.R.; Alverson, E.R.; Hardison, L.K.; RodrÍguez, J.D.; Junak, S.A.; et al. Plant diversity and endemism in the California Floristic Province. *Madroño* **2016**, *63*, 3–206. [CrossRef]
24. Baker, H.G. Sources of the Naturalized Grasses and Herbs in California Grasslands. In *Grassland Structure and Function*; Huenneke, L.F., Mooney, H.A., Eds.; Springer: Dordrecht, The Netherlands, 1989; pp. 29–38.
25. Mooney, H.A.; Hamburg, S.P.; Drake, J.A. The Invasions of Plants and Animals into California. In *Ecology of Biological Invasions of North America and Hawaii*; Mooney, H.A., Drake, J.A., Eds.; Springer: New York, NY, USA, 1986; pp. 250–272.
26. Zeder, M.A. Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion, and impact. *Proc. Natl. Acad. Sci. USA* **2008**, *105*, 11597–11604. [CrossRef]
27. Simberloff, D.; Martin, J.L.; Genovesi, P.; Maris, V.; Wardle, D.A.; Aronson, J.; Courchamp, F.; Galil, B.; García-Berthou, E.; Pascal, M.; et al. Impacts of biological invasions: What's what and the way forward. *Trends Ecol. Evol.* **2013**, *28*, 58–66. [CrossRef] [PubMed]
28. Huntsinger, L.; Bartolome, J.W.; D'Antonio, C.M. Chapter 20. Grazing Management of California Grasslands. In *Ecology and Management of California Grasslands*; Corbin, J., Stromberg, M., D'Antonio, C.M., Eds.; University of California Press: Berkeley, CA, USA, 2007; pp. 233–253.
29. Huntsinger, L.; Bartolome, J.W. Cows? In California? Rangelands and livestock in the golden state. *Rangelands* **2014**, *36*, 4–10. [CrossRef]
30. Edwards, S.W. A Rancholabrean-age, latest Pleistocene bestiary for California botanists. *Four Seas.* **1996**, *10*, 4–34.
31. Maestas, J.D.; Knight, R.L.; Gilgert, W.C. Cows, condos, or neither: What's best for rangeland ecosystems? *Rangel. Arch.* **2002**, *24*, 36–42. [CrossRef]
32. Díaz, M.; Tietje, W.D.; Barrett, R.H. Effects of Management on Biological Diversity and Endangered Species. In *Mediterranean Oak Woodland Working Landscapes Landscape Series, vol 16*; Campos, P., Huntsinger, L., Oviedo Pro, J.L., Starrs, P.F., Diaz, M., Staniford, R.B., Montero, G., Eds.; Springer: Dordrecht, The Netherlands, 2013; pp. 213–243. [CrossRef]
33. Kremen, C. Reframing the land-sparing/land-sharing debate for biodiversity conservation. *Ann. N. Y. Acad. Sci.* **2015**, *1355*, 52–76. [CrossRef]
34. Phalan, B.; Green, R.; Balmford, A. Closing yield gaps: Perils and possibilities for biodiversity conservation. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2014**, *369*, 1–16. [CrossRef]
35. Butsic, V.; Kuemmerle, T. Using optimization methods to align food production and biodiversity conservation beyond land sharing and land sparing. *Ecol. Appl.* **2015**, *25*, 589–595. [CrossRef]
36. Mottet, A.; de Haan, C.; Falcucci, A.; Tempio, G.; Opio, C.; Gerber, P. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Glob. Food Sec.* **2017**, *14*, 1–8. [CrossRef]
37. Center for Conservation Innovation. Defenders of Wildlife, ESA Docs Search. Available online: https://esadocs.cci-dev.org/ (accessed on 10 July 2017).
38. United States Fish and Wildlife Service. USFWS Environmental Conservation Online System (ECOS) Species Profiles. Available online: https://ecos.fws.gov/ecp0/reports/species-listed-by-state-report?state=CA&status=listed (accessed on 31 August 2017).
39. Natureserve. Available online: http://services.natureserve.org (accessed on 1 May 2019).
40. Comer, P.J.; Faber-Langendoen, D.; Evans, R.; Gawler, S.C.; Josse, C.; Kittel, G.; Menard, S.; P yne, M.; Reid, M.; Schulz, K.; et al. *Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems*; NatureServe: Arlington, VA, USA, 2003.
41. Franke, T.M.; Ho, T.; Christie, C.A. The chi-square test: Often used and more often misinterpreted. *Am. J. Eval.* **2012**, *33*, 448–458. [CrossRef]
42. United States Fish and Wildlife Service. *Sierra Nevada Bighorn Sheep (Ovis Canadensis Californiana = Ovis Canadensis Sierrae) 5-Year Review: Summary and Evaluation*; United States Fish and Wildlife Service: Ventura, CA, USA, 2008.
43. United States Fish and Wildlife Service. *Sidalcea keckii, Keck's Checkermallow, 5-Year Review: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2012.
44. United States Fish and Wildlife Service. *Cirsium Fontinale Var. Obispoense, Chorro Creek Bog Thistle, 5-Year Eeview: Summary and Evaluation*; USFWS: Ventura, CA, USA, 2014.
45. United States Fish and Wildlife Service. *Arctostaphylos Pallida, Pallida Manzanita, 5-Year Eeview: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2010.
46. United States Fish and Wildlife Service. *Cordylanthus Mollis Spp. Mollis, 5-Year Eeview: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2009.
47. United States Fish and Wildlife Service. *Little Kern Golden Trout (Oncorhynchus Mykiss Whitei), 5-Year Eeview: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2011.
48. United States Fish and Wildlife Service. *Paiute Cutthroat Trout (Oncorhynchus Clarkii Seleniris), 5-Year Eeview: Summary and Evaluation*; USFWS: Reno, NV, USA, 2013.
49. United States Fish and Wildlife Service. *Kern Mallow (Eremalche Kernensis), 5-Year Eeview: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2013.

50. United States Fish and Wildlife Service. *Blunt-Nosed Leopard Lizard (Gambelia Sila), 5-Year Eeview: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2010.
51. United States Fish and Wildlife Service. *Giant Kangaroo Rat, Dipodomys ingens, 5-Year Eeview: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2010.
52. United States Fish and Wildlife Service. *San Joaquin Kit Fox, Vulpes Macrotis Mutica, 5-Year Review: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2010.
53. United States Fish and Wildlife Service. *Santa Cruz Tarplant, Holocarpha Macradenia, 5-Year Review: Summary and Evaluation*; USFWS: Ventura, CA, USA, 2014.
54. United States Fish and Wildlife Service. *Ohlone Tiger Beetle, Cicindela Ohlone, 5-Year Review: Summary and Evaluation*; USFWS: Arcata, CA, USA, 2009.
55. United States Fish and Wildlife Service. *Bay Checkerspot Butterfly, Euphydryas Editha Bayensis, 5-Year Review: Summary and Evaluation*; USFWS: Sacramento, CA, USA, 2009.
56. United States Fish and Wildlife Service. *Lilium Occidentale, 5-Year Review: Summary and Evaluation*; USFWS: Arcata, CA, USA, 2009.
57. United States Fish and Wildlife Service. *Conservancy Fairy Shrimp, Branchinecta Conservation, 5-Year Review: Summary and Evalution*; USFWS: Sacramento, CA, USA, 2012.
58. United States Fish and Wildlife Service. *Lasthenia Conjugens Contra Costa Goldfields, 5-Year Review: Summary and Evaluation*; USFWS: Sacrmanto, CA, USA, 2013.
59. Marty, J.T. Effects of cattle grazing on diversity in ephemeral wetlands. *Conserv. Biol.* **2005**, *19*, 1626–1632. [CrossRef]
60. Fleischner, T.L. Ecological costs of livestock grazing in western North America. *Conserv. Biol.* **1994**, *8*, 629–644. [CrossRef]
61. Brown, J.H.; McDonald, W. Livestock grazing and conservation on southwestern rangelands. *Conserv. Biol.* **1995**, *9*, 1644–1647. [CrossRef]
62. D'antonio, C.M.; Meyerson, L.A. Exotic plant species as problems and solutions in ecological restoration: A synthesis. *Restor. Ecol.* **2002**, *10*, 703–713. [CrossRef]
63. Jackson, R.D.; Bartolome, J.W. Grazing Ecology of California Grasslands. In *Ecology and Management of California Grasslands*; Corbin, J., Stromberg, M., D'Antonio, C.M., Eds.; University of California Press: Berkeley, CA, USA, 2007; pp. 197–206.
64. Lowell, N.; Kelly, R.P. Evaluating agency use of "best available science" under the Endangered Species Act. *Biol. Conserv.* **2016**, *196*, 53–59. [CrossRef]
65. Belsky, A.J.; Matzke, A.; Uselman, S. Survey of livestock influences on stream and riparian ecosystems in the western United States. *J. Soil Water Conserv.* **1999**, *54*, 419–431.
66. Hayes, G. The saga of the Santa Cruz tarplant. *Four Seas.* **1998**, *10*, 18–21.
67. Germano, D.J.; Rathbun, G.B.; Saslaw, L.R. Managing exotic grasses and conserving declining species. *Wildl. Soc. Bull.* **2001**, *29*, 551–559.
68. Briske, D.D.; Derner, J.D.; Milchunas, D.G.; Tate, K.W. An Evidence-Based Assessment of Prescribed Grazing Practices. In *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*; Briske, D.D., Ed.; USDA-NRCS: Washington DC, USA, 2011; pp. 21–74.
69. Mysterud, A. The concept of overgrazing and its role in management of large herbivores. *Wildl. Biol.* **2006**, *12*, 129–141. [CrossRef]
70. Coughenour, M.B.; Singer, F.J. The Concept of Overgrazing and Its Application to Yellowstone's Northern Range. In *The Greater Yellowstone Ecosystem: Redefining America's Wilderness Heritage*; Yale University Press: New Haven, CT, USA, 1991; pp. 209–230.
71. Diaz, S.; Lavorel, S.; McIntyre, S.; Falczuk, V.; Casanoves, F.; Milchunas, D.G.; Skarpe, C.; Rusch, G.; Sternberg, M.; Noy-Meir, I.; et al. Plant trait responses to grazing–a global synthesis. *Glob. Chang. Biol.* **2007**, *13*, 313–341. [CrossRef]
72. Boyd, C.S.; Beck, J.L.; Tanaka, J.A. Livestock grazing and sage-grouse habitat: Impacts and opportunities. *J. Rangel. Appl.* **2014**, *1*, 58–77.
73. Krausman, P.R.; Naugle, D.E.; Frisina, M.R.; Northrup, R.; Bleich, V.C.; Block, W.M.; Wallace, M.C.; Wright, J.D. Livestock grazing, wildlife habitat, and rangeland values. *Rangelands* **2009**, *31*, 15–19. [CrossRef]
74. Jones, A. Effects of cattle grazing on North American arid ecosystems: A quantitative review. *West. N. Am. Nat.* **2000**, *60*, 155–164.
75. George, M.R.; Jackson, R.D.; Boyd, C.S.; Tate, K.W. A Scientific Assessment of the Effectiveness of Riparian Management Practices. In *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*; Briske, D.D., Ed.; USDA-NRCS: Washington, DC, USA, 2011; pp. 213–252.
76. Sliwinski, M.S.; Koper, N. Managing mixed-grass prairies for songbirds using variable cattle stocking rates. *Rangel. Ecol. Manag.* **2015**, *68*, 470–475. [CrossRef]
77. Malan, J.A.C.; Flint, N.; Jackson, E.L.; Irving, A.D.; Swain, D.L. Offstream watering points for cattle: Protecting riparian ecosystems and improving water quality? *Agric. Ecosyst. Environ.* **2018**, *256*, 44–152. [CrossRef]
78. O'Callaghan, P.; Kelly-Quinn, M.; Jennings, E.; Antunes, P.; O'Sullivan, M.; Fenton, O.; Huallachain, D.O. The environmental impact of cattle access to watercourses: A review. *J. Environ. Qual.* **2019**, *48*, 340–351. [CrossRef] [PubMed]
79. Derose, K.L.; Roche, L.M.; Lile, D.F.; Eastburn, D.J.; Tate, K.W. Microbial Water Quality Conditions Associated with Livestock Grazing, Recreation, and Rural Residences in Mixed-Use Landscapes. *Sustainability* **2020**, *12*, 5207. [CrossRef]
80. Holechek, J.L.; Gomez, H.; Molinar, F.; Galt, D. Grazing studies: What we've learned. *Rangel. Arch.* **1999**, *21*, 12–16.

81. Luoto, M.; Pykälä, J.; Kuussaari, M. Decline of landscape-scale habitat and species diversity after the end of cattle grazing. *J. Nat. Conserv.* **2003**, *11*, 171–178. [CrossRef]
82. Cameron, D.R.; Marty, J.; Holland, R.F. Whither the rangeland?: Protection and conversion in California's rangeland ecosystems. *PLoS ONE* **2014**, *9*, e103468. [CrossRef]
83. Knapp, A.K.; Blair, J.M.; Briggs, J.M.; Collins, S.L.; Hartnett, D.C.; Johnson, L.C.; Towne, E.G. The keystone role of bison in North American tallgrass prairie: Bison increase habitat heterogeneity and alter a broad array of plant, community, and ecosystem processes. *BioScience* **1999**, *49*, 39–50. [CrossRef]
84. Scott, J.M.; Goble, D.D.; Wiens, J.A.; Wilcove, D.S.; Bean, M.; Male, T. Recovery of imperiled species under the Endangered Species Act: The need for a new approach. *Front. Ecol. Environ.* **2005**, *3*, 383–389. [CrossRef]
85. Rohlf, D.J.; Carroll, C.; Hartl, B. Conservation-Reliant Species: Toward a Biology-Based Definition. *BioScience* **2014**, *64*, 601–611. [CrossRef]
86. Scott, J.M.; Goble, D.D.; Haines, A.M.; Wiens, J.A.; Neel, M.C. Conservation-reliant species and the future of conservation. *Conserv. Lett.* **2010**, *3*, 91–97. [CrossRef]
87. Blackburn, T.M.; Bellard, C.; Ricciardi, A. Alien versus native species as drivers of recent extinctions. *Front. Ecol. Environ.* **2019**, *17*, 203–207. [CrossRef]
88. Zavaleta, E.S.; Hobbs, R.J.; Mooney, H.A. Viewing invasive species removal in a whole-ecosystem context. *Trends Ecol. Evol.* **2001**, *16*, 454–459. [CrossRef]
89. Kettenring, K.M.; Adams, C.R. Lessons learned from invasive plant control experiments: A systematic review and meta-analysis. *J. Appl. Ecol.* **2011**, *48*, 970–979. [CrossRef]
90. D'antonio, C.M.; Vitousek, P.M. Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Ann. Rev. Ecol. Syst.* **1992**, *23*, 63–87. [CrossRef]
91. Shapero, M.W.K.; Huntsinger, L.; Becchetti, T.A.; Mashiri, F.E.; James, J.J. Land manager perceptions of opportunities and constraints of using livestock to manage invasive plants. *Rangel. Ecol. Manag.* **2018**, *71*, 603–611. [CrossRef]
92. Stark, J.D.; Chen, X.D.; Johnson, C.S. Effects of herbicides on Behr's metalmark butterfly, a surrogate species for the endangered butterfly, Lange's metalmark. *Environ. Pollut.* **2012**, *164*, 24–27. [CrossRef]
93. Germano, D.J.; Rathbun, G.B.; Saslaw, L.R.; Cypher, B.L.; Cypher, E.A.; Vredenburgh, L.M. The San Joaquin Desert of California: Ecologically misunderstood and overlooked. *Nat. Areas J.* **2011**, *31*, 138–148. [CrossRef]
94. Minnich, R.A. *California's Fading Wildflowers: Lost Legacy and Biological Invasions*; University of California Press: Berkeley, CA, USA, 2008.
95. Yuan, Z.Y.; Jiao, F.; Li, Y.H.; Kallenbach, R.L. Anthropogenic disturbances are key to maintaining the biodiversity of grasslands. *Sci. Rep.* **2016**, *6*, 1–8. [CrossRef] [PubMed]
96. Loeser, M.R.; Sisk, T.D.; Crews, T.E. Impact of grazing intensity during drought in an Arizona grassland. *Conserv. Biol.* **2007**, *21*, 87–97. [CrossRef]
97. Rook, A.J.; Dumont, B.; Isselstein, J.; Osoro, K.; WallisDeVries, M.F.; Parente, G.; Mills, J. Matching type of livestock to desired biodiversity outcomes in pastures—A review. *Biol. Conserv.* **2004**, *119*, 137–150. [CrossRef]
98. Fuhlendorf, S.D.; Engle, D.M. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. *BioScience* **2001**, *51*, 625–632. [CrossRef]
99. Noy-Meir, I. Interactive effects of fire and grazing on structure and diversity of Mediterranean grasslands. *J. Veg. Sci.* **1995**, *6*, 701–710. [CrossRef]
100. Holechek, J.L.; Baker, T.T.; Boren, J.C.; Galt, D. Grazing impacts on rangeland vegetation: What we have learned. *Rangelands* **2006**, *28*, 7–13. [CrossRef]
101. Davidson, K.E.; Fowler, M.S.; Skov, M.W.; Doerr, S.H.; Beaumont, N.; Griffin, J.N. Livestock grazing alters multiple ecosystem properties and services in salt marshes: A meta-analysis. *J. Appl. Ecol.* **2017**, *54*, 1395–1405. [CrossRef]
102. Chaplin-Kramer, R.; George, M.R. Effects of climate change on range forage production in the San Francisco Bay Area. *PLoS ONE* **2013**, *8*, e57723. [CrossRef]
103. Fenn, M.E.; Allen, E.B.; Weiss, S.B.; Jovan, S.; Geiser, L.H.; Tonnesen, G.S.; Johnson, R.F.; Rao, L.E.; Gimeno, B.S.; Yuan, F.; et al. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. *J. Environ. Manag.* **2010**, *91*, 2404–2423. [CrossRef]
104. Lunt, I.D.; Eldridge, D.J.; Morgan, J.W.; Witt, G.B. A framework to predict the effects of livestock grazing and grazing exclusion on conservation values in natural ecosystems in Australia. *Aust. J. Bot.* **2007**, *55*, 401–415. [CrossRef]
105. Carroll, C.; Rohlf, D.J.; Li, Y.W.; Hartl, B.; Phillips, M.K.; Noss, R.F. Connectivity conservation and endangered species recovery: A study in the challenges of defining conservation-reliant species. *Conserv. Lett.* **2015**, *8*, 132–138. [CrossRef]