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Ecological role of cattle at Point Reyes National Seashore: effects of grazing history on coastal plant communities

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ABSTRACT

There is ongoing debate over the effectiveness of cattle grazing as a prospect for plant community conservation. Since the National Park Service acquired the land at Point Reyes Seashore, controversies over whether ranching should continue in the protected area have defined part of the park's public image. Resolving uncertainties over impacts of cattle on the Point Reyes landscape could inform these debates and lead to viable long-term management strategies. In this study, we examine grassland species richness and composition under four different grazing land-use histories throughout the park (active grazing and 17, 39, and 87 years-since-grazing). Results point toward positive effects of active grazing on native forb richness through suppression of the invasive grasses *Holcus lanatus* and *Festuca perennis*. We find steep declines in native plant richness and abundances in the early decades following cessation of grazing and subsequent partial recovery of native species over longer timescales. Our research suggests that cattle foraging impacts plants according to functional group more than provenance. Cattle grazing and associated disturbances may have promoted the initial introduction and establishment of exotic plants into the Point Reyes landscape, but with exotic plants now well established throughout California and most native grazers absent or severely declined, new research suggests that cattle fill an important ecological role in promoting coexistence by native species on exotic-dominated landscapes.

INTRODUCTION

Agriculture is fundamental to the United States economy and to the health and well-being of the American people, and as with many large industries it places extreme demands on the ecosystems that support it. As the human population continues to grow, so too do our demands on natural resources, our potential impacts on these resources, and our need to fully understand these impacts so we can assure continued delivery of critical resources.

Animal agriculture provides food and consumer products, jobs, and a rich culture deeply rooted in American society. Prairie and grassland productivity is especially critical to humans, with grains constituting over 50% of the calories we eat (Awika, 2011). But our use of these ecosystems comes at a huge ecological cost as animal agriculture—and in particular large ungulate species—can impact far more than just the grassland communities on which they feed. Animal agriculture affects terrestrial, riparian, and aquatic environments through trampling, fine sediment deposition, manure dumping which can cause eutrophication, and water diversion (Belsky et al. 1999). On a global scale animal agriculture generates large quantities of greenhouse gasses, concentrates huge amounts of toxic waste into waterways, which results in oceanic dead zones, and is the leading cause of deforestation around the world (Koneswaran & Nierenberg, 2008, Diaz & Rutger, 2008). Within the United States, animal agriculture requires more freshwater than any other agricultural product in the United States (Hoekstra & Mekonnen 2012). As such, agricultural practices must balance production and efficiency with its environmental, social, and political impacts.

In California, agriculture is a major part of the state's history, economy, society, politics, and ecology. California's economy is the sixth largest in the world of which agriculture plays a huge part (CA Department of Finance, 2017). This stems from the unique and complex geology of the state, which creates a diverse range of terrain and climates, creating the habitats which in turn support one of the most agriculturally productive regions in the world. In particular, California coastal grasslands as well as the Central Valley grasslands host a tremendous amount of fertile agriculture. However, these grasslands are under threat both from increasingly restrictive droughts over the past 30 years in addition to an incredible amount of exotic invasion. Animal agriculture, in its dynamic nature, both effects and is affected by both. The most water intensive crops in the state are alfalfa and other cattle forage, with meat and milk products themselves consuming 22 and 7 percent of a US consumer's daily water footprint, respectively (Hoekstra & Mekonnen, 2013). Interestingly, the drought and increasing water use from these crops may actually be exacerbating the invasion of exotic species (Harrison *et al.* 2015). Invasive European grasses have become the dominant biomass across California's grasslands, and native biodiversity has suffered a huge decline because of their invasion. But just as they may be exacerbating the problem, cattle and grazing are increasingly relevant as a conservation effort (Pasarai *et al*. 2014). Cows have co-evolved alongside the quick-growing European annuals and may therefore decrease their spread through selective grazing. Clear understanding and full accounting of these concerns can only help as we seek to manage our natural resources to the best of our ability. California sets the perfect stage for this debate, as nowhere else in the country do debates over agriculture rage more than in this state—the most agriculturally abundant and one of the most environmentally progressive.

Perhaps the epicenter of the debate over conservation and ranching is found at Point Reyes National Seashore. Point Reyes has historically cattle grazed land that has been slowly phased out of ranching and replaced by Tule Elk (*Cervus canadensis nannodes*) habitat. Point Reyes as a National Park presents as an ideal location for studying grassland ecology because the grazing histories of the parcels of land are all publicly available, and as the National Park Service shut down ranching operations across decades, it acts to conserve the land across a timeline. Over the previous decades, the elk built up their populations, resulting in the still active ranching operations feeling increasingly at odds with the elk populations, due to competition over forage and water as well as the destruction of fencing (Elk Fences Now, 2014). Additionally, paratuberculosis, a disease passed from cattle to the elk herds, is blamed for a more recent population decline of the elk. The National Park Service now must balance the interests of conservation, welfare, and ecotourism for the elk as well as the interests of the ranches that operate within the Park. Today, the ranches are operating under five-year contracts with the National Park Service. Since these contracts and the continuation of ranching itself are currently in debate in Point Reyes National Seashore, it is critical to understand the impact cattle grazing places on grassland plant communities in time to make the best decisions for all stakeholders.

In this study, we examine the effects of cattle grazing and time since cessation of cattle grazing on coastal grassland plant communities in Point Reyes. We test for differences in plant species richness and plant species composition between habitats with active current cattle grazing and those from which cattle have been removed across a chrono-sequence of removal. Native plant diversity is an important measure of overall biodiversity and ecosystem health. This research will help us to understand how cattle affect the ecosystems they graze in, at a time when this very issue is being debated over within this national land.

METHODS

Natural History of the Study System

Point Reyes National Seashore (38.0723° N, 122.8817° W), encompasses over 280 square kilometers along the Northern California coast. The Mediterranean climate of Point Reyes is characteristic of the California coast, with mild, wet winters and cool summers. The average January temperatures range from 7.3° C to 12.3° C, while the average September temperatures range from 10.9° C to 16.1° C. Annual precipitation levels average 433 mm, with heavy fogs providing considerable moisture in the summers. Geologically, Point Reyes National Seashore is separated from most of the continental United States by the San Andreas Fault, which creates a geologically complex area resulting in a variety of soil types and vegetation assemblages. The Seashore has a plethora of ecosystems, comprising of dunes, beaches, coastal grasslands, wetlands, chaparral, wilderness lakes, and Douglas Fir (*Pseudotsuga menziesii*) and Bishop Pine Forests (*Pinus muricata*) (U.S. National Parks Service 2017).

Point Reyes hosts high biological diversity and represents 15 percent of California's flora. It is home to 900+ vascular plants, of which 61 are endemic to the region, and over 50 are listed as rare, threatened or endangered. However, 292 species in Point Reyes are non-native, and often these exotic species are highly invasive (U.S. National Park Service 2017). Invasive species are the second highest threat to biodiversity, threatening 49 percent of endangered or threatened species (HilleRisLambers 2010; Wilcove et al. 1998). Exotic annual grasses such as Italian Wild Rye (*Festuca perennis*), and Slender and Wild Oats (*Avena barbata, Avena fatua)*, and perennials such as Velvet Grass *(Holcus lanatus)* have invaded the coastal grassland of Point Reyes. We focused our species-level analysis on Velvet Grass, Italian Wild Rye, and Wild Radish as they are considered highly invasive within the Point Reyes peninsula and previous studies have established these species as potentially sensitive to grazing regimes (U.S. National Park Service; Johnson & Cushman, 2006). Additionally we focused on the native species Coyote Brush (*Baccharis pilularis)* as an individual species as it is a successional species and may be used as an indicator for successional stage post-grazing (Elliott & Wehausen, 1974).

Land Use History

Point Reyes National Seashore has an extensive history of land use development. Predating written history by 5000 years, the Miwok Native Americans were the first inhabitants of the land until the Spaniards seized the region in the early 1800s. This was followed by the establishment of cattle ranches and agricultural operations throughout the region, soon followed by the introduction of invasive European grasses. During the California Gold Rush, Tule Elk, an abundant grazer in the region, saw a dramatic decline in population due to widespread hunting as well as displacement from cattle. Tule Elk were thought to be extinct until Henry Miller, a ranch owner, discovered the last remaining herd of Tule Elk in his property in 1874. Point Reyes National Seashore was established in 1962, and Tule Elk were reintroduced to Point Reyes in the early 1970s. In 1978 the 10.5 square kilometer Tule Elk reserve was created and fenced off from the cattle, and since then Tule Elk populations have increased to an estimated 3900 individuals and 22 herds throughout the Point Reyes Peninsula. While Point Reyes National Seashore is public land, the National Park Service has made a commitment to preserving the long-run agricultural and cattle ranch industry in addition to supporting the Tule Elk population. Today, Point Reyes National Seashore is a conservation enterprise visited by thousands of researchers, students, and to tourists looking to explore the unique landscape, flora, and fauna (U.S. National Park Service 2017).

Research Design

We selected sites with different grazing histories, which we defined as years since active grazing. In total we had four distinct grazing treatments- sites, which were currently grazed, and sites, which had not been grazed for 17 years, 39 years, and 87 years. (Figure 1).

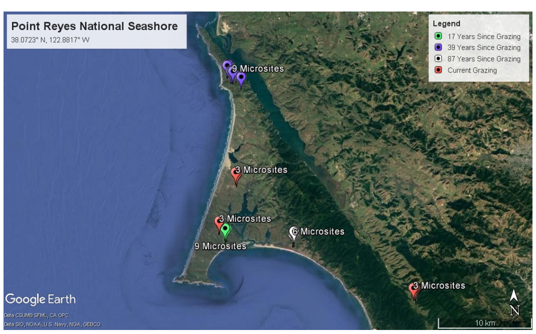

Figure 1. Point Reyes Site Location Map by Grazing Regime. 33 total microsites were sampled over the Point Reyes peninsula, ranging from currently grazed to 87 years-since-grazing.

The 87-year site was the former Muddy Hollow Ranch, now the location of Muddy Hollow trailhead. The ranch was one of the first dairies at Point Reyes, and operated from 1859 to 1930 (Livingston, 1993). Cattle were excluded from Pierce Point Ranch in 1978 to create the Tule Elk Reserve, which we used as the 39-years post-grazing site (U.S. National Park Service 2017). The Historic D Ranch, our 17-year site, operated until 2000, when it was closed down to restore both the historic structures and the native vegetation (Dave Press, Personal Communication, August 2017). There are approximately 28,000 acres of active cattle and dairy operations within the park, and as such we chose our active grazing areas primarily on accessibility (U.S. National Park Service 2017). Additionally we attempted to sample a balance of both cattle and dairy fields to account for potential variation in management practices between ranches.

Tule Elk, Point Reyes' native large ungulate grazer, now occupy all of the inactive graze sites we sampled. Both the 17-year D ranch site and the 87-year Muddy Hollow site are occupied by free-range elk herds, while the 39-year Tule Elk Reserve herd is isolated from active graze sites by an elk fence. As such our former grazing sites provide a glimpse into what the park may look like should cattle ranching be removed and the peninsula returned to the elk.

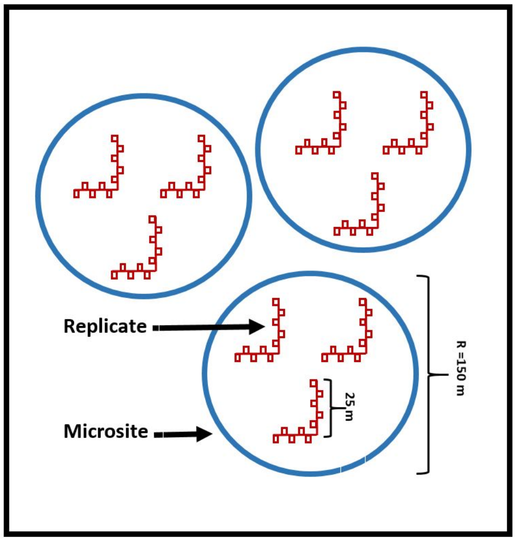

Figure 2. Research Schematic. Within each grazing regime (black rectangle), we generated three sites (blue circle). At each site, we generated another three GPS points within a 150-meter radius of the original site as our microsites (red "L"). Each microsite consisted of two 25 meter transect lines going west and north. Along the two transect lines, we used a point-intercept technique to sample from 2500m^2 quadrats (red square) spread out every 5 meters along the transect lines.

We conducted field sampling of grassland communities for plant species richness and relative abundance across multiple grassland sites on the Point Reyes landscape. Sampling was conducted August 3rd through 6th, 2017. We selected three GPS points within each grazing regime to use as a midpoint (N = 11; one site was excluded due to overwhelming poison oak). Within a 150-meter radius from the GPS midpoint point we generated three additional GPS points via a random point generator, hereafter referred to as microsites (geomidpoint.com). At each microsite we measured two 25 meter transects to the North and West (N = 33) (Figure 2). Along the 25m transects we placed quadrats at 5m intervals with alternating positions to the left or right of the transect tape, which was determined haphazardly (N = 330). The quadrat area was 2500 cm^2, which was divided into 25 smaller squares of 100cm^2.

We measured plant abundance and richness within each meter square quadrat. To measure species richness we identified all of the species which were present within our quadrat and marked them as present, then later compiled a list of all species seen at all the sites and determined which species were absent. We used point intercepts to measure relative abundance, and counted each time a species crossed one of the 16 intercepts as one hit.

Statistical Analysis

Prior to comparisons, we ran tests of unequal variance in order to determine the appropriate method of analysis for each variable. We ran Kruskal-Wallis Tests for richness, Velvet Grass (*Holcus lanatus*), Italian Wild Rye (*Festuca perennis*), and Coyote Brush (*Baccharis pilularis*) abundance all by years-since-grazing. We also ran a regression on species richness by Italian Wild Rye abundance. We considered these species to be important or characteristic species of these ecosystems and worthy of individual relative abundance analysis.

Plants were classified as exotic or native and either grasses or forbs creating four categories along with a fifth category for shrubs. For the rest of these comparisons we summed our quadrat data in their microsite, reducing number of replicates but allowing us to look at larger scale trends. We performed an ANOVA on abundance in each of these categories against years-since-grazing. We also performed ANOVAs on native and exotic species richness as well as proportion of native species by years-since-grazing. The actual native proportion for each grazing regime was calculated from total native and overall richness values for each site. We also analyzed species composition of transect level relative abundance data using nonmetric multidimensional scaling.

RESULTS

We found a total of 63 species over 330 quadrats in 4 different regions of varying cattle grazing history. A Kruskal-Wallis test showed significant difference in plant richness explained by years-since-grazing (χ^2 = 98.15, P < 0.0001).

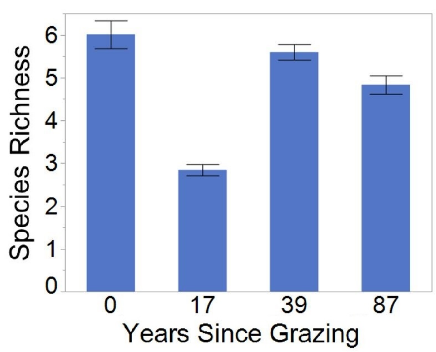

Figure 3. Plant Species Richness by Grazing Regime. Mean quadrat-level species richness for all grasses, forbs, and shrubs are plotted by time since grazing. Sites where active cattle grazing was observed showed the most species richness when compared to sites without cattle grazing. (χ^2 = 98.15, P < 0.0001)

The highest richness occurred at currently grazed sites and lowest richness occurred at 17 years post grazing sites (Figure 3). Kruskal-Wallis determined there to be significant variation in Velvet Grass correlated to years-since-grazing (χ^2 = 48.04, P < 0.0001). Velvet grass had its highest abundance at 39 years-since-grazing sites, and its lowest abundance at currently grazed sites (Figure 4).

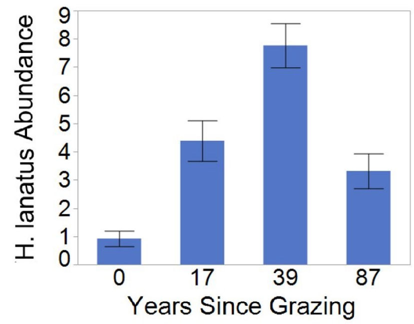

Figure 4. Velvet Grass Abundance by Grazing Regime. Mean quadrat-level Velvet Grass abundance is plotted by time since grazing. Velvet grass abundance increases after removal of grazing until reaching a maximum at 39 years post grazing at which point it decreases. (χ^2 = 48.04, P < 0.0001)

Kruskal-Wallis also found Italian Wild Rye abundance to vary significantly with changes in years-since-grazing (χ^2 = 76.42, P < 0.0001). Italian Wild Rye had its highest abundance at 17 years post grazing sites and lowest abundance at 39 years post grazing sites (Figure 5).

We found a significant negative association between species richness and Italian Wild Rye abundance (R^2 = 0.268, P < 0.0001; Figure 6).

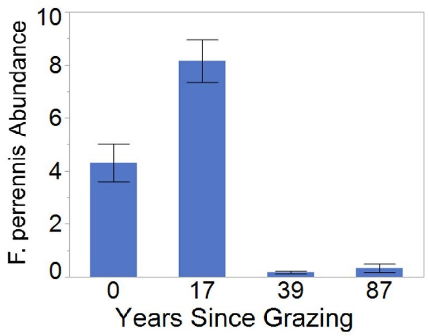

Figure 5. Italian Wild Rye Abundance by Grazing Regime. Mean quadrat-level Italian Wild Rye abundance is plotted by time since grazing. Abundance increases initially after removal of cattle until after 39 years it decreases to near 0. (χ^2 = 76.42, P < 0.0001)

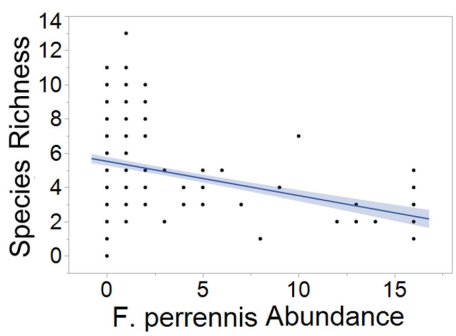

Figure 6. Species Richness by Italian Wild Rye Abundance. Mean quadrat-level species richness is plotted on the y-axis as explained by Italian Wild Rye Abundance. A Regression was run and found a negative correlation between the two. (R^2 = 0.268, P < 0.0001)

Relative abundance of Coyote Brush was also found to be significantly different with time since grazing using Kruskal-Wallis (χ^2 = 43.56, P < 0.0001; Figure 7). Coyote Brush had its highest abundance at 87 years-since-grazing sites and lowest at currently grazed sites.

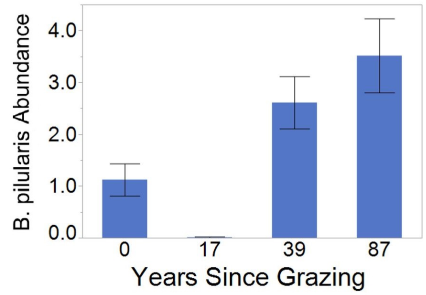

Figure 7. Coyote Brush Abundance by Grazing Regime. Mean quadrat-level Coyote Brush abundance is plotted by time since grazing. The lowest abundance was found at 17 years post grazing sites while the highest abundance was found at 87 years post-grazing sites.

We found significant differences in abundance of exotic forbs by years-since-grazing (F = 3.404, P < 0.05; Figure 7). Exotic forb abundance was significantly higher in 17 years-since-grazing sites than 87 years-since-grazing sites (Tukey < 0.05). We found significant differences in abundance of native forbs by years-since-grazing as well (F = 6.034, P < 0.005; Figure 8).

Native forb abundance was significantly higher in currently grazed sites than both 17 and 39 years-since-grazing sites (Tukey < 0.05). For exotic and native grasses as well as shrub abundance, we found no significant difference associated with variation in years-since-grazing (P > 0.05; Figure 9).

Figure 8. Native and Exotic Forb Abundance by Grazing Regime. Mean Microsite-level abundance of Native and Exotic Forbs plotted on the x-axis as explained by years-since-grazing. Native Forb abundance is shown in blue while exotic abundance is in orange. Significant difference was found between exotic forb abundance between grazing regimes (F = 3.404, $P < 0.05$). Significant difference was found between native forb abundance between grazing regimes. (F = 6.034, $P < 0.005$)

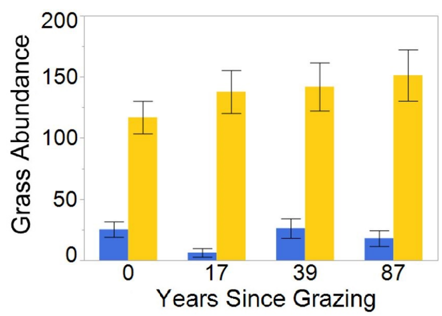

Figure 9. Native and Exotic Grass Abundance by Grazing Regime. Mean microsite-level abundance of Native and Exotic Grasses plotted on the y-axis as explained by years-since-grazing. Native Grass abundances are shown in blue while exotic abundance is in orange. Exotic grasses exist in far higher abundance across all grazing regimes. No significant difference was found between grazing regimes. ($P > 0.05$)

We found the highest total richness, 39 species, as well as highest proportion of native species, 53.85 percent, in the currently grazed sites. We found the lowest richness, 21 species, in the 87 years-since-grazing sites but the lowest proportion native, 33.33 percent, in the 17 years-since-grazing sites (Figure 10).

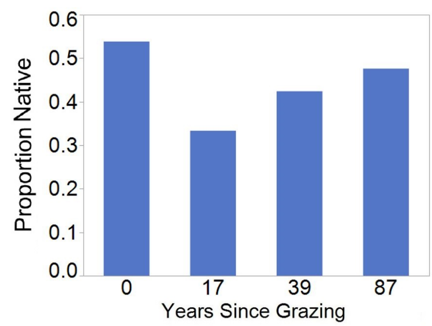

Figure 10. Proportion of Native Flora by Time Since Grazing. The richness of native plants as a ratio of the total plant richness for each grazing regime. The highest was 0.538 at currently grazed sites and the lowest was 0.333 at 17 years post grazing sites.

ANOVA determined there to be significant difference in exotic species richness explained by years-since-grazing (F = 3.342, $P < 0.05$). ANOVA found significant difference in native plant richness explained by years-since-grazing (F = 7.847, $P < 0.001$). Precisely, we found that the 17 years-since-grazing sites had significantly lower native species richness than currently grazed, 39, and 87 years-since-grazing (Tukey < 0.05). The average proportion of native plants was shown to vary significantly with changes in years-since-grazing (F = 17.937, $P < 0.0001$). Specifically samples at sites 17 years post cattle grazing had a far lower mean proportion of plants that were native than all other sites (Tukey < 0.05).

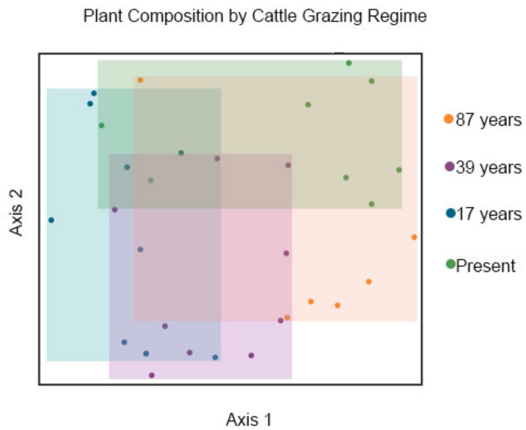

Figure 11. Plant Composition by Cattle Grazing Regime Ordination. This plot accounts for 66.6 percent of variation within plant communities organized by years since cattle grazing. Axis 1 accounts for 36.6 percent of variation while axis 2 accounts for 30 percent. Each colored box represents the potential range of community composition according to our data, with overlapping regions sharing similar relative species abundances.

Nonmetric multidimensional scaling returned ordination results for plant composition by cattle grazing regime (Stress for 3d solution = 11.2289, instability = 0.0000, Figure 11). Though a 3-dimensional solution is recommended, our chosen axes represent the majority of the variation in species composition and therefore a 2-dimensional model is satisfactory to represent the ordination. Axis 1 represents 36.6 percent while axis 2 represents 30.0 percent of plant community variation. Variation in Wild Radish presence accounts for 42.6 percent of differences within Axis 1 while variation in Velvet Grass abundance explains 73.8 percent of Axis 2.

DISCUSSION

We found plant species richness varied significantly with grazing history on the Point Reyes National Seashore, but not in a linear or straightforward way. Quadrat-scale plant species richness was highest under current active grazing (mean = 6.011; Figure 3) While quadrat-scale plant species richness was found to be lowest in plots where grazing had been most recently removed (mean = 2.844; Figure 3). Plant species richness in grasslands where cattle were removed 39 and 87 years ago was intermediate between current grazing and 17 years-since-grazing regimes. Among grazing treatments, currently grazed sites had the highest variation in richness, which may be associated with differences in location permitting increased community differentiation. However the high average richness at currently cattle grazed sites may also be attributed to disturbance facilitated coexistence. Cattle grazing at intermediate levels, considered as an anthropogenic disturbance have been found to lead to increased levels of vascular-plant species richness (Yuan et al. 2016). We found the invasive European grasses, Italian Wild Rye and Velvet grass, to have significantly lower abundance counts in currently grazed sites compared to the 17 years post grazing sites, which suggests a feeding preference in the cattle (Figure 4 & 5). This follows our hypothesis of selective grazing due to coevolution between the cattle and these invasive grasses. At moderate density, selectively grazing free-range cattle may prevent these large seed load invasive grasses from dominating the ecosystem. Lower density of these grasses may give slower reproducing native species a better chance of survival and propagation due to reduced competitive pressure.

In the 17-year site, both Italian Wild Rye and Velvet Grass have far higher abundance levels than in currently grazed sites, which implies they are able to propagate at high success rates post disturbance (Figure 4 & Figure 5). We found a negative association between Italian Wild Rye abundance and plant species richness, which suggests competitive exclusion, occurs as this species increases in abundance (Figure 6). This aligns with our finding of the lowest richness at 17 years-since-grazing sites along with highest Italian Wild Rye abundance. Velvet grass has its highest abundance at 39 years post grazing while Italian Wild Rye actually has its lowest abundance at this point. Succession of dominant species is illustrated in our data by this change in Velvet Grass and Italian Wild Rye abundance from currently grazed to 39 years-since-grazing (Figure 4 & Figure 5). Velvet is lower in abundance that Italian Wild Rye but both increase until at the 39-year sites, Velvet Grass has become the most abundant and Italian Wild Rye has fallen to near 0 appearances. Velvet Grass decreases in abundance at 87 years post grazing sites which may be due to undisturbed, competitively superior species reaching a life stage in which they can better utilize resources and exclude grasses. This is supported by our data as Coyote Brush, a native shrub, had significantly higher abundance at 39 and 87 years-since-grazing sites (Figure 7). This is assuming that the 87-year site had a similar composition to currently grazed sites when it was an active ranch.

Recent studies have found that plant communities grazed by cattle experienced greater native species richness and greater native forb cover when compared to ungrazed communities (Beck et al. 2005). Our study confirms this precedent. We found significantly higher native forb abundance in cattle grazed sites compared to sites 17 and 39 years post grazing (Figure 8). Native proportion of plants is highest at currently grazed sites as well (Figure 10) However, there is a trend for both native forb abundance and proportion native to increase from the 17 years post grazing sites to the 87 years post grazing sites suggesting that native plant species may take back control of the ecosystem to some extent after their initial fall after removal of disturbance.

The nonmetric multidimensional scaling analysis revealed over time plant composition becomes more varied, even though richness did not increase accordingly. The presently grazed site and the most recent 17-year site both had the most constrained plant compositions along a singular axis, while the 87-year site spanned almost the entire range (Figure 11). The large change in plant community composition that occurs soon after removing disturbance that we discussed previously can be seen in the large shift in axes range from the currently grazed to 17 years post grazing sites. Some of the species, which were the primary drivers of variation, were *Asteraceae,* Italian Wild Rye, Rattlesnake Grass, Velvet Grass, Coyote Brush, and California Blackberry. Generally, exotics explained the most variation along the axes, which may be due to their disproportionate abundance relative to their proportion of the total richness. Interestingly, even though the presently grazed sites were most geographically separated, they were still constrained fairly well by microsite.

Experimental Concerns

When selecting the sites under current grazing, we chose the three areas to sample spread over the peninsula (Figure 1). Our other sites within a particular grazing regime were geographically clustered much closer together. This distance between sites could be responsible additional variance. Additionally, Point Reyes National Seashore wildlife ecologist, Dave Press, explained to us that cattle and dairy operations use the land a bit differently as dairy cows must stay close to the barn where they are milked and cattle intended for beef can roam the full stretches of land available to them. The microsites we sampled under current grazing had one site under beef cattle grazing and the other two under dairy grazing. This creates two variables that could explain the additional variability seen amongst the current grazing sites.

While sampling the sites in the region that had been excluded from grazing for 87 years, it became apparent that the last three random GPS points that were generated happened to land on terrain that sloped upward through thick overgrown scrubland dotted with poison oak. This was our last day to collect data preventing us from generating new points and sampling the same number of quadrats for each region of grazing. This creates a discrepancy in the precision to which we measured the diversity of grassland plants between the region that has gone 87 years without cattle and the rest of the regions.

Fog abundance varied across sites that were more or less inland, potentially affecting the plant communities across our sites. This becomes especially relevant considering that the tip of Point Reyes is the windiest and second foggiest point on the North American continent (U.S. National Park Service 2017).

Finally, of all the taxonomic families of plants, grasses are subjectively the most difficult to identify. When classifying the morpho-species we encountered in the field, each plant's life history attributes and distinction as native or exotic to California could have been misidentified despite our best efforts to identify every plant to the species level.

Further Research

To get a clearer understanding of the effects of grazing on plant community composition, more variables need to be accounted for. For example, it would be beneficial to measure the average height of the plants in each quadrat in order to understand how primary productivity differs from site to site. We ultimately decided that it would be difficult to compare these values because cow and elk herbivory removes plant matter at different rates that we cannot currently measure. Ungulate density on the landscape also varied between sites. At some sites there were elk herds calling out from the hills surrounding us, at other sites only dry elk scat was observable. Attaining a measure of ungulate abundance per area would allow us to control for this variability.

Economic Considerations

Our findings indicate that some invasive plants, in particularly Velvet Grass, are less abundant in areas under current grazing. We also found that native plant richness was greater in areas of current grazing. These results indicate that European cattle are effective at controlling the invasion of exotic plants. This makes it appears as though the ranching management approaches taken by the National Park Service and the historic ranching operations at Point Reyes create a sustainable model for cattle grazing. A significant issue with how these farms operate is that they struggle to makes ends meet ranching organically (Elk Fences Now 2014). The ranching fees these organic ranches pay cost them one tenth of the cost for an average organic ranch to operate on private land (Center for Biological Diversity 2015). In the 1960s, he Federal government brought out these ranches for hefty sums of money, over $160 million dollars in today's money (Bancroft Library, R.O.H.O. 1993). Many of them struggle even with the government effectively subsidizing their ranches (Elk Fences Now 2014). The extreme pressure of demand and competition placed on commercial dairies and cattle ranches operating on private land has driven the cost of their product down to a point where sustainable practices can barely survive, even with this support from the government (Elk Fences Now 2014). This results in a pseudo-sustainable agricultural model that becomes unfeasible for existing ranching across the country due to the financial and land use constraints that are levied against each organic cow. While this might be a historic and valuable model for Point Reyes and the National Park Service's invasive plant control efforts, this system is not economically feasible without the support of the government.

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