Ecological and Economic Benefit-Cost Comparison of Grazed and Ungrazed Prairie Land for Critical Species Protection in Western Washington

2020 Annual Report

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Abstract

Most rangelands west of the Cascades in the Pacific Northwest occur on sites that historically supported native prairie. Over 90% of the prairies in this region have been converted to agriculture or lost to development, making conservation of this rare system a top conservation priority. At the same time, the human population in this region continues to grow, demanding more from regional food production systems. Therefore, agricultural producers are under great pressure from growing needs for food production and habitat conservation. Because of this, it is increasingly recognized that effective prairie conservation can only be achieved by partnering with private landowners to develop incentivized conservation strategies that maintain productive farms. Through a unique collaboration between agricultural producers, conservation scientists, economists, sociologists, regulators and agricultural researchers, we propose to evaluate if and how agricultural productivity can be maintained or enhanced in working landscapes while simultaneously accruing conservation value for rare native plants and animals. Through replicated on-farm experimental demonstrations, we will quantify the 'ecological lift' generated by conservation tools (altered grazing regimes, spring rest period, seeding native species). Additionally, we will evaluate the costs and benefits associated with conservation actions, to provide guidance on strategies and expenses for agricultural producers. Finally, we will survey producers to identify concerns, questions and needs (financial, technical, other) surrounding habitat conservation on their properties. The combined ecological, economic and social survey data will help guide government incentive programs. We expect this work to identify opportunities for agricultural producers to increase the conservation value of their properties, while maintaining or even enhancing their bottom line. Study findings and educational materials resulting from the demonstration trials will be communicated through peer-reviewed publications, presentations at academic conferences, a published grazing management guidebook, and a series of collaborative regional workshops for agricultural producers, researchers, extension agents, and land managers.

Project Objectives

1. Develop a regional network of three grazed prairie research sites to demonstrate and evaluate effects of conservation tools on prairie habitat. This objective will:
    a. Implement conservation tools for target species and habitats, with focus on management intensive grazing, exclusion during critical flowering periods and/or native seeding.
    b. Evaluate the impacts of conservation installations through a range of habitat and species-specific metrics over 3 years.
2. Utilize the regional network of grazed and ungrazed prairie sites, to quantify the financial costs and benefits associated with managing critical habitat and species over a 3-year period. This objective will:
    a. Provide practical financial information to farmers, the conservation community, and the county planners concerning the costs of meeting Habitat Conservation Plan (HCP) requirements on grazed and ungrazed prairies both on private and protected sites.

   b. Develop enterprise budgets and a cost-benefit analysis to inform HCP acreage targets when protecting critical species on grazed land relative to conservation preserve land.
3. Engage private landowners by administering a social survey focused on landowner needs for increased involvement in land conservation programs (conservation easements, HCP, Safe Harbor Agreement). This objective will:
   a. Engage agricultural producers and regulatory entities in a productive discussion on incentives needed for habitat conservation on working lands.
   b. Provide feedback for regulatory programs on effective strategies to engage private landowners.
4. Present opportunities for technical assistance related to habitat management and discuss incentive opportunities with agricultural producers, regulatory agencies, and conservation land managers through several mechanisms:
   a. Workshop series, with field tours of the agricultural demonstration sites and native prairie preserve sites. Field tours will be sponsored by Washington State University (WSU), Center for Natural Lands Management (CNLM), Thurston County Conservation District, and Natural Resource Conservation Service (NRCS).
   b. Publications including a WSU-Extension technical bulletin providing management guidelines and financial data for conservation tools, as well as two published manuscripts in peer-reviewed journals.
   c. Presentation of findings at regional and national conferences.

Cooperators

Jensen, Kevin. Riverbend Ranch, Tenino, WA
Colvin, Fred. Colvin Ranch. Tenino, WA
Fisher, Bryan. Fisher Ranch. Rochester, WA
Chaney, Marty. NRCS. Olympia, WA
Chaput, Chris. Thurston County Community Planning, Olympia, WA
Watson, Phillip. University of Idaho Economics Dept., Moscow, ID
Painter, Kathleen. University of Idaho Extension, Bonner sFerry
Mallonee, Maynard. Mallonee Family Farm, Boistfort, WA
Sanders, Christina. WSU Division of Governmental Studies and Services, Pullman, WA.
Anderson, Brian. WSU Division of Governmental Studies and Services, Pullman, WA.
Bussan, Samantha. WSU Natural Sciences Graduate Program, Vancouver, WA.

Research

Hypotheses

1. Adoption of conservation grazing practices can improve the habitat value of grazed prairie sites
2. Conservation grazing practices may approach habitat value of ungrazed native upland prairie, as measured by native species richness, percent native groundcover, and butterfly behavior
3. Endangered or threatened species populations, such as Mazama pocket gopher, may be comparable in occupancy between grazed and ungrazed prairie sites

4. Grazing land productivity will not decrease as a result of adopting conservation grazing practices that improve habitat for endangered and threatened species
5. Integrating grazed working lands into conservation practices can result in a significant economic contribution to the regional economy, in comparison to removing working land from production for habitat and species protection
6. Specific strategies can be identified by farmers and ranchers to improve participation and trust in conservation programs and conservation partners

Materials and Methods

Three farm sites (Colvin Ranch, Fisher Ranch and Riverbend Farm) and three ungrazed prairie sites (Johnson Prairie, West Rocky Prairie, and Wolf Haven) were chosen for this study to represent a range of forage quality and practices and upland prairie habitat conditions. Within each farm site, six 1-acre paddocks were chosen for Conservation Grazing Practice (CGP) treatments (n=30), along with paired 1-acre Business as Usual (BAU) paddocks (n=30) (see site maps in Appendix 1). Assigned CGP treatments were developed through the NRCS Site Inventory Planning process (NRCS, 2017) and reflect site-specific conditions and desired natural resource outcomes for each ranch (Table 1).

Table 1. BAU and CGP Treatments for each farm site

Farm Site	BAU Treatment	CGP Treatment
Colvin Ranch	Rotational grazing with spring deferment	Native seeding
Fisher Ranch	Rotational grazing w/ spring deferment	Rotational grazing w/ spring deferment and native seeding
Riverbend Farm	Continuous grazing	MiG w/ spring deferment; native seeding

Six areas within each of the selected native upland prairie (NUP) sites were also chosen as replicate plots to provide a comparison to the BAU and CGP treatments at the farm sites (Appendix A). We placed a 15 m x 15 m grid over maps of each of the 1-acre treatment plots at each site and randomly chose 5 subplots within each treatment plot. A range of community and species-specific variables were measured in these plots (Table 2).

Table 2. Treatments and response variables evaluated

Treatments (independent variables)	Business as Usual grazing (BAU), Conservation Grazing Practices (CGP), Native Ungrazed Prairie (NUP)
Site responses (response variables in BAU and CGP)	Forage height & biomass, uniformity of use, livestock concentration areas, soil compaction, erosion
Plant community (response variables)	Native and non-native species richness, percent cover of trees, shrubs, forbs, native grass, and forage grass; abundance of butterfly nectar and hostplants
Gophers (response variables)	gopher mounds/grid cell
Butterfly behavior (response variable)	Move lengths, turning angles and diffusion rates
Soil measures (response variable)	Soil temperature, soil bulk density
Soil measures (site-level co-variates)	soil classification, soil nutrients

We constructed the necessary semi-permanent infrastructure for CGP treatments at Riverbend Farm (creating rotational paddocks) in fall 2018 and seeded a site-specific mix of native species into each of the CGP treatment paddocks at each site in October-November 2018 (Figure 1). Species were chosen according to several criteria: previous successful establishment in grazing systems, early season phenology, diversity of life histories (i.e., perennial, annual), low seed cost, and sufficient seed availability (see Appendix B for more information on species). Seeding rates were based on previously used rates in both upland prairie and in grazing systems and documented germination rates, when available. In spring 2019, we quantified seeded species establishment by counting individual seedlings within 4 systematically placed 1 m^2 quadrats within each 15 m x 15 m vegetation monitoring subplot.

Figure 1. The ten species selected for native seeding into farm sites. See Appendix B for full species descriptions.

Vegetation monitoring

To determine the native and non-native species richness in each site and each treatment, we recorded all plant species present in each of the five 15 m x 15 m subplots within each plot in each treatment (CGP, BAU, NUP) in May-June 2018-2020. Additionally, we recorded the percent cover of trees, woody shrubs, native forbs, forage species, native grasses, and abundance of butterfly resource species in each subplot (Figure 2, Table 2). Finally, we measured abundance of seeded species in four 1 m x 1 m quadrats in each subplot. To evaluate differences in plant community composition, we used nonparametric

Figure 2. Conducting vegetation monitoring using socially-distanced COVID-19 safety protocols in spring 2020 at Riverbend Farm.

methods (Kruskal-Wallis, Non-metric Multidimensional Scaling) because our data were not normally distributed and transformations were inadequate to fit data to a normal distribution.

Gopher monitoring

Mazama pocket gophers are 100% fossorial, making measures of abundance extremely difficult and labor intensive. Instead of tracking abundance through live-trapping, we have chosen to track presence/absence sign (i.e., mounds; Figure 3) and use these data to determine occupancy estimates. Occupancy as a metric of population status that indicates the proportion of the landscape that is being utilized by the target species. This technique requires repeat visit surveys of fresh mounds (< 48 hrs. old) within the treatment areas so that seasonal and annual impacts to mound-building are accounted for. We visited plots three times in Fall 2018, 2019 and 2020 with a 3- to 4-day interval between visits. Each survey consisted of searching plots for two minutes or until fresh gopher mounds were located.

Figure 3. Old gopher mound with native *Ranunculus occidentalis* growing out of it at Colvin Ranch.

Butterfly behavior

In high quality habitat, butterflies tend to have movement paths comprised of short, quick steps and high turning angles. This behavior results in concentrated individual search behavior in areas with high reward (high density of resources or oviposition/ reproductive sites) in contrast to highly mobile search behavior in areas with low reward (low density of resources or rep roductive sites, often called "matrix"). This is also often called an "Area Restricted Search". With measures of move rate (low or high mobility) and turning angles, we can calculate habitat-specific dispersal, or diffusion rates. We focused on two species for all butterfly observations: silvery blue butterfly (*Glaucopsyche lygdamus)* in the early season (late April-early June) and ochre ringlets (*Coenonympha tullia eunomia*) in early and late season (May-mid July and August-September).

Figure 4. Silvery blue (Glaucopsyche lygdamus) and Ochre ringlet (Coenonympha tullia eunomia) butterflies.

2020 Methods

COVID-Related Impacts: Due to restrictions on research and travel by WSU and Washington State in the wake of COVID-19, we changed our initial research plans and limited our work to one site. In addition, the universities (WSU and The Evergreen State College) would not permit undergraduate interns or volunteers to participate in research in May 2020. This resulted in substantially lower sample size than prior years.

We focused on Riverbend Ranch, which had the most significant changes to its management as part of its CGP treatment (introduction of rotational grazing and native seeding—see Appendix A, Figure 4). We pivoted our work to test the influence of CGP vs BAU on butterfly performance and butterfly behavior with the hypothesis that if CGP influences habitat quality, butterflies would show both great preference towards the habitat and higher performance. Together preference and performance are measures of the effective habitat quality, i.e. whether a habitat is a potential demographic source or demographic sink. We conducted a modified preference-performance study (Thompson and Pellmyr 1991) to test whether there was a difference between the BAU and CGP on Riverbend Ranch treatments in terms of larval survival ("performance") and adult edge behavior ("preference"), and if so, whether the adults preferred the treatment that maximized larval performance.

To measure edge behavior by *G. lygdamus* and *C.t. eunomia ,* we released butterflies at the boundary of BAU and CGP and compared this behavior to releases at a "virtual" boundary of BAU and CGP. After release, we quantified the direction of movement as well as subsequent flight paths (movement steps and turning angles) to quantify habitat-specific diffusion using method described for 2019 behavioral research. We released individuals at haphazardly chosen locations in the CGP and BAU treatments as far from borders and fence lines as possible, as well as haphazardly chosen locations along the border between treatments.

To measure performance, we collected females of both species in the field and attempted to encourage them to lay eggs in captivity. Then we would have raised their larvae to third instar before placing them in the BAU and CGP treatments and tracking their growth, residence time, and ant tending interactions. However, the field house did not have adequate conditions for oviposition or larvae growth. Due to COVID travel restrictions we were unable to travel to and from WSU Vancouver to use the greenhouse and we were unsuccessful in raising enough larvae to conduct the "performance" part of the study.

2019 Methods
Funds from Western SARE did not include funding for this aspect of the study in Year 2 (2019). We obtained another grant from Conservation, Education, and Research Opportunities International (CREOi) for butterfly behavior observations (Figure 4). From April-September 2019, we quantified behavior at six sites, two in each of three management categories: "conventional grazing," defined as continuous grazing with no spring rest period, "conservation grazing," defined as rotational grazing with a spring rest period, and native upland prairie (see Table 3). While there was overlap with some sites included in the experimental grazing manipulation part of this project, we worked only in areas that were not being manipulated. We observed two species: silvery blue butterfly (*Glaucopsyche lygdamus)* in the early season and ochre ringlet (*Coenonympha tullia eunomia*) in early and late season. We conducted observations by releasing an individual and following for up to 60 minutes. Each individual's behavior was recorded and position marked with a pin flag every 15 seconds. From these

observations we measured the move length and turning angles. From these we calculated habitat-specific diffusion rates assuming a correlated random walk model of movement, as consistent with prior studies of similar butterfly species (Schultz 1998). Butterfly host plant and nectar data were also collected.

Data Analysis

Using the G. lygdamus data, we ran a generalized linear mixed model (GLMM) with diffusion rates as the response variable, sex and management type as fixed effects and site as a random effect. See results section for future analyses.

Table 3: Site Management Categorization*

Management Category	Sites
Conventional grazing	Maynard Mallonee's farm Riverbend Ranch
Conservation grazing	Mary Mallonee's farm Colvin Ranch
Native Upland Prairie	Johnson Prairie (Joint Base Lewis McChord) West Rocky Prairie (Washington Department of Fish and Wildlife)

**The grazing categories are separate from the CGP and BAU categories in the larger project.*

Soil nutrient assessment

Baseline soil nutrient status was evaluated in Fall 2018 from the three cooperating ranch sites and the three prairie sites. Where soil conditions allowed, fifteen ¾" soil cores from each replicate paddock/unit were obtained to a depth of 8 inches. In instances where rockiness prevented soil auger penetration, at least one exposed face soil sample from each quadrant of each replicate was collected to 8". The exposed face consisted of exposing a vertical soil profile to 8", which required an approximately 6" x 6" area excavation through gravelly conditions. Sub-samples from each replicate were combined, and a composite sample from each of the six replicates within each research site was sent to A&L Soil Testing Laboratories (Portland, OR) for analysis. Samples were refrigerated prior to shipping, then wrapped with gel packs in bubble wrap for transit. Samples were analyzed for nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, iron, copper, zinc, manganese, boron, pH, cation exchange capacity, organic matter and estimated nitrogen release.

Forage biomass sampling

Timing and frequency of forage biomass and height estimations at prairie and ranch sites varied by site (Table 4). Sampling was designed around the seasonality of cool-season grass production (Figure 5) and deferment periods for native prairie plants to set seed. These two factors effectively identify key management periods (Figure 6), including an early season (February – March) grazing period prior to deferment, grazing deferment during native plant seed set (April – May/June), post-deferment grazing of stockpiled forage (June – July but as late as September), a roughly coinciding summer dormancy, a fall regrowth period (September –

October), a late season grazing of fall regrowth where soil conditions permit, and finally winter dormancy when cool conditions limited further growth.

Table 4. Timing of biomass and height measures at grazed and ungrazed prairie sites in 2019.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Fisher				x		x			x			x+
Colvin				x		x			x			x
Riverbend				x	x	x	x	x	x			x
John						x						
West						x						
Wolf						x						

Rotational grazing management employed at Fisher and Colvin ranches
Rotational and continuous grazing employed at Riverbend where CGP included not only seeding but also a grazing paddock system.
Total spring-summer biomass only was measured at ungrazed prairie sites (Johnson Point, West Rocky, and Wolf Haven)

Total forage biomass production at ranch sites was estimated by sampling at least four times in an attempt to capture a full picture of annual forage production. Each sampling period captured forage growth that occurred in the time since the previous sampling. Colvin and Fisher Ranches, which are rotationally grazed sites, were sampled in April, June, and December to capture early season, spring, and fall forage production, respectively. A post graze sampling (July – September) occurred to estimate 'before-after' forage presence to calculate utilization. The BAU (continuous grazing) and CGP (introduced rotational grazing paddocks) treatments at Riverbend were sampled monthly from April through September.

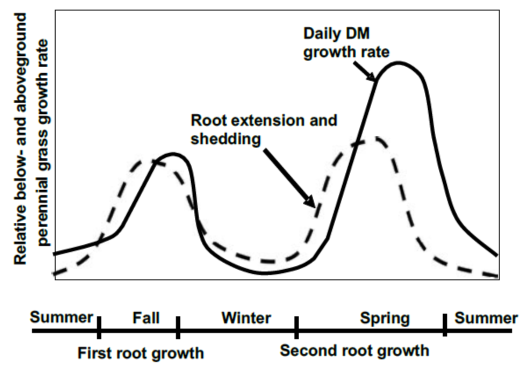

Figure 5. Typical cool-season grass growth cycle in the Pacific Northwest, emphasizing the importance of fall root growth that sets the stage for spring forage production (Franzen et al. 2017).

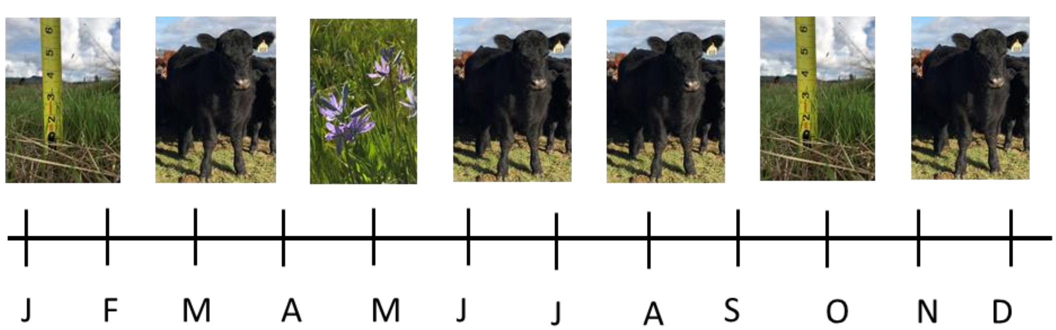

Figure 6. Primary Conservation Grazing management periods, including early spring forage growth (Jan-Feb), an early spring flash graze (Feb-Mar), deferment period (~Apr-May), summer grazing season and forage dormancy (Jun-Aug), fall forage regrowth (Sept-Oct), and fall/winter forage utilization (Nov-Jan).

Prairie sites were sampled in June only, capturing forage growth during the primary growing season, after which point dry conditions effectively precluded further growth and forage dormancy began. Total biomass production at prairie sites was therefore based on June measurements.

At the ungrazed prairie sites, three of five 15 m x 15 m subplots within each replication were randomly selected along a rough transect through each of six replications. One biomass sample was collected from each of the three subplots using a randomly tossed 4.8 ft^2 cable ring (Figure 7). Aboveground plant material was clipped to ground level within each ring, creating a total of 3 sub-samples per replication. Sub-samples were dried at 55°C for five days at the WSU Puyallup Research and Extension Center. Dried weights were obtained to the nearest one-tenth gram and averaged to provide six replicate values per site (18 total measures, n=6).

Figure 7. Forage biomass sampling utilizing NRCS cable hoop method.

Sampling at grazed sites utilized two grazing exclusion cages (Figure 8) per treatment (one in CGP, one in BAU). Each of the two cages was paired, at each time of sampling, with a no-cage sample randomly collected using the same cable method described above, providing a protected and unprotected biomass estimation (Figures 9, 10). Cages were used to detect any grazing that occurred prior to sampling (such as unplanned grazing in a site that should be in a rest period), as well as quantify cumulative biomass additions from the previous sampling (see below).

Figure 7. Installing a grazing exclusion cage at Riverbend Farm.

Total production and utilization measures relied on coordinated use of cage and no-cage samples. A cage-only or a cage/no-cage average in April provided the first production measure, onto which subsequent production estimates were added cumulatively. At the time of sampling, three cage forage heights, as well as a hoop biomass sample from within the cage were obtained (Figure 11). The hoop was then randomly tossed to a new location, and heights and a hoop biomass sample obtained as illustrated in figure 8. Then the exclusion cage was relocated directly adjacent to the no-cage hoop sampling site. Monthly cumulative biomass production additions were calculated by subtracting the no-cage hoop measure from the prior sampling periods from the cage hoop measure from the current sampling period, providing an estimation of the biomass added since the previous sampling.

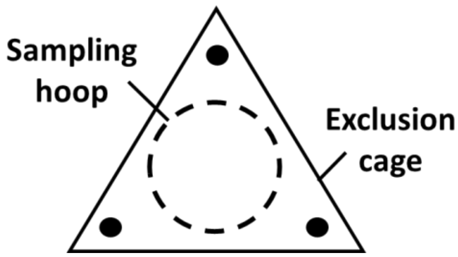

Figure 9. One biomass sample was collected per exclusion cage within each experimental unit, and one in an adjacent 'no-cage' position. The ring was well within the cage footprint to avoid peripheral grazing. Height measurements were taken at 3 locations (black circles) approximately 10 in. inside each corner of the exclusion cage.

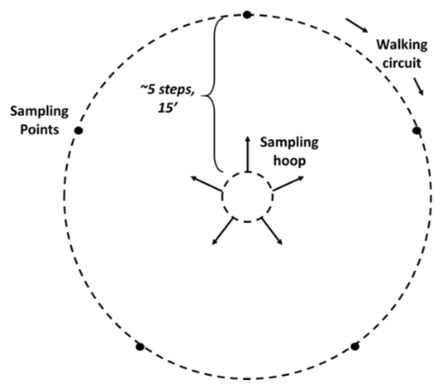

Figure 10. One 'no-cage' biomass paired with the cage measure was collected by randomly tossing the cable ring within each respective experimental unit. Height measurement were taken at 5 locations distributed at equidistant points along a circle around the randomly cast sampling hoop as illustrated.

April biomass at ranch sites contributed or did not to production based on whether cattle consumed detectable amounts. Summer (July/August) regrowth was analyzed specifically at Riverbend Ranch by shifting from measuring early season growth (dormant by late June) to the small amount of green post-graze summer regrowth (Figure 11), with the intent of tracking potential extension of forage production into the dry season in CGP treatments. Fall biomass production data were not yet analyzed at the time or reporting.

Figure 11. Grass regrowth in July 2020 at Riverbend Ranch. Note evidence of prior grazing (low in frame), and subsequent growth during rest period.

Forage height

At ungrazed prairie sites, three height samples were collected in each of three subplots used for biomass sampling. Starting from a reference point on the southwest corner (located by GPS) of each subplot, three height measures were collected at a series of 15-pace intervals in the directions north by northwest, then northeast, and then again north by north by northwest. Three height

Figure 12. Preparing Americorps volunteers for field work at Riverbend Farm.

measures per sub-sample across three subplots across six replications were collected (36 total measures, n=6). Americorps members assisted with data collection for all vegetation, gopher, and forage metrics (Figure 12).

Forage height estimations at grazed sites were collected as noted in Figures 9 and 10. At cage locations, a measure was taken within each corner of the exclusion cage, while at no-cage locations, five measures were collected along a circle around the randomly tossed no-cage biomass sampling ring.

Biomass Utilization

Percent biomass utilization is reported here and is important to monitoring efficiency of forage use. However, it is complicated by potentially incomparable sampling methods, and high variability across sites, between treatments, and within experimental units. Some challenges were as follows:

- Monitoring continuous grazing using the cage method relied upon calculating the difference between cage and no-cage biomass (a spatial approach: one protected sample here, a second unprotected sample there, taken during the same visit). Percent utilization can be estimated for each sampling period by dividing the biomass consumed (difference) by the total (caged). This measure averaged over every sampling period provided a season-long estimation of forage utilization.
- Monitoring rotationally grazed biomass relied upon calculating the difference between pre-grazed treatments (June sampling), and post-grazing (July September sampling), representing a temporal approach: post-grazing samples (leftovers) substracted off pre-grazed samples (total available) to estimate forage consumed. In all cases reliable post-graze samples were difficult to obtain based on different grazing regimes and seasonal timing at the different ranches.
- While these are arguably the only available methods to compare percent forage utilization (spatial cage/no-cage and before/after) between these grazed systems, the methods are concerningly different, particularly in light of additional differences in overall biomass available in these systems at each time of sampling. Continuously grazed forage was between 0.25 and 3 in tall, and biomass in continuously grazed systems caged one month since the previous clipping was hardly taller. By comparison, rotationally grazed paddocks prior to grazing were 15 in and greater, while post-grazing paddocks in rotational systems remained 5 to 10 in in height with considerable variability from trampling and oxidation by post-graze sampling. In 2020 a post-graze sample at Colvin could not be obtained and thereby only April utilization could be estimated for that site-year.

Soil taxonomy work

Taxonomic soil descriptions were completed by the USDA Natural Resource Conservation Service Soil Survey staff operating out of Olympia, WA. One to three soil pits were excavated at each site; the number of pits depended on the presence or absence of mima mounds or low-lying topography. Both mound and intermound soil pits were dug on sites with mounds and pits were dug at other distinct landforms such as a low-lying area. Soil taxonomic work consisted of excavating soil with shovels to appropriate diagnostic horizons, which typically did not exceed 100 cm. Methods presented in the *NRCS Field Book for Describing and Sampling Soils* (version 3.0) were utilized to document site characteristics including parent material, landforms, land shape, and drainage, as well as diagnostic features (i.e., diagnostic horizons) and soil pit descriptions consisting of horizonation, color, texture, and structure (Table 2). Full soil taxonomic descriptions were included in a final report by NRCS staff.

Survey of Grazing Practices in Southwest Washington

We developed a survey to gather information on grazing practices in western Washington, potential barriers and incentives to implementing conservation practices for landowners, and feedback regarding regulatory programs and agency relationships. The survey contained questions related to land use and land use history, potential conservation barriers and conservation incentives, relationships with agencies/organizations, and demographics. The questions were formatted as multiple choice or Likert Scale. There was also a section where we invited respondents to tell us any information they felt was not covered in the rest of the survey.

We vetted the survey through a meeting with a focus group comprised of producers participating in the grant (Fred Colvin, Kevin Jensen, and Maynard Mallonee) in fall 2018. The producers each took the survey in draft form and then provided feedback on terminology, clarity, length, flow, and question relevance. We obtained the certificate of exemption from further review from Washington State University's Internal Review Board in February 2019. We used a mixed method (Dillman 2007) to distribute the surveys online and in print for producers for whom we did not have email addresses. We built the emailed surveys through the survey software Qualtrics© and built the printed version in Microsoft Word. We partnered with participating organizations throughout western Washington, including WSU county extensions, farm bureaus, conservation districts, and others, to distribute the survey via anonymous Qualtrics link to their email databases. We were also able to obtain mailing addresses of some landowners through the Thurston and Lewis county extensions and mailed surveys to landowners for whom we did not have email addresses. Over 300 printed surveys were mailed.

Enterprise budgets

Enterprise Budget Development for Cattle Production

A meeting with producers was held for the purpose of conducting a Delphi Method survey of costs of cattle production in Thurston County. The DM is a formalized approach to assembling a group ofexperts and soliciting information in their area of expertise (Linstone and Turoff, 1975 and Weblar et al 1991), in this case, regarding the costs and earnings associated with various prairie grazing practices. Enterprise budgets were created that compare earning from traditional cow-calf production systems and grass-finished beef enterprises that market directly to consumers. These budgets will be finalized pending review by subject area specialists, and a draft 50-head Cow-Calf and Grass Finished Steers Enterprise Budget is pending.

Costs Estimates for Prairie Habitat Restoration Scenarios
A meeting with project personnel and stakeholders provided detailed scenarios for determining costs for three different prairie habitat restoration scenarios. These include Scotch Broom infested parcels, abandoned farmland, and abandoned rangeland. Specific annual operations for habitat restoration extend over multiple years. Relatively aggressive management is required to convert previously unmanaged land into prairie habitat with native species. Repeated burning, mowing, spraying and planting over many years would be required to restore these lands to their native status. These cost estimates are currently being developed and reviewed.

Soil Quality Parameters – Soil Temperature, Bulk Density and Forage Dynamics
An evaluation of the relationships between forage height, soil temperature, grazing treatment and soil bulk density was added to the study in 2020. The research team was interested in the potential of higher residual forage in CGP treatments to decrease mean daily high soil temperatures, presumably due to shading effect, and thereby extend forage growth into the summer dormant period. This would be beneficial to ranchers.

Soil temperature data loggers (HOBO Pendant® MX 2201) were placed at 10cm depth in three replications in CGP and BAU treatments at Riverbend Ranch, and in three replicated plots at West Rocky Prairie. Temperature data was collected from late March through November 2020. Forage height was measured weekly, and soil temperature data was downloaded once per month.

Soil bulk density measures were obtained using an AMS Bulk Density Sampler Cup and AMS Compact Slide Slide Hammer. Samples were collected in May and dried at 105 C for 72 hours. Bulk density was calculated as the dry mass per volume of the sampling ring (g/cm^3).

<u>Results and discussion</u>
Out of the 10 species we seeded into CGP treatments, 5 successfully established in at least one CGP site by spring 2020 (as captured in our $1m^2$ quadrats): *Castilleja levisecta* (golden paintbrush), *Collinsia parviflora* (maiden blue-eyed Mary), *Lupinus bicolor* (bicolor lupine), *Plectritis congesta* (sea blush), *Ranunculus occidentalis* (western buttercup) (Figure 13). Presence of *Collinsia parviflora* and *Lupinus bicolor* in the BAU treatments was due to the fact they were already established at sites before seeding occurred (Table 5). The persistence of the annual species 2 years post-seeding shows that they are reproducing on their own in the CGP units. It is also worth noting that due to the patchy nature of establishment for some of the seeded species at the grazed sites, our monitoring quadrats did not capture their presence, despite large established patches in the paddocks. This is especially true for *Cerastium arvense* (field chickweed), which we found at both Fisher Ranch and Colvin Ranch (Figure 13).

Figure 13. Seeded species at Colvin Ranch: a) *Castilleja levisecta*, b) *Cerastium arvense* and *Plectritis congesta*, and c) *Lomatium triternatum*.

Table 5. Mean abundance of native seeded species (± 1SD) across the different sites and the three treatments (n=6). Absolute abundance is quantified as the number of individuals per 1m^2 monitoring quadrat. *R. occidentalis* was already present in large quantities at Colvin Ranch so it was not seeded, nor was it monitored there. This is represented by 'N/A'.

Treatment	**Site**	*Castilleja levisecta*	*Collinsia parviflora*	*Lupinus bicolor*	*Plectritis congesta*	*Ranunculus occidentalis*
BAU	Colvin	0	0	0.01 ± 0.09	0	N/A
	Fisher	0	0.05 ± 1.3	0.03 ± 0.20	0.02	0.13 ± 0.88
	Riverbend	0	0	0.05 ± 0.31	0	0
CGP	Colvin	0.03 ± 0.20	0.4 ± 1.74	0.06 ± 0.33	0.40	N/A
	Fisher	0	0.4 ± 1.71	0.18 ± 0.51	0.55	0.18 ± 0.73
	Riverbend	0	0.02 ± 0.12	0	0	0.03 ± 0.22
NUP	Johnson	0	2.37 ± 9.60	0.58 ± 1.23	0.80	0.32 ± 1.49
	West Rocky	0	0.31 ± 1.83	0.03 ± 0.22	0.34	0.13 ± 0.83
	Wolf Haven	0.21 ± 1.15	0.72 ± 1.49	0.16 ± 0.42	1.04	0.18 ± 0.93

Native Species Richness

While the mean native species richness is still 4-5 times greater in the NUP than in either grazing treatment, the CGP treatments significantly increased native species richness over the BAU treatment in just two years (Figure 14).

Increased native species richness was observed at all ranch sites: Colvin gained five species, Fisher gained three species while Riverbend gained one species (Figure 15). The increase in richness was due to the seeding of native species, in particular *Plectritis congesta*, *Collinsia grandiflora*, and *Ranunculus occidentalis* (Table 5). Compared to native ungrazed prairies, native species richness at ranch sites was much lower (2-12 species on average at ranch sites compared to 15-23 species on average in NUPs) (Figure 15).

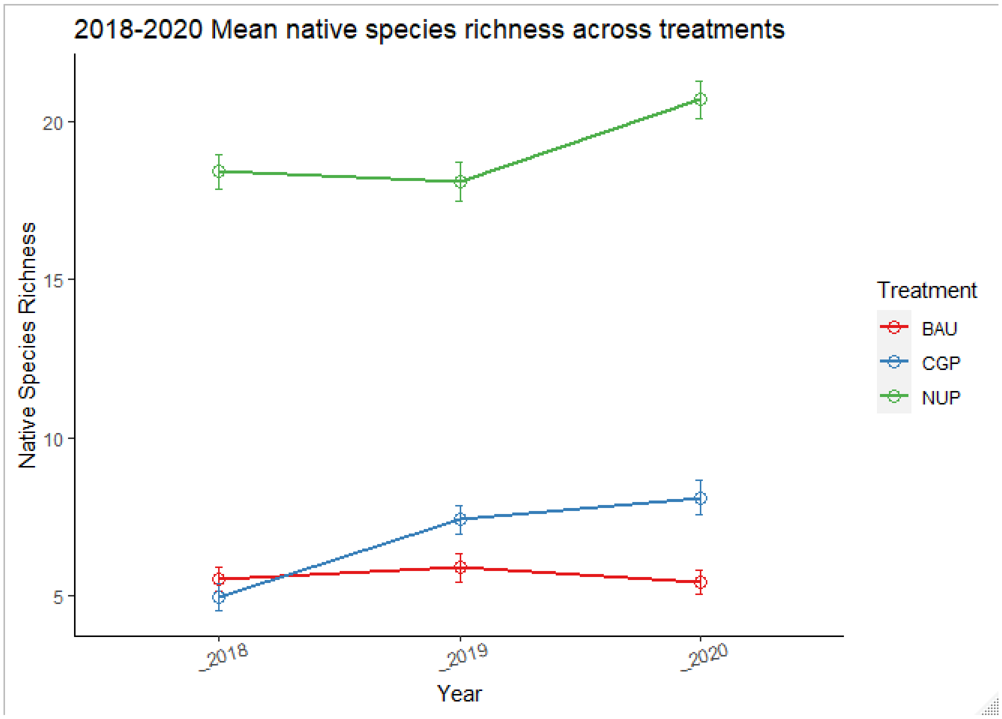

Figure 14. Native species richness across treatments from 2018 to 2020. Error bars represent ±1 SE.

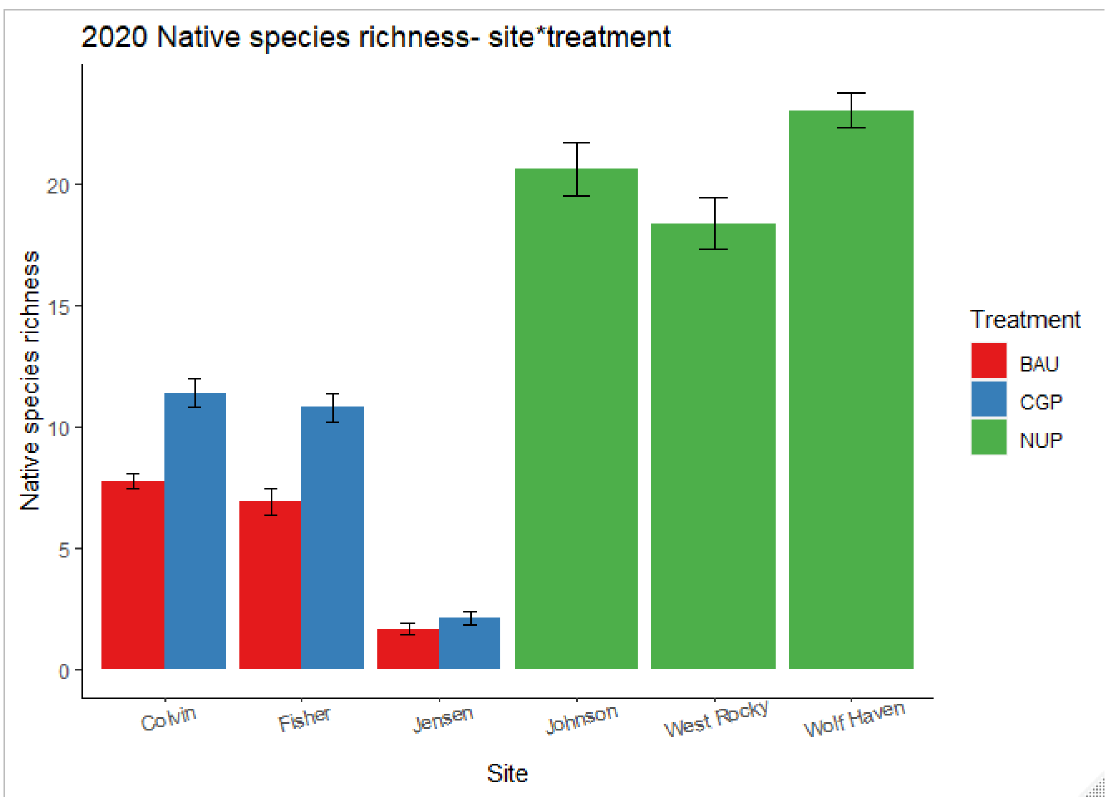

Figure 15. Native species richness across study sites and treatments in 2020. Error bars represent ±1 SE.

Non-native Species Richness

Non-native species richness showed minimal change from 2018 to 2019 but increased substantially in the CGP treatment in 2020 (Figure 16). Both BAU and NUP treatments showed a slight increase in non-native species richness over time (~1.7 species on average for each treatment), but the CGP treatment gained an average of 6.2 species over the three years of the study. This increase was largely driven by increased richness at Fisher Ranch and Riverbend (Figure 17). Further analysis into the species composition and individual species showing up at each site will provide insight into the potential impacts (both positive and negative) these additional species might have on the community.

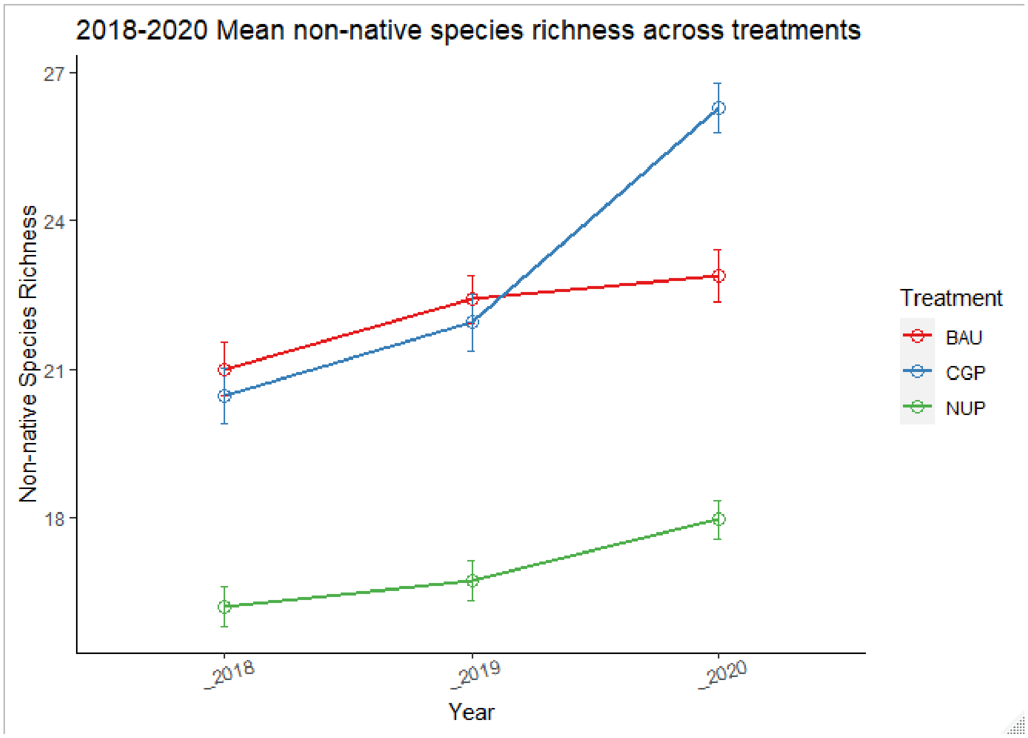

Figure 16. Non-native richness across treatments from 2018 to 2020. Error bars represent ±1 SE.

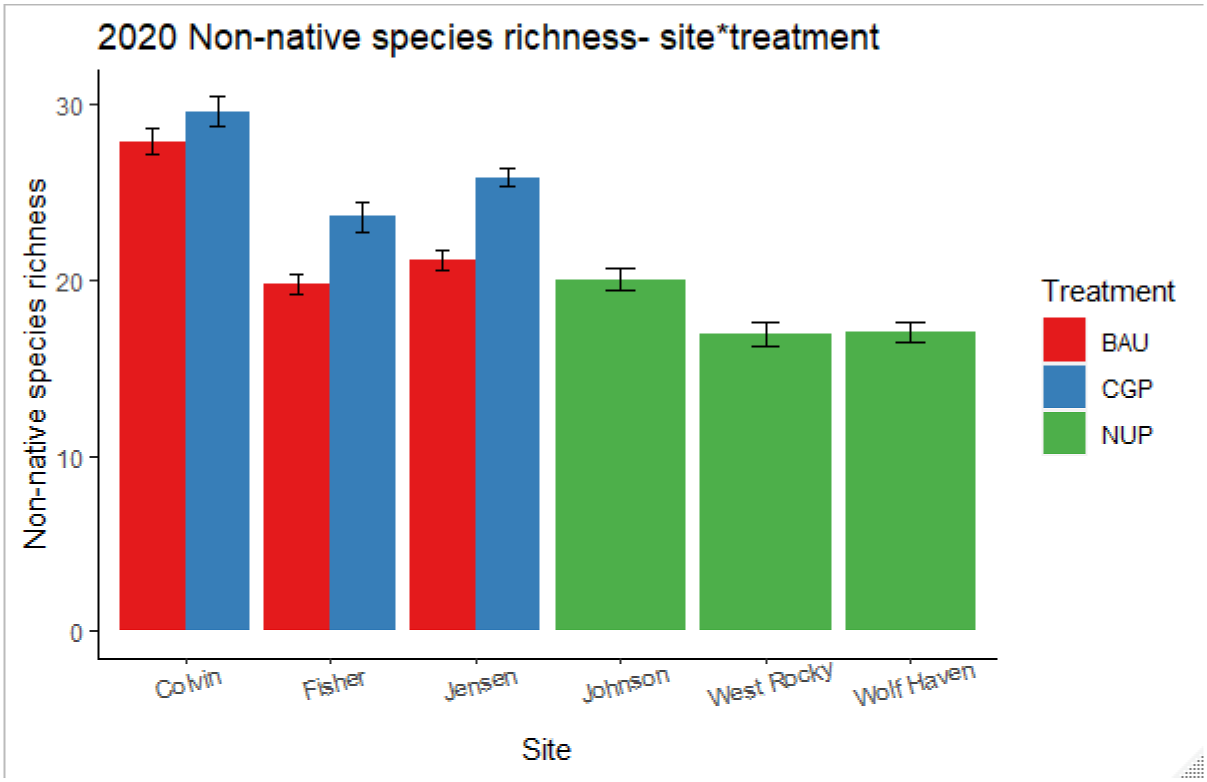

Figure 17. Non-native species richness across study sites and treatments in 2020. Error bars represent ±1 SE.

Plant community composition over time

To visualize changes in plant community composition over time, we used non-metric multidimensional scaling (NMDS) ordination. This method clusters communities based on similarity so that assemblages that are more similar in species composition are closer together while those with disparate compositions are farther apart.

Overall, species composition across all plots became more similar from 2018 to 2020, as indicated by tightening of the plots across both Axis 1 and Axis 2 (Figure 18). Subsequent similarity percentage analysis (SIMPER) showed that *Hypochaeris radicata*, *Plantago lanceolata*, and *Rumex acetosa* increased in frequency across monitoring plots between 2018 and 2020, leading to increased similarity in composition. The native ungrazed prairie (NUP) sites all clustered together, reflecting similarity in composition. The ranch sites also clustered together more over time, with Fisher Ranch and Colvin Ranch hosting several plots with similar plant community compositions. Additionally, plant communities in the CGPs (green shapes have tightened along Axis 2, representing the native seeded species that have become established there.

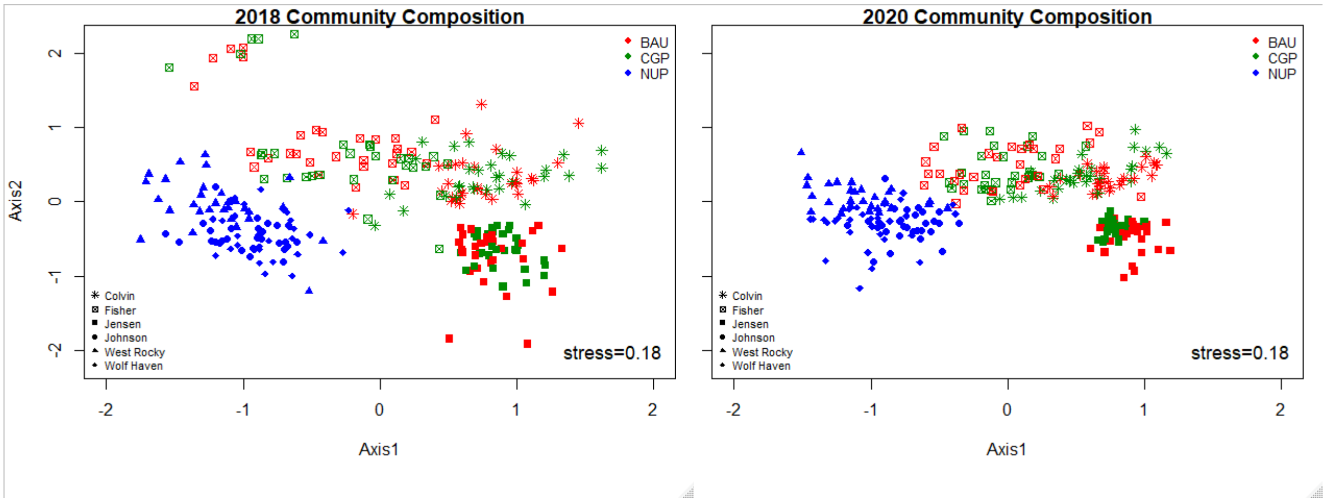

Figure 18. Non-metric multidimensional scaling (NMDS) ordination of plant communities in 2018 and 2020. Each point represents the plant community in a single monitoring plot. Study sites are represented by different shapes while treatments are denoted with varying colors. The stress value indicates how well the data are represented by the ordination with stress = 0.18 indicating a fair representation.

Percent cover of native forbs and forage species

Two years after the implementation of conservation grazing practices (CGP), there was no significant difference in native forb cover ($p=0.06$; Figure 19) or forage species cover ($p=0.90$; Figure 20) compared to BAU practices. Not surprisingly, native ungrazed prairies varied considerably from ranch sites in these two metrics with higher native forb cover ($p<0.001$) and lower cover of forage species ($p<0.001$).

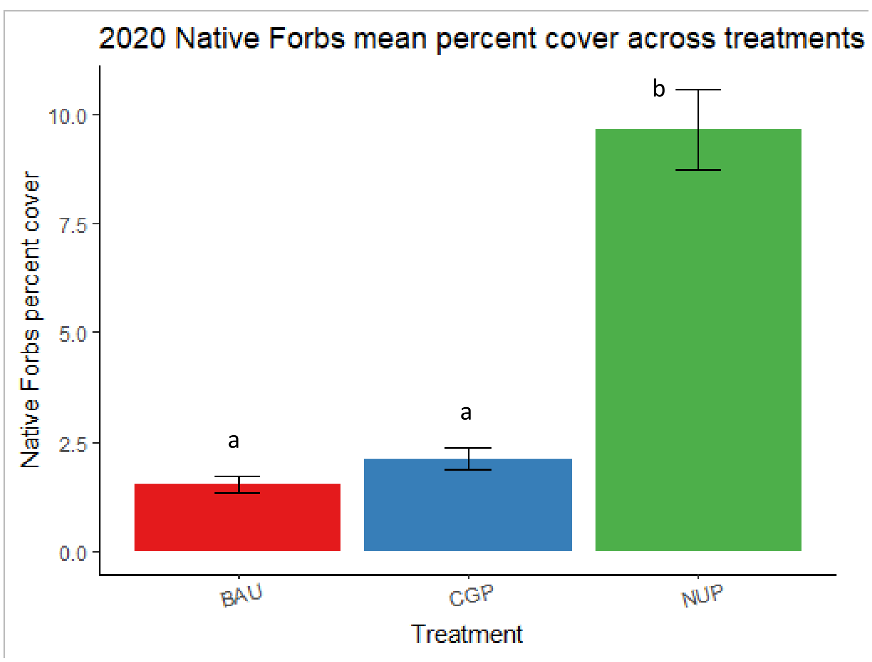

Figure 19. Average percent cover of native forbs species across treatments in 2020. Different letters represent significant treatment differences determined from Kruskal-Wallis tests.

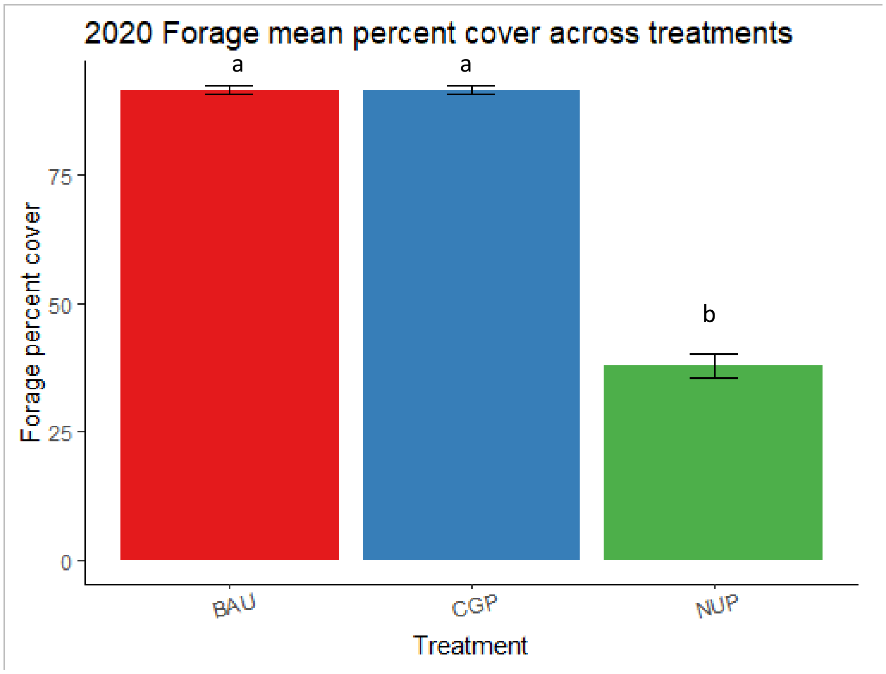

Figure 20. Average percent cover of forage species across treatments in 2020. Different letters represent significant treatment differences determined from Kruskal-Wallis tests.

Gopher Occupancy

Gopher occupancy, measured as the proportion of plots with fresh gopher mounds present, increased over the project period at all sites except Johnson prairie. The greatest increases occurred in the CGP treatments (56% occupied in 2018 to 83% occupied in 2020; Figure 21), potentially reflecting additional belowground resources available from the increasing native and total species richness in those areas.

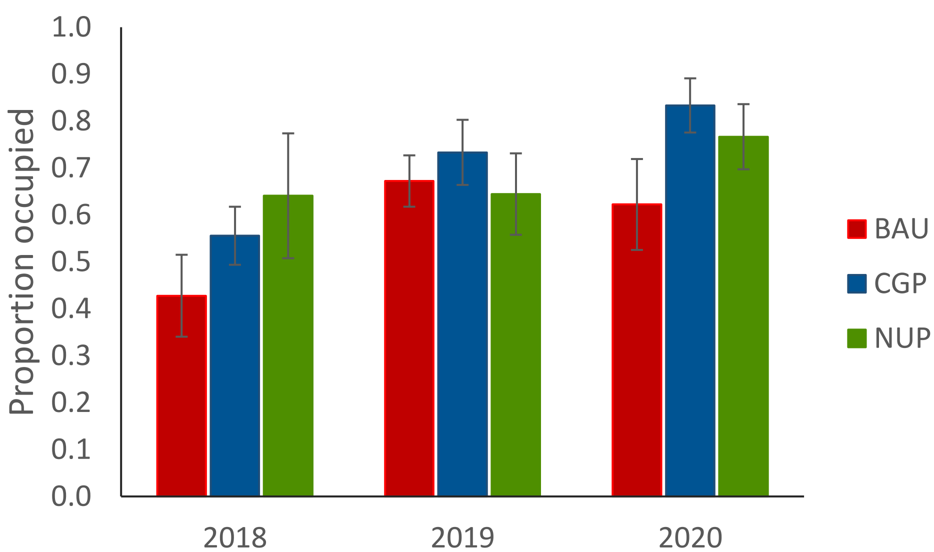

Figure 21. Average proportion of monitoring plots occupied by gophers from 2018 to 2020 across all treatments.

Forage biomass

Biomass production ranged from 0.49 to 1.76 (2019) and 1.54 to 2.5 (2020) tons per acre for ranch sites, and from 0.53 to 0.61 (2019) and 0.48 to 0.58 (2020) tons per acre for upland prairie (Figures 22 and 23). The highlights of this work indicate that:

- Biomass production in all years was generally the highest and not significantly different across CGP and BAU treatments at the Colvin and Riverbend Ranch sites (Figures 22 and 23).
- CGP practices did not depress overall forage production and thereby native seeding is unlikely to negatively affect forage production in grazed systems.
- Significantly lower forage production was observed at Fisher Ranch, likely due to a combination of high stocking rate, shorter and inconsistent rest periods (data not shown), and lower soil fertility (Table 6).
- Early spring grazing prior to the deferment period effectively utilized spring forage availability in paddocks at Colvin Ranch, while lack of early spring grazing at Riverbend Ranch lowered overall utilization (wasted forage, Figure 26) by allowing grasses to become overly tall and mature during the grazing deferment.
- Taller stubble height, and more regular rest periods resulted in greater forage production longer into the summer forage dormancy period in CGP as compared to BAU treatments (Figure 24).

Forage production at Riverbend and Colvin ranches were not significantly different. Due to higher stocking rates, Fisher Ranch was generally utilized fewer and shorter rest periods between grazing rotations, detected in significant cage/no-cage grazing differences during rest periods (data not shown). This resulted in lower biomass production (Figures 22 and 23). Additionally, low productivity at Fisher Farm is very likely also linked to lower phosphorus and potassium levels at this site (Table 6).

A notable dynamic in CGP treatments was the importance of utilizing spring forage prior to deferment. Missing this utilization as occurred at Riverbend depressed overall forage production below BAU at Riverbend, and lower than overall production as compared to Colvin Ranch generally. Nevertheless, CGP biomass totals were not statistically less than BAU totals, indicating no detrimental effect of seeding native species into pastures. In the future, improved spring biomass utilization in rotationally grazed fields at Riverbend combined with extended forage production into the summer would very likely eventually yield greater overall forage than continuously grazed fields.

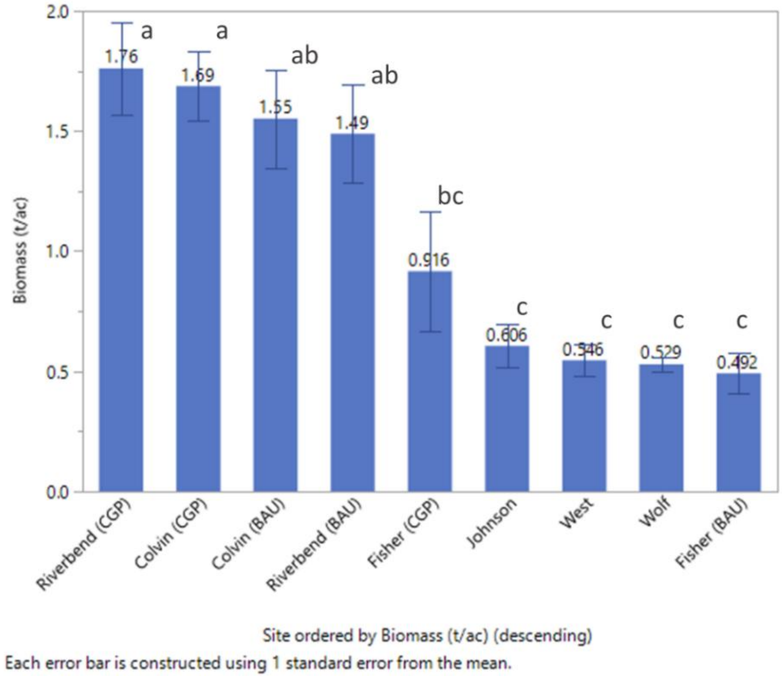

Figure 22. Total 2019 biomass production measured across sites and treatments. Significant differences denoted by non-connecting levels as determined by Tukey pairwise comparisons.

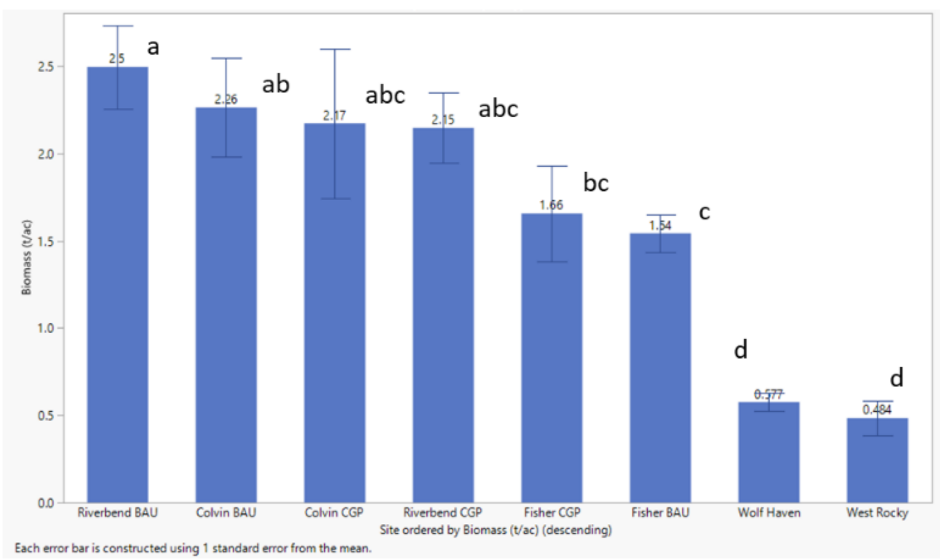

Figure 23. Total 2020 biomass production measured across sites and treatments. Comparison for each pair analyzed using Student's t test. Levels not connected by same letter are significantly different.

Lower biomass production at the ungrazed prairie sites (Johnson West Rocky, and Wolf Haven) in relation to Colvin and Fisher may be due to lower nutrient levels at these sites, in particular phosphorus and potassium (Table 6). Another factor may be soil moisture. Forage and soils work in 2020 included forage quality assessment, soil compaction and soil temperatures, to evaluate the potential impacts of grazing generally, conservation grazing in particular, and lack of grazing on these forage quality and soil health parameters (see below).

Table 6. Soils Nutrient Data Collection in 2018 as Expressed as the Sample Mean ± 1 Standard Deviation.

Habitat Metric	Variable	Farm sites			Upland Prairie Sites		
		Colvin	Fisher	Riverbend	Johnson	West Rocky	Wolf Haven
Soils	Nitrogen (NO3-N) ppm	8.16 ± 3.06	11.16 ± 4.79	6.16 ± 1.60		12.50 ± 7.12	8.33 ± 0.82
	Phosphorus (Weak Bray) ppm	49.83 ± 23.72	5.16 ± 6.11	99.83 ± 30.29		1.00 ± 0.00	2.00 ± 2.45
	Potassium (K) ppm	93.00 ± 27.68	63.33 ± 18.81	135.50 ± 34.51		53.00 ± 3.90	65.17 ± 10.61

In 2020 an expanded forage evaluation was developed to investigate the relationships between forage height, soil temperatures, and the potential to extend forage production further into the dry summer period when forage typically enters dormancy. Forage biomass aspects of this work are reported here and below under the section titled "Forage Heights, Soil Parameters and Soil Taxonomic Work". Generally, CGP paddocks did exhibit the capacity to produce more, longer into the summer than BAU, as illustrated in significant differences in July biomass measured under exclusion cages in the two treatments (Figure 24).

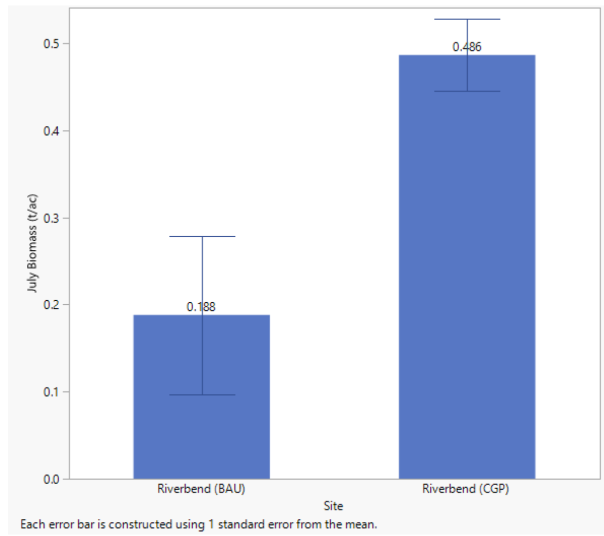

Figure 24. Mean biomass production (tons per acre) in July as measured under exclusion cages in CGP and BAU treatments at Riverbend Ranch.

Forage Utilization

A take-half/leave-half approach to forage utilization is generally encouraged in rotational grazing systems. While it requires ranchers to forego usage, leaving forage allows for greater biomass productivity as a result. Percent forage utilization provides an indication of the extent to which this strategy is implemented by different ranch operations.

As noted in the Methods section, utilization estimates are fraught with opportunity for error due to considerable variability and differences in utilization data collection methods and calculations between rotationally and continuously grazed sites. Year 2019 forage utilization is being re-analyzed.

In 2020 forage utilization was apparently highest at Fisher at in BAU at Riverbend (Figure 25). Riverbend BAU and both Fisher treatments tended to exhibit very low stubble height (data not shown, being analyzed), high grazing pressure, and consequently high utilization rates. The 70-84% utilization rates in these systems effectively prevent robust root establishment, elevate daily average soil temperatures (Figure can delay regrowth in the spring and fall (data not shown, being analyzed), and lead to earlier forage dormancy in the summer dry season (Figure 24).

Relatively low utilization (47-50%) in Riverbend CGP reflects a better approach to conserving stubble, but also some June/July forage trampling due to missed grazing prior to deferment. Given similar forage trampling was observed at Colvin Ranch, the higher utilization (62-73%) there in 2019 was somewhat surprising. Utilization at Colvin in 2020 was only obtained for the spring rest period due to missing post-graze data. The lower March forage utilization rates (34-51%) reflect a modest and strategic use going into deferment. Additional analysis is required.

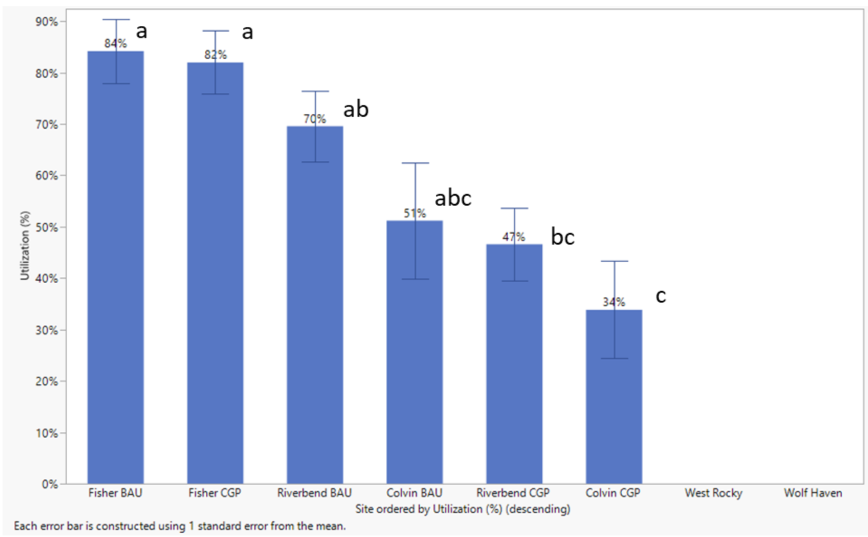

Figure 25. Estimation of 2020 forage utilization. Utilization measures in 2020 relied upon cage and no-cage comparisons and before-after measures based on the grazing system. Non-connecting letters indicate significant differences as determined by Tukey pairwise comparisons.

2020 Butterfly Behavior Results

In 2020, we obtained a total of 52 butterfly behavior observations (Table 7). We achieved our goal of a minimum of five successful observations in each category (BAU, CGP, and Edge) with male and female silvery blues and male ringlets, but not with female ringlets. We were limited by an unusually wet and windy season and lack of available field assistants due to COVID-19 (see above note on COVID-related impacts). This data will be analyzed in 2021.

Table 7: Number of successful behavior observations per release location by species and sex in 2020

	C.t. eunomia		*G. lygdamus*	
Release Location	Female	Male	Female	Male
Business-as-Usual	0	5	5	6
Conservation Grazing Practice	0	5	5	6
Edge	1	6	5	8

2019 Butterfly Behavior Results

In 2019 a total of 122 butterfly observations were obtained throughout the season (see Table 8 for more detail). A goal of five male and five female observations per site for silvery blue butterflies (*G. lygdamus)* at all sites except one was achieved. A goal of five male ochre ringlet butterfly (*C.t. eunomia)* paths per site in the early season at all sites except one was also achieved.

Table 8. The total number of observation paths* obtained per site separated by species and sex

	C.t. eunomia				*G. lygdamus*		Total per site
	Female		Male		Female	Male	
Location	Early	Late	Early	Late			
Colvin Ranch	1	1	5	3	5	4	19
Johnson Prairie	2	1	5	3	7	6	24
Mary Mallonee's Farm	1	1	3	3	5	5	18
Maynard Mallonee's Farm	1	2	5	0	5	4	17
Riverbend Ranch	2	1	5	3	6	5	22
West Rocky Prairie	3	2	4	3	5	5	22
Total per sex per species	10	8	27	15	33	29	122

** C.t. eunomia is further separated by the flight period in which the observation was collected. The early flight ran May-July and the late flight ran July-September. G. lygdamus has only one flight period (May), so the data is not separated by flight period.*

Female *C.t. eunomia* are more difficult observe as they are skittish and sedentary. This limited the number of observations that could be completed. In the late season, weather limited progress, as it was unusually cloudy and extremely windy in the afternoons. A total of 22 total *C.t. eunomia* paths in the late season were obtained.

We were unable to detect significant differences in *G. lygdamus* diffusion rates between management types with a GLMM (Figure 26). However, there are likely differences at the site level that are obscured by lumping management types together. Our next steps are to evaluate the *C.t. eunomia* diffusion rates with a GLMM and to use partial least squares regression to evaluate the effects of nectar and host plant availability on butterfly diffusion rates.

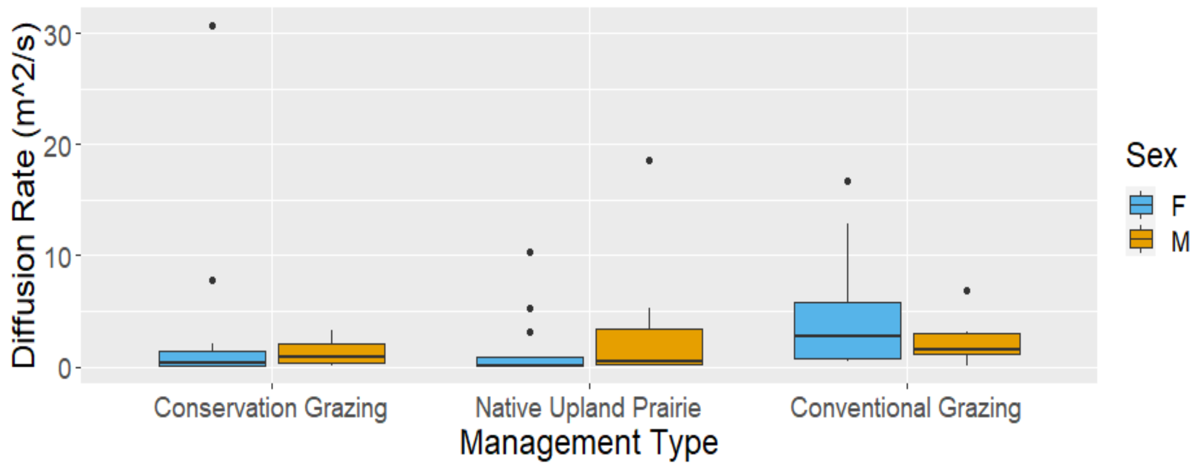

Figure 26: A bar plot of silvery blue diffusion rates broken down by management type and sex. We were unable to detect significant differences in diffusion rates between management types, although it does appear that females do move faster in conventional grazing, indicating that they may view it as poorer habitat than conservation grazing or native upland prairie.

2018 Butterfly Behavior Results

Preliminary analysis of 2018 flight paths suggests that female diffusion rates were lower in native habitat than CGP but male movement behavior did not show a detectable difference in diffusion rates (Figure 27). This was an indication of the concentrated search patterns exhibited in areas with high reward. Silvery blue males did not appear to differ in their diffusion rates. Ochre ringlets did not exhibit a trend in diffusion rates across management types, regardless of sex (Figure 28). We planned to repeat these methods 2020 to gather final experimental data. However (see above), COVID-related impacts prevented this.

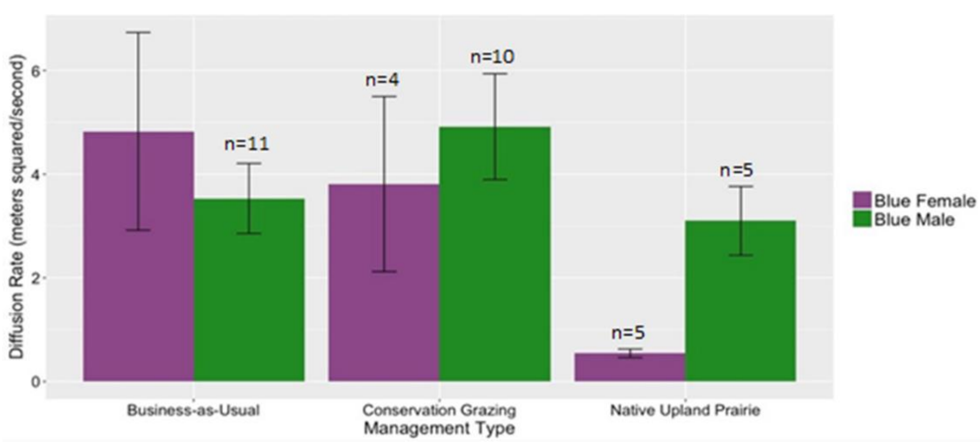

Figure 27. Mean diffusion rates of male and female silvery blue butterflies under each management type.

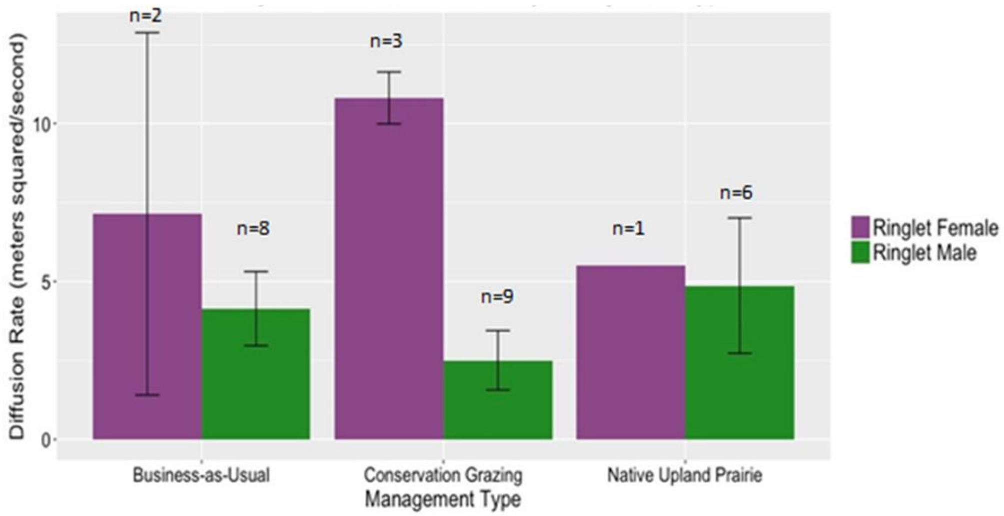

Figure 28: Mean diffusion rates of male and female ochre ringlet butterflies under each management type.

Forage Heights, Soil Parameters and Soil Taxonomic Work

Grazing treatments (CGP and BAU) and site management (grazing as compared to no grazing) were evaluated for their effect on residual biomass (ie stubble height) and soil parameters including soil bulk density and soil temperature. Stubble height and soil temperatures are illustrated in Figures 29 and 30. The goal of this evaluation was to understand potential impacts of stubble height on soil temperature, both from the point of view of climate resilient grazing systems, and for the potential of conservation grazing management to extend forage production into the warm dormant season by means of cooler soil temperature.

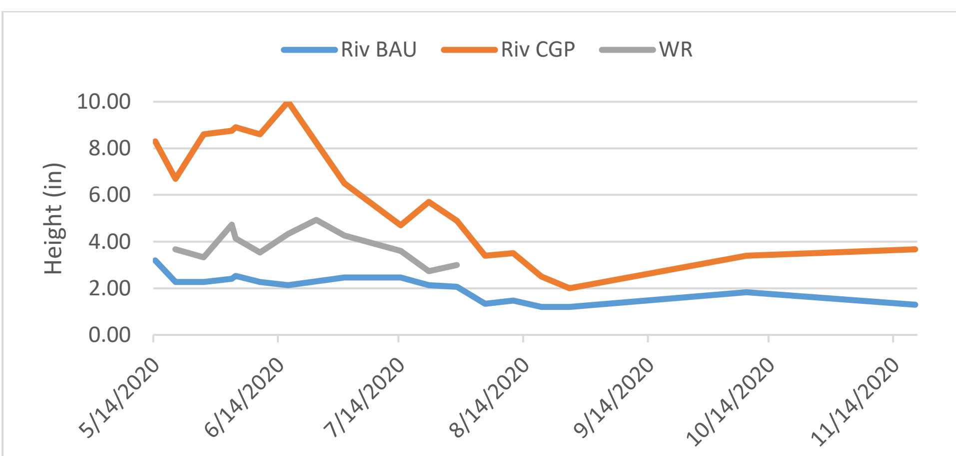

Figure 29. Forage height (in) next to soil temperature loggers. (Riv BAU = Riverbend BAU, Riv CGP = Riverbend CGP, WR = West Rocky Prairie)

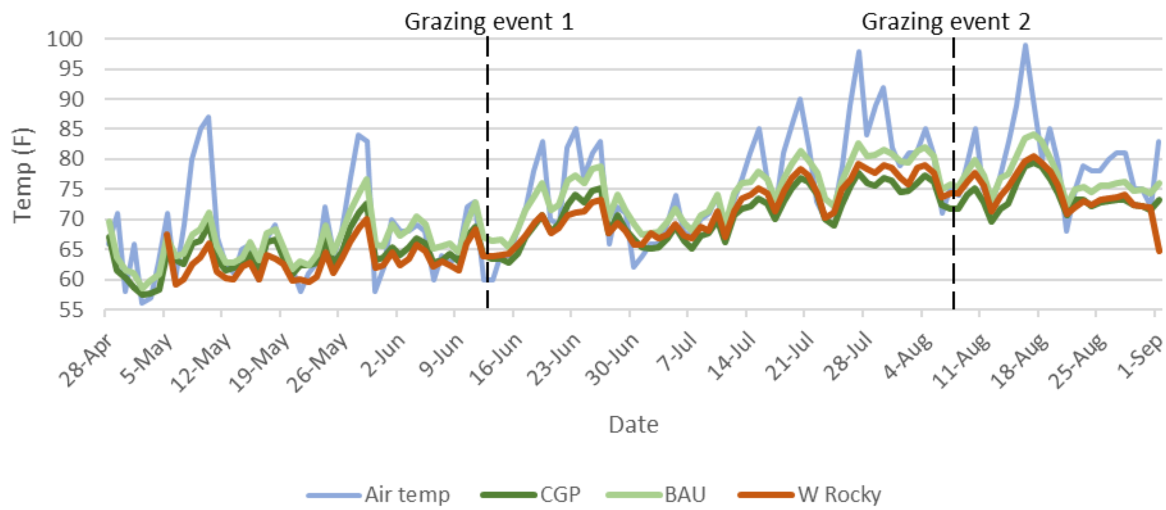

Figure 30. Soil temperatures measured at Riverbend Ranch and West Rocky Prairie in relation to air temperature.

Wide separation in stubble heights were observed between sites (West Rocky, Riverbend) and grazing treatments (CGP and BAU); however, analyses are not yet completed. Significant differences in soil temperatures were observed (Table 9) between sites and treatments yet data is not fully analyzed. Soil temperatures were apparently highest in BAU (lowest stubble heights) and lowest in CGP (highest stubble height), with West Rocky Prairie soil temperatures typically in the middle. Grazing events in which forage height was reduced appear to have led to temperature increases in CGP plots in relation to West Rocky.

Higher stubble height management, and consequent shading effects, may have a beneficial impact on forage growth by decreasing summer average daily high soil temperatures. Significantly greater July biomass observed in CGP as compared to BAU cage samples (Figure 24) illustrate this promising effect of CGP management.

Table 9. One-tailed Analysis of Variance of Soil Temperature at West Rocky Prairie, Riverbend Ranch BAU Plots, and Riverbend Ranch CGP Plots.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	186.448	2	93.22401	9.064161	0.000289	3.113792
Within Groups	802.2224	78	10.2849			
Total	988.6704	80				

Soil Bulk Density

Soil bulk density vales were obtained from CGP and BAU treatments at Riverbend Ranch. Mean bulk density in CGP and BAU were 1.14 g/cm^3 and 1.15 g/cm^3, respectively, and were not significantly different (data not shown). Typical bulk density values for moderately grazed sites are reported to be 0.9 g/cm^3 (Engels n.d), indicating Riverbend sites (BAU as well as CGP) with a history of continuous grazing exhibit soil compaction. While we were not able to demonstrate that pasture rest associated with the CGP treatment decreased bulk density, it is possible that the duration of the study was insufficient for shifts in soil bulk density to occur.

Soil Taxonomy

Regarding soil taxonomy, the majority of soil profiles at ranch and prairie preserve sites classified as either a Spanaway (Typic Humixercept) or Nisqually (Pachic Humixerept) series, or a higher-taxa of Pachic Humixercept (i.e., there is no existing soil series that would be a good fit). In general, the Spanaway-like soils were found in intermound areas, and the Nisqually-like soils were found on the mound sites that had a deeper, darker surface horizon(s). The higher-taxa Pachic Humixerepts, were described as Loamy-skeletal as compared to the sandy Nisqually, or sandy-skeletal Spanaway, meaning it had slightly more clay content within the control section. One outlier was a poorly drained, Norma soil found near a drainage ditch on one of the ranch research sites.

Based on these sites, a fairly clear pattern of deeper, more organic rich surface A horizons found on mounded areas and thinner A horizons found in the intermound position emerged. In addition, the mounded areas generally had either less rock fragment content by volume and/or smaller rock fragment diameter within the surface A horizons. In general, soil pit descriptions mostly conformed (though did not capture the higher taxa) to soil units mapped on NRCS Web Soil Survey (Table 10). Full soil pit descriptions are available upon request.

Table 10. Mapped soil series and soil series as verified by soil pit descriptions at ranch and prairie preserve research sites.

Site	Mapped soil series	Soil pit description	Notes
West Rocky	Spanaway Nisqually complex	Mound: Nisqually or higher order taxa Intermound: Spanaway	Mound land form resulted in loamier soil (slightly higher clay and silt content) than typical Nisqually
Wolf Haven	Spanaway Nisqually complex	Mound: Nisqually Intermound: Spanaway	
Johnson Prairie	Not complete	Not complete	
Riverbend	Nisqually	Upland pit: Nisqually Pit near drainage: Norma	Clay, loam content not elevated as in higher taxa Pachic Humixerept.
Colvin	Spanaway Nisqually complex	Mound: Nisqually or higher order taxa Intermound: Spanaway	Mound site with elevated clay and silt content in A1 horizon
Fisher	Spanaway Nisqually complex	Upper field: Nisqually or higher order taxa Lower field: Nisqually or higher order taxa	Both sites with elevated clay and silt content in A1 horizon
Maynard Mallonee	Alvor, Reed, Chehalis, Newberg	Not complete	

Survey of Grazing Practices in Southwest Washington

Due to the method of distribution, we are unable to know exactly how many people the emailed survey reached. We received a total of 133 responses, 95 of which were from the emailed link and 38 from the printed surveys. 89 of the responses were from producers who have livestock and 39 were from producers who do not. Five respondents did not answer the question about whether they had livestock. As respondents could choose not to answer individual questions, response numbers per question varied. Please see the included supplementary survey results report for the full questionnaire results.

Perception of Conservation Incentives

Initial data exploration suggests that many respondents were interested in financial assistance programs such as on-farm cost-share programs or tax incentives for conservation management practices (see Figure 31). Respondents were generally not interested in selling property for restoration for conservation purposes. Responses varied widely on incentives such as conservation easements and transferring/selling development rights. There was little interest in registry or branding programs.

Kruskal Wallis test results (see Table 11) indicate that age is statistically significant (chi-squared = 12.06, p = 0.017) in explaining attitudes towards on-farm cost share. Farm size is significant in relation to attitudes towards on-farm cost share (chi-squared = 8.59, p = 0.014), selling property for restoration and conservation (chi-squared = 6.52, p = 0.038), and registry and branding programs (chi-squared = 9.28, p = 0.01).

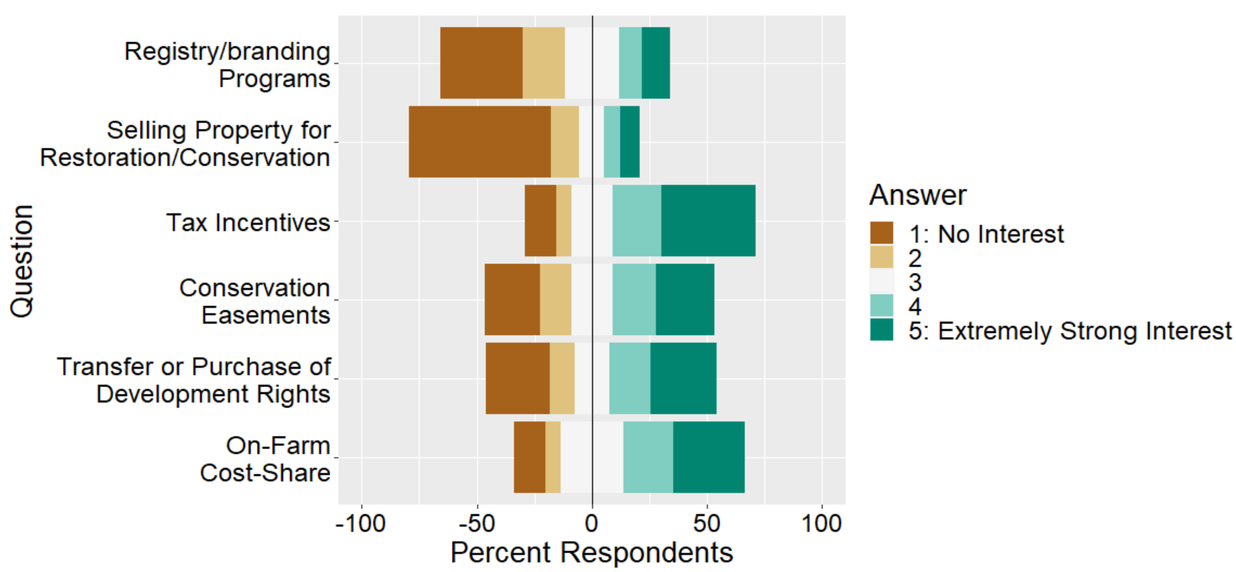

Figure 31: A stacked diverging barplot representing how respondents categorized their interest in the incentives (incentives paraphrased for clarity; see supplementary material for full questionnaire phrasing). Respondents who categorized their interest as 4 or 5: Extremely strong interest are shown on the right side of the center line, and respondents who categorized their interest as 2 or 1: No interest are shown on the left side of the center line. Respondents who marked the neutral category, 3, are centered on the center line.

Table 11: Kruskal Wallis test* results comparing each incentive with each explanatory variable

Incentive	Explanatory Variable	Chi-squared	Degrees of Freedom	P-value	Mean Likert Score
On-farm cost share	**Farm Size**	**12.07**	**4**	**0.017**	**2.952**
	Gross Sales	5.08	5	0.407	2.952
	Percent Income	5.29	4	0.259	2.952
	Age	**8.59**	**2**	**0.014**	**2.952**
	Gender	1.54	2	0.462	2.952
	Education Level	7.51	5	0.186	2.952
Transfer or Purchase of Development Rights	Farm Size	3.98	4	0.408	3.096
	Gross Sales	2.86	5	0.722	3.096
	Percent Income	2.43	4	0.657	3.096
	Age	5.76	2	0.056	3.096
	Gender	1.81	2	0.404	3.096
	Education Level	4.22	5	0.519	3.096
Conservation Easements	Farm Size	8.95	4	0.062	3.081
	Gross Sales	1.26	5	0.939	3.081
	Percent Income	2.25	4	0.690	3.081
	Age	3.11	2	0.212	3.081
	Gender	2.33	2	0.312	3.081
	Education Level	4.70	5	0.454	3.081
Tax Incentives	Farm Size	5.41	4	0.248	3.689
	Gross Sales	4.12	5	0.533	3.689
	Percent Income	4.13	4	0.389	3.689
	Age	0.86	2	0.652	3.689
	Gender	4.19	2	0.123	3.689
	Education Level	5.44	5	0.364	3.689
Selling property for Restoration/Conservation	Farm Size	2.62	4	0.624	1.877
	Gross Sales	3.49	5	0.625	1.877
	Percent Income	6.90	4	0.141	1.877
	Age	**6.53**	**2**	**0.038**	**1.877**
	Gender	0.68	2	0.711	1.877
	Education Level	7.39	5	0.193	1.877
Registry/Branding Programs	Farm Size	4.04	4	0.400	2.444
	Gross Sales	4.56	5	0.471	2.444
	Percent Income	3.12	4	0.538	2.444
	Age	**9.28**	**2**	**0.010**	**2.444**
	Gender	0.43	2	0.805	2.444
	Education Level	4.69	5	0.455	2.444

**Significant comparisons at $p < 0.05$ are shown in bold.*

Perception of conservation barriers
The data on perceived barriers showed that most respondents did not perceive lack of knowledge about conservation, lack of technical assistance, uncertainty about where to find technical assistance, lack of trust in conservation regulatory agencies or NGOs, or social stigma as barriers to implementing conservation strategies on their land (see Figure 32). While there was a lot of variation in responses, the strongest barriers appear to be concern over loss of development rights if an endangered species is found and lack of financial assistance. Interestingly, the loss of development rights appeared to be a polarized issue; respondents were split nearly evenly and most marked the extreme ends of the Likert scale (1: Not a barrier or 5: Extremely Strong Barrier).

Kruskal Wallis Test results (see Table 12) indicate that farm size (chi-squared = 15.07, p = 0.004), gross sales (chi-squared = 16.00, p = 0.007), and percent of income represented by the farm (chi-squared = 11.11, p = 0.025), were all statistically significant in relation to the barrier "Don't know enough about conservation." Farm size was statistically significant in relation to the barrier "Don't trust conservation NGOs" (chi-squared = 10.07, p = 0.039). Gender was significant in relation to "Loss of development rights if endangered species was found" (chi-squared = 8.72, p = 0.013), and "social stigma from peers" (chi-squared = 8.30, p = 0.016).

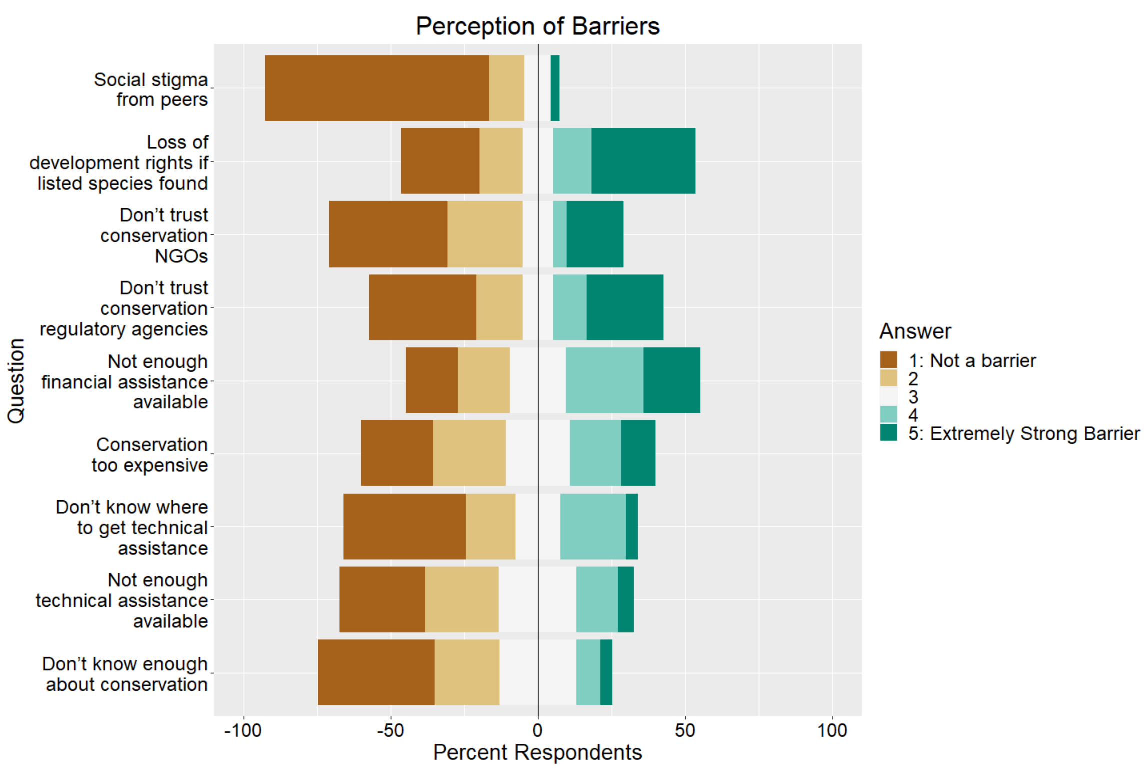

Figure 32: A stacked diverging barplot representing respondents categorized their perceptions of barriers to implementing conservation strategies on their land (barriers paraphrased for clarity; see supplementary material for full questionnaire phrasing). Respondents who categorized their perceptions of barriers as 4 or 5: Extremely strong barrier are shown on the right side of the center line, and respondents who categorized the barrier as 2 or 1: Not a barrier are shown on the left side of the center line. Respondents who marked the neutral category, 3, are centered on the center line.

Table 12: Kruskal Wallis test* results comparing each barrier with each explanatory variable

Barrier	Explanatory Variable	Chi-squared	Degrees of Freedom	P-value	Mean Likert Score
Don't know enough about conservation	**Farm Size**	**15.07**	**4**	**0.005**	**2.483**
	Gross Sales	**16.00**	**5**	**0.007**	**2.483**
	Percent Income	**11.12**	**4**	**0.025**	**2.483**
	Age	4.56	2	0.102	2.483
	Gender	1.93	2	0.381	2.483
	Education Level	4.52	5	0.477	2.483
Not enough technical assistance available	Farm Size	4.05	4	0.400	2.417
	Gross Sales	3.18	5	0.672	2.417
	Percent Income	1.58	4	0.813	2.417
	Age	2.93	2	0.231	2.417
	Gender	1.76	2	0.416	2.417
	Education Level	5.18	5	0.394	2.417
Don't know where to get technical assistance	Farm Size	5.24	4	0.264	2.306
	Gross Sales	3.49	5	0.624	2.306
	Percent Income	3.74	4	0.442	2.306
	Age	3.27	2	0.195	2.306
	Gender	1.39	2	0.498	2.306
	Education Level	2.63	5	0.757	2.306
Conservation too expensive	Farm Size	2.28	4	0.684	2.667
	Gross Sales	4.18	5	0.523	2.667
	Percent Income	8.63	4	0.071	2.667
	Age	2.44	2	0.296	2.667
	Gender	0.27	2	0.875	2.667
	Education Level	2.35	5	0.800	2.667
Not enough financial assistance available	Farm Size	3.72	4	0.446	3.118
	Gross Sales	7.07	5	0.216	3.118
	Percent Income	0.98	4	0.914	3.118
	Age	0.97	2	0.617	3.118
	Gender	0.42	2	0.812	3.118
	Education Level	2.03	5	0.845	3.118
Don't trust conservation regulatory agencies	Farm Size	2.73	4	0.605	2.754
	Gross Sales	3.30	5	0.653	2.754
	Percent Income	5.99	4	0.200	2.754
	Age	1.13	2	0.569	2.754
	Gender	1.28	2	0.527	2.754
	Education Level	3.09	5	0.686	2.754
Don't trust conservation NGOs	**Farm Size**	**10.07**	**4**	**0.039**	**2.373**
	Gross Sales	3.14	5	0.678	2.373
	Percent Income	5.09	4	0.278	2.373
	Age	2.33	2	0.312	2.373

	Gender	1.17	2	0.557	2.373
	Education Level	3.77	5	0.583	2.373
Loss of development rights if listed species found	Farm Size	2.46	4	0.653	3.162
	Gross Sales	4.02	5	0.546	3.162
	Percent Income	4.68	4	0.322	3.162
	Age	1.17	2	0.556	3.162
	Gender	**8.72**	**2**	**0.013**	**3.162**
	Education Level	2.61	5	0.759	3.162
Social stigma from peers	Farm Size	7.70	4	0.103	1.388
	Gross Sales	4.59	5	0.468	1.388
	Percent Income	1.19	4	0.880	1.388
	Age	1.57	2	0.457	1.388
	Gender	**8.30**	**2**	**0.016**	**1.388**
	Education Level	3.75	5	0.586	1.388

**Significant comparisons at p < 0.05 are shown in bold.*

Educational and Outreach Activities

Three on-farm workshops were held in 2019 with 98 participants (14 attendees in the spring, 61 in the summer, and 23 in the fall). Seventy-one percent of attendees rated themselves with moderate to advanced experience with raising livestock. Fifty-five percent rated themselves with moderate to advanced experience with habitat conservation. Ninety to ninety-two percent of attendees indicated they would use the information learned at the field day, consisting of knowledge of and skills for applying rotational grazing, use of the Pasture Calendar (an NRCS publication) for planned grazing, fencing systems, grazing systems for habitat, native plants in grazed systems, and butterflies in grazed systems. Ninety percent of attendees rated the events as very useful, and 10 percent as somewhat useful.

<u>Consultations:</u>
Two consultations were held in 2018, focused mostly on gaining farmer feedback and input on economic and social aspects of conservation grazing practices. *Economic cost/benefit consultation:*

  - We gathered economic data on grazing operations that will be used to complete a *Fifty Head Cow-Calf Grazing Enterprise Budget in South Puget Sound.*
  - Three of our farmer-cooperators, and two additional farmers participated.

- *Farmer survey review & consultation:*
  - We gathered feedback on a draft farmer-rancher survey evaluating perspectives on conservation programs for working lands.
  - Three of farmer-cooperators and two additional farmers participated.

Two consultations were held in 2019

- A follow-up review of the cow-calf and grass-finished steer budget with farmer cooperators
- A review of the budget with Thurston County Agriculture Committee members

Two consultations were held in 2020

- One budget development and review meeting was held with ranchers
- One restoration budget development and review meeting was held with conservation lands managers.

Curricula, factsheets or educational tools

- Factsheet in progress

Journal articles

- None yet

On-farm demonstrations

- Fisher, Colvin, Riverbend

Published press articles

- Partners for Conservation Newsletter. Collaboration across Conservation and Agriculture in western Washington. February 2020. https://partnerscapes.org/conservationagriculturecollaboration/
- Olympian article with information on HCP and prairie grazing study and workshop
- Newsletter information in WSU Ag Sounder

Tours

-

Webinars, talks and presentations:

- Bramwell, S. and S. Hamman. February 2021 (accepted, forthcoming). Grazing for Conservation: Ecological Opportunity for Ranchers at the Urban-Rural Frontier. Society for Range Management 2021 Conference. Virtual Session Symposium.
- Bramwell, S. May 2021 (accepted, forthcoming). Can these Critters Get Along? Conservation Grazing Practices for Endangered Species Protection on South Puget Sound Prairies. Association of Natural Resource Extension Professionals. Virtual Conference Presentation.
- Bussan S and C. Schultz. Butterfly diffusion rates as an index of habitat quality under cattle grazing management. Presented at: Ecological Society of America meeting. Virtual Conference. August 2020.
- Hamman, S. 2020. Hidden prairies of the PNW: how unique conservation strategies are restoring diversity and resilience to a highly fragmented system. UW Tacoma, 15 attendees.
- Hamman, S. 2019. Expanding the conservation portfolio: reintroducing native plants to working lands in western Washington. Eighth Western Native Plant Conference, November 13th, 45 attendees.

- Bramwell, S. 2019. Evaluation of Grazed and Ungrazed Prairie Land for Species Protection in Western Washington. Tilth Producers Conference of Washington. November 10th. 20 attendees.
- Habenicht, M. 2019. Native plant habitat on grazed and ungrazed working lands. Tilth Producers Conference of Washington. November 10th. 20 attendees.
- Bussan, S. 2019. Butterfly Behavior Research, Case Studies on the Effects of Grazing in Europe, and Methods Demonstration for Evaluating Butterfly Behavior. Thurston Conservation District Workshop. 15-20 attendees.
- Bussan, S. 2018. Can conservation grazing maintain habitat quality for butterflies? Presentation at the Entomological Society of America Conference. Vancouver, BC. Approximately 30 attendees.
- Bussan, S. 2018. A review of the literature on butterflies and cattle grazing. Presentation and panel discussion at the Cascadia Prairie Oak Partnership. Eugene, OR. Approximately 100 attendees.

<u>Workshops, field days</u>

- Spring, summer, fall 2019
- Conservation Easement Essentials, December 2020. 25 attendees

Other educational activity

<u>Number of farmers who participated in research</u>

- 30 farmers attended grazing workshops in 2019.
- 130 farmers participated in the survey of grazing and on-farm conservation practices in southwest WA (92 livestock producers, and 38 non-livestock producers)
- 8 farmers in the Thurston County Agriculture Committee provided feedback on the research project and received regular updates, assisting in guiding workshop content and outreach
- Approximately 200 farmers received three research updates in 2019 regarding the project through the WSU Ag Sounder newsletter
- 4 farmers directly cooperated in 2018 and 2019 field-based research
- 3 of those farmers plus 2 additional consulting farmers participated in the fall 2018 Delphi Method economic interviews to gather data for grazing enterprise budget development, as well as to provide responses on a farmer-rancher survey that will be circulated in 2019.
- 177 total farmers participated in education and outreach activities (not counting those who received the Ag Sounder newsletter, but those directly involved).

Learning outcomes

- 54 Farmers reported changes in knowledge, attitudes, skills and/or awareness as a result of their participation

Key areas taught:

- What rotational grazing is
- Skills for applying rotational grazing
- Existence of pasture calendar as a planning tool
- Fencing systems
- Grazing systems that improve habitat
- Native plants in grazed systems
- Butterflies in grazed systems

Key changes:

- What rotational grazing is (85%, 54 farmers)
- Skills for applying rotational grazing (80%, 50 farmers)
- Existence of pasture calendar as a planning tool (90%, 57 farmers)
- Fencing systems (95%, 60 farmers)
- Grazing systems that improve habitat (89.5%, 56 farmers)
- Native plants in grazed systems (75%, 47 farmers)
- Butterflies in grazed systems (80%, 50 farmers)

Number of farmers/ranchers who report changes in knowledge, attitude, skills and/or awareness

Key knowledge and skills that were taught through the project

Project outcomes

- Number of farmers who intend to change their practices:
- Number of farmers who intend to use the knowledge/skills gained: 57

- Additional grants received that built upon this project (for project leader, cooperators and/or beneficiaries):
    - C. Schultz, WSU-Vancouver - Received a CEREO grant to support a portion of S. Bussan's time
    - Hamman, S., J. Alvarez, S. Bramwell, S. Moorehead, B. Amrine, M. Nordin, J. Yancey, and Saunders. Submitted a grant ($1,309,037) titled: Enhancing biodiversity of prairie habitat and economic resilience of rural economies through conservation grazing. Washington Coast Restoration and Resiliency Initiative. 2021-23.
    - Hamman, S., S. Bramwell and S. Moorehead. Submitted a grant (~$100,000) titled Building a grassland grazing association to support conservation grazing in southwest Washington. Western SARE Research to Grassroots.

- New working collaborations:
    - Sentinel Lands working group in Olympia, WA
    - WSU Kittitas County Extension

There are approximately 15,319 acres of permanent pasture and rangeland in Thurston County, down 27% between 2012 and 2017 from 21,113 acres. Thurston County is at the southern terminus of the Seattle-Tacoma-Olympia metropolitan region in South Puget Sound, and is experiencing rapid development pressure. Requirements to protect endangered species, on droughty soils typically underlaying pasture and rangeland, adds additional pressure to remove grazing land from production. This project provides County decision makers and state and federal Fish and Wildlife departments data to evaluate the potential of grazing lands to contribute to conservation outcomes without removing it from production.

In 2018, 2019, and 2020 annual reports were provided to Thurston County Community Planning, and the US Fish and Wildlife Service to contribute local data to development of a Habitat Conservation Plan to preserve several listed threatened and endangered species. The Thurston HCP could utilize as much or more than 2,500 acres of working grazing land of the total approximately 5,000 mitigation acres needed, mostly for Mazama Pocket Gopher habitat, but for other species (such as Vesper Sparrow, Taylors Checkerspot Butterfly, and Streak Horned Lark) as well. The report data to date, among other findings, indicates that Mazama Pocket Gopher occupancy is not necessarily native vegetative dependent as both the CGP ag site and the NUP site had better than 50% MPG occupancy and the native vegetation for the CGP ag site was quite low. This assists with the credit-debit methodology work with USFWS about what habitat features to value when determining functional value of a site. This enables working grazing land to be utilized in meeting HCP requirements, keeping more land in agriculture, while also providing opportunity to improve the conservation value of these lands.

Data and findings from this research are helping to inform proposals to acquire funding for conservation easement acquisition, while results from the Grazing Lands Survey conducted will inform the kind of conservation programs farmers are mostly likely to participate in. Current development of a funding proposal with project partners, and a local Sentinel Lands group (or other funding) will provide outreach capacity to provide farmers with information they need to participate in voluntary conservation programming such as easements, transfer of development rights, cost-share efforts, or other programs.

Economic data from the enterprise budgets and Contributions Analysis has been requested by Thurston County to complete an Environmental Impact Statement (2021) associated with the Thurston County Habitat Conservation Plan. The County has also requested published Fact Sheets and a Landowner Conservation Grazing Guide to assist in HCP implementation, and landowner recruitment to the HCP.

Two project co-PIs and a project collaborator at NRCS worked with US Fish and Wildlife to develop an "Easement Staircase; Landowner Guide to Conservation on Working Lands" publication to determine the conservation value represented by grazing lands.

Success Stories

<u>Success Story 1</u>

Riverbend Ranch, a farmer cooperator on this trial, implemented rotational grazing on an additional 7 acres of their property, expanding their involvement from a trial site to a ranch adopting new conservation grazing measures.

<u>Success Story 2</u>

Tracking Y Ranch, which participated in the farmer-cooperator workshop to develop the Conservation Grazing Survey deployed in 2019 began contracting with the Center for Natural Lands Management (a project co-PI) as a result of contacts made through this research. Tracking Y Ranch has implemented targeted grazing in Oregon Spotted Frog (*Rana pretiosa*) habitat that is managed by CNLM. Oregon Spotted Frog requires low clipped, seasonally inundated grassy areas abutting streams or wetlands. Targeted seasonal grazing provides the required forage height reduction, and cattle are removed from the grazing paddocks during seasonal inundation when the OSP lays its eggs.

Recommendations

Appendix A. Site Maps

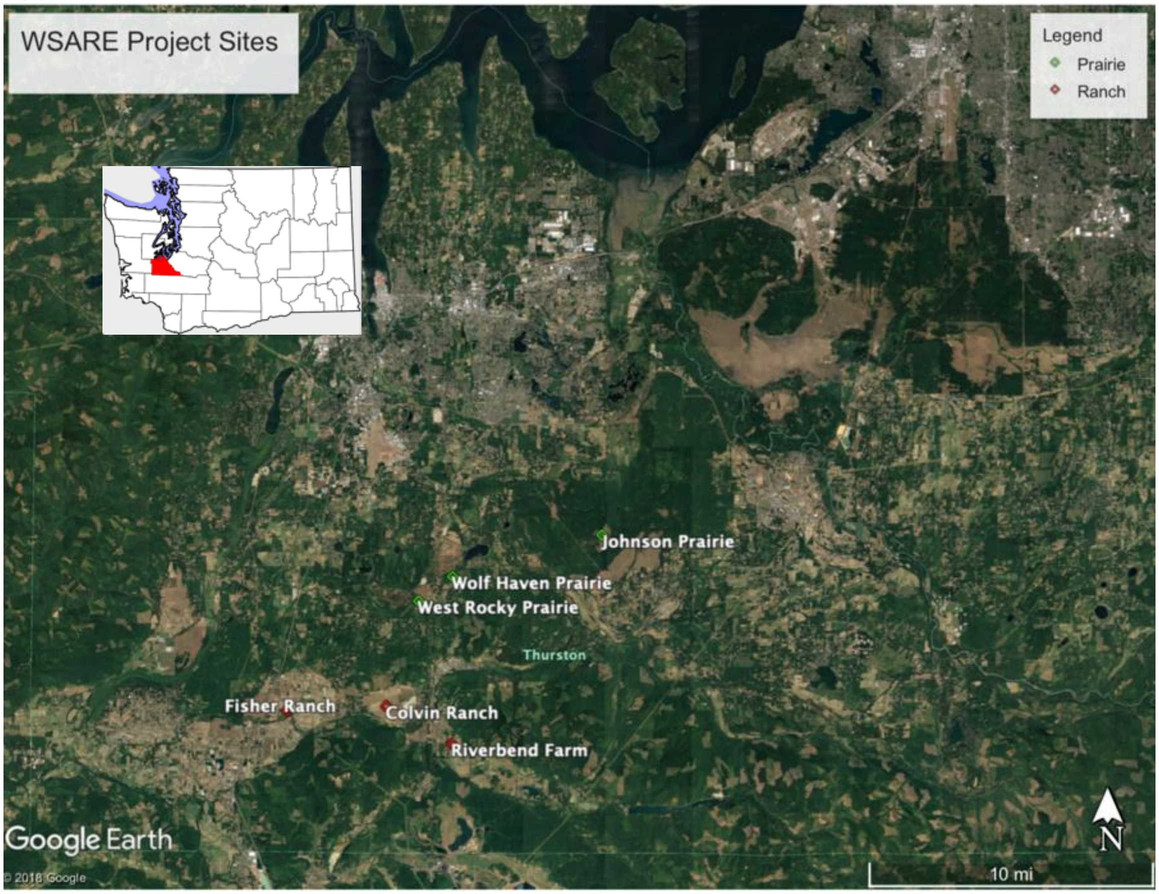

Figure 1. Location of all ranch sites and native upland prairie sites within Thurston County, Washington State, USA.

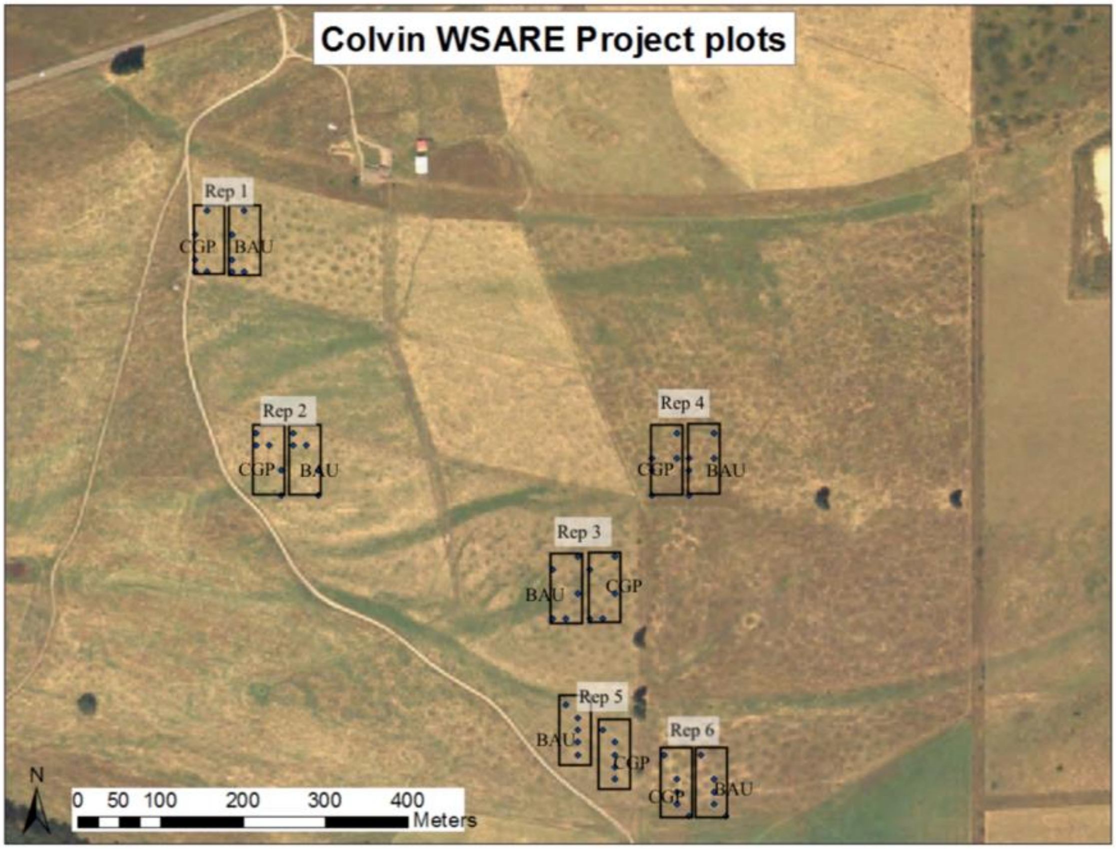

Figure 2. Replicate 1-acre CGP and BAU paddocks at Colvin Ranch

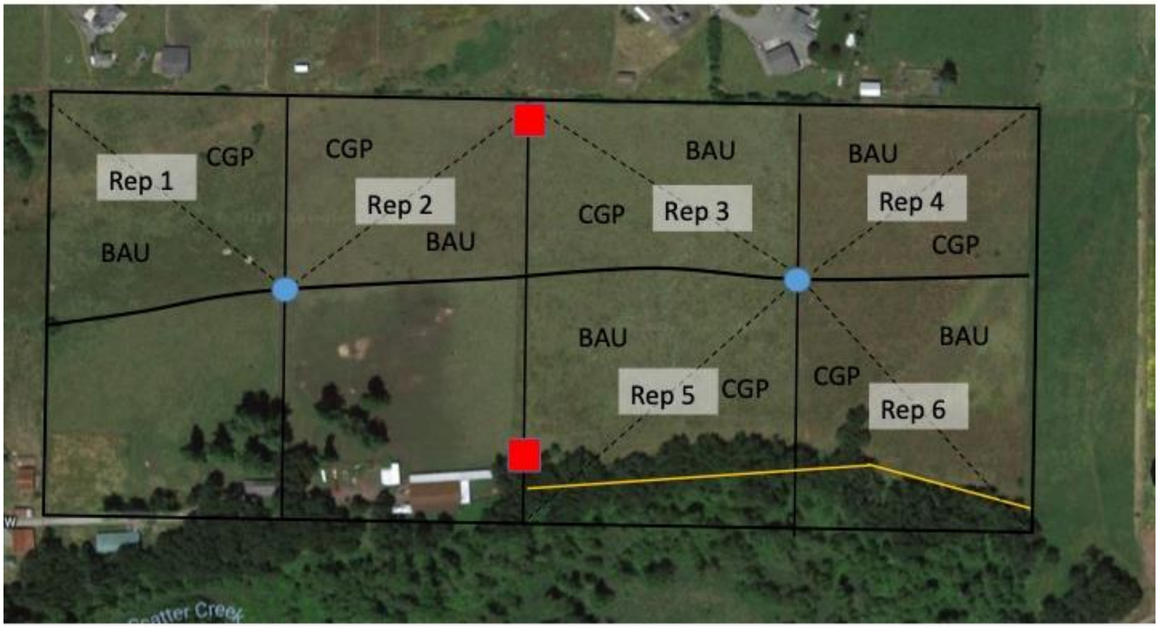

Figure 3. Replicate 1-acre CGP and BAU paddocks at Fisher Ranch

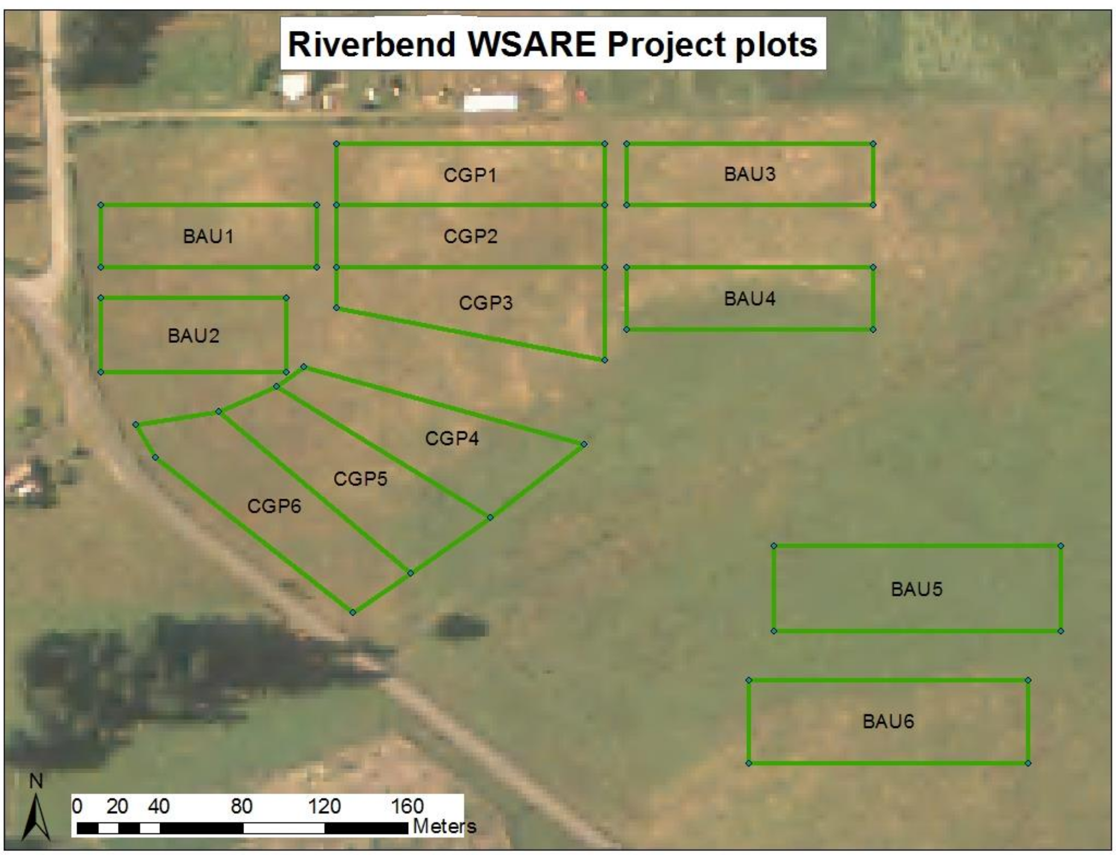

Figure 4. Replicate 1-acre CGP and BAU paddocks at Riverbend Farm

Appendix B. Species seeded into farm sites, along with life history and seeding rates

Scientific Name	**CODON**	**Common Name**	**Family**	**Life History**	**Sites where seeded**	**Seeding Rate (lbs/acre)**	**PLS/m^2**
*Castilleja levisecta**	CASLEV	Golden paintbrush	Orobanchaceae	Perennial, hemi-parasite	Colvin, Riverbend	0.350	297.589
Cerastium arvense	CERARV	Field chickweed	Caryophyllaceae	Annual	Fisher, Colvin, Riverbend	0.022	13.916
Collinsia parviflora	COLPAR	Maiden blue-eyed Mary	Scrophulariaceae	Annual	Fisher, Colvin, Riverbend	0.153	12.436
Eriophyllum lanatum	ERILAN	Oregon sunshine	Asteraceae	Perennial	Riverbend	0.059	16.768
Lomatium triternatum†	LOMTRI	Nineleaf biscuitroot	Apiaceae	Perennial	Fisher, Colvin, Riverbend	0.353	5.205
Lupinus bicolor	LUPBIC	Bicolor lupine	Fabaceae	Annual, legume	Fisher, Colvin, Riverbend	0.246	5.182
Microseris laciniata	MICLAC	Cut-leaf microseris	Asteraceae	Perennial	Fisher, Colvin, Riverbend	0.062	6.093
Plectritis congesta	PLECON	Sea blush	Caprifoliaceae	Annual	Fisher, Colvin, Riverbend	0.110	17.646
Ranunculus occidentalis	RANOCC	Western buttercup	Ranunculaceae	Perennial	Fisher, Riverbend	0.213	9.621
Viola adunca	VIOADU	Hookedspur violet	Violaceae	Perennial	Fisher, Colvin, Riverbend	0.113	16.864

* Only seeded CASLEV into 3 of the paddocks at Colvin and into 6 plots (1 per paddock) at Riverbend due to limited seed availability. Seeding rate of CASLEV at Riverbend was slightly higher than other sites: 309 PLS/m^2; PLS = Pure Live Seed

† Only seeded into plots, not the entire paddock, at Fisher due to limited seed availability