Multi-Scale Analysis of Grazing Impacts on Plant Diversity at Point Reyes National Seashore

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ABSTRACT

Point Reyes is a protected National Seashore which simultaneously aims to conserve biodiversity and support extensive ranching operations. This study analyzes the influence of grazing on plant diversity over long time periods and at multiple spatial scales. To determine influence of grazing on fine-scale grassland community structure, I sampled species richness in grazed and ungrazed areas. I found no significant difference between the two areas, but noticed slightly higher average species richness and native species richness in grazed areas at the quadrate level. To determine broad-scale patterns of shrubland and grassland vegetation, I used Geographic Information Systems to map vegetation changes from the 1940s, 1960s, and 1990s. I found relatively consistent land cover between the 1940s and 1960s, and wide-scale shrub encroachment between the 1960s and 1990s. These results were paired with a historical analysis of ranching management and land ownership at the Point Reyes Peninsula. The largest changes in the landscape occurred between the 1960s and 1990s, when the National Parks Service bought the land. Overall, these results suggest that large scale shifts in land ownership, rather than individual ranch management techniques, can cause broad vegetation changes in a relatively short time. Uncertain rancher land ownership and short term lease agreement between the ranchers and the National Parks Service may have directly impacted grazing management and shrub encroachment. Creating long-term lease agreements could give ranchers more ownership over their land and protect the grassland community at Point Reyes.

KEYWORDS

grassland, shrubland, plant diversity, ranching, National Parks Service

INTRODUCTION

Conservation programs around the world show how community engagement in conservation management can create more sustainable conservation models (Herrmann and Torri 2009, Khalyani et al. 2014, Nepal 2002, Pokharel et al. 2015, Thompson et al. 2011, Wiens 2009). To safeguard species, the International Union for Conservation of Nature ("IUCN") governmental agency established the use of Protected Areas as "clearly defined geographical spaces, recognized, dedicated and managed… to achieve the long-term conservation of nature" (Dudley 2013). These conservation areas restrict economic activity such as logging, grazing, or cultural use of the land, and strictly exclude people who originally occupied these lands (Dudley 2013). Many Protected Areas are plagued by inadequate size, lack of funding, insufficient infrastructure, sparse staff training, and come into conflict with surrounding communities (Andrade and Rhodes 2012, Leverington et al. 2010, Struhsaker et al. 2005). As a result, Protected Areas are failing to protect many threated species and continuously threaten peoples livelihoods (Brooks et al. 2004). The incorporation of community management is a potential tool to help reverse the trend of declining biodiversity and displacing people by expanding the range of conservation practices to include more human-managed activities.

Directly involving community stakeholders in decision-making can address many short fallings of strict and exclusive conservation strategies (Andrade and Rhodes 2012). An example of this is the Category V Protected Landscape or Seascape, which addresses the need to recognize human influence on a landscape that is rooted historically and continues to actively contribute to the land both ecologically and culturally (Phillips and IUCN World Commission on Protected Areas 2002, Dudley 2013, Brown 2015). In 1962, the National Parks Service (NPS) designated Point Reyes as a Category V National Seashore. Incorporating historic use of the land and long-term community management is a necessary step to protecting cultural livelihoods. While Point Reyes integrates the historic use of the land for grazing as a conservation model, it's primary goal is still to preserve biodiversity (Boitani et al. 2008, Locke and Dearden 2005). To evaluate the effectiveness of this management strategy in achieving these goals, it is crucial to trace the historical relationship between the Parks Service and the ranchers at Point Reyes as an indicator of successful biodiversity conservation and cultural preservation.

Although Point Reyes has a long history of cattle farms on its land, the impacts of cattle grazing and human management on biodiversity need further study. Studies of fine-scale grazing impacts observe how overgrazing reduces biodiversity and soil nutrient levels in semiarid grasslands (Deng et al. 2014b). Overgrazing is also associated with soil erosion, soil compaction, runoff, reduced nutrient cycling, water contamination, and reduced species richness (*Resource Renewal Institute et al v. National Parks Service et al.* 2016, Shook 1990). On the other hand, grazing reduces vegetation height and litter accumulation, which in turn promotes diverse seed propagation and increases plant species richness (Schwabe et al. 2013, Seifert et al. 2014). Historical presence of grazing is also an important consideration. When grazing is present for hundreds of years at a vernal pool site, a reduction of grazing increased the presence of non-native grasses (Marty 2005). In addition, while high density grazing may reduce species richness, moderate grazing was found to have a higher species richness (Deng et al. 2014a, Elliott and Wehausen 1974, Hayes and Holl 2003, Shook 1990).

Grazing intensity can be measured by cattle stocking rates and Residual Dry Matter (RDM), which is the amount of forage plant material left on a range after summer grazing (Bartolome et al. 2002, Shook 1990). At Point Reyes, moderate grazing is defined at grasslands having a minimum average of 1200lbs/acre of RDM, comparted to less than 1000lbs/acre of RDM in heavily grazed areas (Shook 1990). Point Reyes ranches monitoring protocols use active management techniques to adjust stocking rates and management practices based on the RDM for each ranch to reduce erosion and to protect watersheds (Shook 1990).

On a landscape-scale, grazing disturbance can restrict the dominance of a single land-cover type and provide good conditions for suppressed vegetation types, resulting in higher landscape heterogeneity and diversity (Adler et al. 2001, Schwabe et al. 2013). Landscape-scale heterogeneity is found to support species richness, which can benefit biodiversity conservation as a whole (Hovick et al. 2015, Kesting et al. 2015, Oliver et al. 2010). Cultural landscapes, such as the grazing lands at Point Reyes, can help to create and maintain heterogeneous landscapes through active management techniques (Agnoletti 2007, Marignani et al. 2008).

Grazing is known to reduce the expansion of shrubs into grassland communities, and studies show a significant increase in shrub density when grazing is excluded from grassland areas (Cipriotti and Aguiar 2012, Good et al. 2013). Plant species richness if found to be highest with a medium amount of shrub presence and decreases as shrub become more abundant (Kesting et al.

2015). In addition, shrub encroachment can rapidly replace diverse grassland species in the absence of active management (Kesting et al. 2015). The different grazing practices of beef versus dairy cows may also contribute to different vegetation structures, as beef cattle are found to create more open landscapes and may restrict shrub encroachment to a great degree than dairy cows (Laurila et al. 2015). Given that ranchers depend on high-quality grassland to sustain their operations, and that shrub encroachment can quickly restrict these species grasslands, it is in the best interest of the ranchers and the NPS to restrict the rapid growth of shrub species.

Conservation and land management must be explored at multiple spatial and temporal scales to better understand how landscapes transform over time (Antrop 2000, Bennett et al. 2006). By exploring grazing impacts on both fine-scale species richness and broad-scale vegetation change, the full impacts of long term grazing can be examined. While a broad-scale analysis is important to identify longer term vegetation structure and shifting biome types, a fine-scale analysis helps to identify grassland community structure, specifically with native species cover. It is essential to understand whether this human influence comes at a cost to biodiversity or improves the overall richness and diversity of the landscape to promote both economic and ecological goals.

BACKGROUND

Point Reyes, a 70,000 acre peninsula north of San Francisco with 80 miles of coastline, reflects a deep history of land accumulation and dispossession, beginning with the Miwok Native American peoples, transitioning to missionaries, Mexican land grantees, White cattle ranchers, and eventually accumulated by the state as a National Seashore conservation space (Livingston 1994, Mullen 2015, Rilla and Bush 2009, Sadin 2007). The physical features of Point Reyes were constructed by the long-term presence of humans and grazers on the land. Before grazing began at Point Reyes, the land was managed by the Miwok Native Americans through regular burning and Tule Elk through grazing, both of which played a role in controlling brush and maintaining the grassland community (Shook 1990, Watt 2016). After the native population was driven off the land and elk had been hunted to near extinction, cattle grazing and rancher brush removal continued to keep grassland open as prime grazing land (Lane 2014, Shook 1990). Point Reyes land has been in the hands of ranchers since the 1850's, with 27 working ranches coving 21,000 acres (Livingston 1994). Historically, ranchers had relatively autonomous decision-making power over their lands

(Mullen 2015). Land management decisions began to shift in the 1930s, driven by the American conservation and environmentalism movements which advocated for more protected lands and the creation of Point Reyes National Seashore. The main goals for protecting this land was to preserve biological diversity, recreation, and scenic values of the land, with the plan of excluding ranches entirely from the land (Mullen 2015). Ironically, it was the historical grazing practices which created and maintained the scenic coastal land which the Parks Service desired, yet the rancher's involvement in shaping the land was completely disregarded (Mullen 2015, Watt 2002).

Plans to develop a National Seashore began as early as 1929. The initial plan proposed the conversion of Point Reyes into a protected seashore and the elimination of ranches, because they seemingly conflicted with conservation goals (Huntsinger and Hopkinson 1996, Mullen 2015). Once the development plan went public there was major opposition by the ranchers, who actively fought against the seizure of their land and livelihoods. Ranchers cared from their land, and as the rancher Al Grossi stated, "I have worked very hard on improving my ranch…if the cattle were taken off of these pastures, there would be no beautiful green hills as you see today. It would turn to nothing but brush in a very short time" (Mullen 2015). Following this logic, another rancher questioned whether "any rancher in his right mind [would] improve land, buildings, and fences that did not belong to him" (Sadin, 2007). Ranchers view government accumulation of the land as a strategy to remove grazing altogether as a proposed method to increase biodiversity (Knapp et al. 2015).

The Parks Service and environmental agencies, because of their status as experts in the environmental field, are given more validity when they make claims of environmental degradation and grazing impacts on the land. Local knowledge of ranchers, such as when ranchers defend their stewardship of the land, is disregarded and unappreciated with the lack of solid scientific evidence. The valuation of one set of knowledge over another creates an atmosphere of resentment and resistance among local ranchers (Knapp et al. 2015). Even if the ranchers and NPS have similar goals to protect and preserve the Point Reyes land for generations to come, this lack of trust built major roadblocks to achieving a consensus on future land management.

Although ranching agreements helped to establish the National Seashore, it was the intention of the Parks Service to prioritize the land for recreation and biodiversity protection and eventually to phase out ranching (Mullen 2015). After the Parks Service purchased the land, ranchers were offered 5-year leasing agreements (Rilla and Bush 2009, Mullen 2015). The Parks

Service controlled the rights to give out permits, conducting biological studies on grazing impacts to determine if permits should be given (Bartolome 2015). This left the ranchers with uncertainty about the future and a precarious means of living. Such short-term leases did not ensure the long-term viability of the ranchers and their incentive to care for the land (Rilla and Bush 2009, Mullen 2015). Recent attempts to expand these lease times to 25 years to provide more stability for ranchers has been met with a lawsuit driven by the Resource Renewal Institute, Center for Biological Diversity, and Western Watersheds Project, who are pushing for permits to be halted altogether (*Resource Renewal Institute et al v. National Parks Service et al. 2016).* With this study, the land acquisition and ranch management changes over time will inform our understanding of how historic land ownership may affect vegetation changes at a broad scale.

OBJECTIVE

This study attempts to answer a central question with a multi-scale spatial analysis. How does the presence of cattle ranches and long-term grazing at Point Reyes National Seashore influence plant diversity in this Protected Area using multiple spatial and temporal scales? At a fine-scale, do plots within grazing sites at Point Reyes support more plant species richness than plots outside of grazing sites? At a broad-scale, how has the range of land cover types across Point Reyes changed over time, and how might this be correlated to historic land management?

METHODS

Study Site

Point Reyes National Seashore covers 28,827 hectares and is located at 38.0178˚ North and 122.9912˚ West. Point Reyes has a Mediterranean climate with vegetation cover including sand scrub, open grassland, and rocky formations (Howell et al. 2002). The coastal climate along the cliffside creates cool, foggy conditions which supports species rich grasslands. Farther inland, climate conditions can become dry and hot. Grasslands, the primary focus of this research, consist both of grasses (such as *Festuca perennis*) and forbs (such as *Linum bienne*).

Point Reyes now serves multiple purposes, including the continuation of ranching, biodiversity conservation, Tule Elk conservation, and tourism. Tule Elk live on the land and overlapped with cattle ranch boundaries in the past, but their extent has been greatly reduced and they currently do not strongly influence cattle grazing patterns (Howell et al. 2002).

Fine-Scale Study

Site Selection Methods

Looking at a species-level scale of Point Reyes, I could capture the details of the grassland community and better understand overall grassland health within grazed and ungrazed areas. In this study, ungrazed areas refer to previously grazed grasslands which have been surrounded by fencing before the year 2005 to exclude grazing. These fences, or exclosure sites, were put up to protect riparian habitat from grazing impacts and erosion. Because of the study design, all study sites are nearby riparian areas and ungrazed transects are always located a few meters closer to riparian areas, but they are still located on grassland habitat.

To determine species richness and differences in richness between grazed and ungrazed sites, I selected sites a total of nine exclosure sites across Point Reyes as potential study sites (Figure 1). I set up parallel transects on both the grazed and ungrazed side of the fences. Upon visiting each site, I developed another set of criteria for rejection of unsuitable sites:

1. Area inside and outside the fence must be comparable in slope, aspect, and sun exposure for each individual site.
2. There must be enough grassland inside and outside of the fence to fit a 25 meter transect parallel to and at least 4 meters away from the fence line.
3. Cows must have access to the outside portion of the fence. At least some grazing evidence must be present, including cow trails, shortened grass height, cow pies, or hoofprints.
4. Cows must not have access to the inside portion of the fence. There should be no evidence of cattle grazing inside the fence.

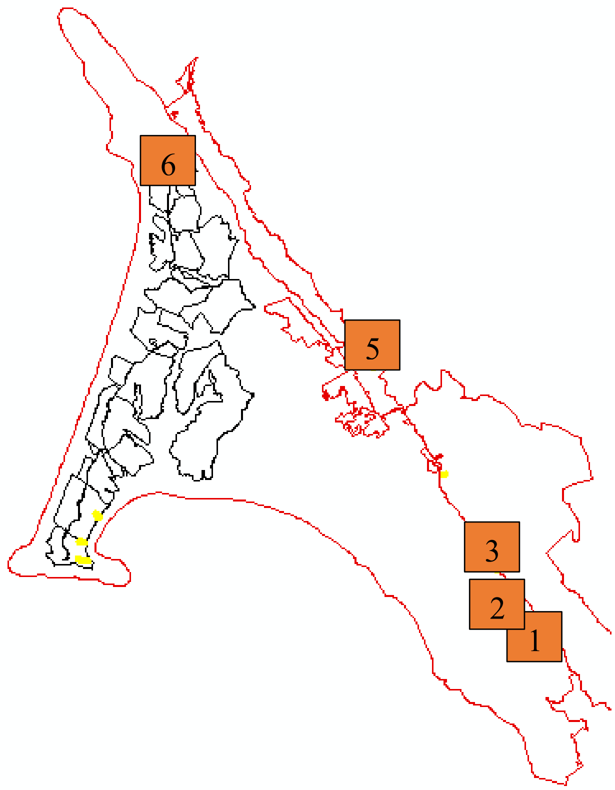
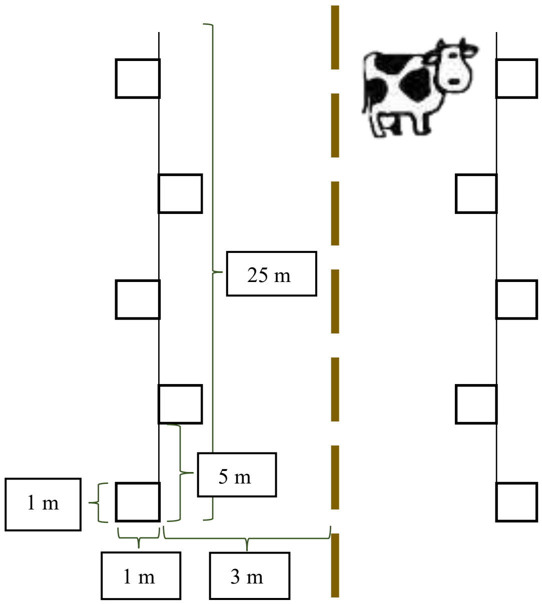


Figure 1:
Study sites for the fine-scale study. The boundary of Point Reyes is outlined in red, the boundary of ranches in my broad-scale study are outlined in black, and the orange squares represent my fine-scale study sites.

Sampling methods

Based on this selective criterion, I chose five study sites across Point Reyes. I placed a 25-meter long transect tape parallel to the fence 3 meters away on either side, and I set up 1m^2 quadrats at 0 meters, 5 meters, 10 meters, 15 meters, and 20 meters (Figure 2). I placed a flag down in the corner of the quadrat and the first species the flag hit was recorded. From that point, I counted every new plant within a 10-cm square that extended from this point. I continued to sample new plants encompassed in a 25cm square, 50cm square, and finally a 100cm square quadrat (Buck-Diaz et al. 2011). I sampled a total of 50 quadrats, 25 placed in grazing excluded portions of the park and 25 in grazed portions; equivalent to 5 paired sites across Point Reyes. The nested study design method is beneficial to analyze species abundance, with more abundant species occurring more frequently in smaller areas (Figure 3). I constructed a Species Area Relationship curve to determine the point of saturation for identifying new plant species within a study site. The quadrats were placed like the figure below:



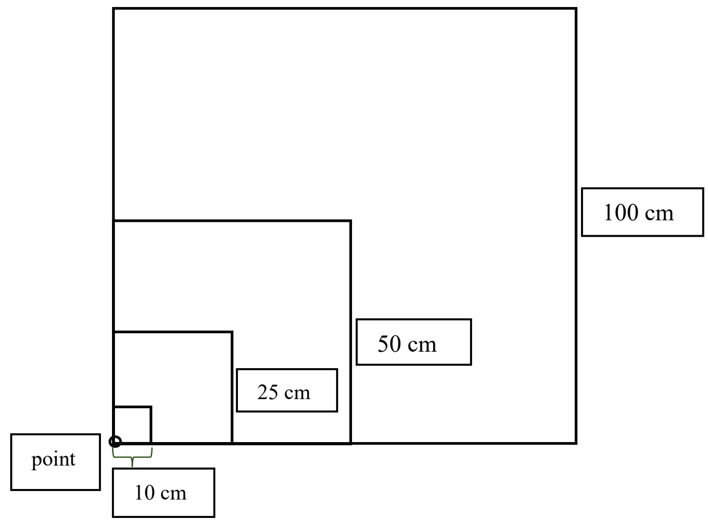


Figure 2: Diagram of site set up

Figure 3: Diagram of quadrat sampling method

Data Analysis

Within grazed and ungrazed sites, I analyzed total species richness, native species richness, and the abundance of two key species I found within my sites. For the species richness and native richness tests, I used a Generalized Linear Model with a Poisson distribution. This model is beneficial for count data, which is generally non-normal and right skewed, such as the data I collected. Consistent with the rules to this statistic model, the variance and mean for these data sets were approximately equal. I calculated the total species richness and native richness by counting the cumulative number of different species found at each grazed and ungrazed sites. I expect a strong correlation between site location and the various factors I study because my sites are distributed across a large area with various climatic factors influencing the results. Thus, I focused specifically on testing for significance of grazing influence on plant species richness and native species richness.

The two key species I identified in my sites were *Stipa pulchra* and *Holcus lanatus*. I selected these two species because they are of interest to the Parks Service and had ideal frequencies to be tested with a Chi Squared test (between 20% and 80% frequency). *Stipa pulchra* is a native perennial grass and was found at a frequency of 54%. Native grasses such as this are beneficial to California grasslands and management techniques that increase this grassland species are preferred. *Holcus lanatus* is an exotic perennial grass and was found at a frequency of 38%. Exotic grasses such as this are of management concern, and management techniques that reduce this grassland species are preferred. I used a Chi Squared test and tested for significance of grazing influence on these key species frequencies.

Broad-Scale Study

Data Collection Methods

Analyzing broad scale vegetation structure across time allows me to gain a more comprehensive understanding of Point Reyes and the relationships between cattle and vegetation change. While the plant community of grasslands help to identify shorter term grassland health, landscape-level information can inform long-term decisions regarding the impact of cattle grazing. To determine changes in broad scale vegetation types over time, I used vegetation classification on Geographic Information Systems ("GIS") (Acre-Nazario 2007, Yu et al. 2006). Maps were created using aerial photos taken from 1942-1943, 1962-1965, and 1994. These maps are a product of the Historic Vegetation Mapping Project between the United States Geological Survey (USGS) and the NPS to georectify (or assign geographic coordinates to) black and white images of Point Reyes for park managers (USGS and NPS 2016). The purpose of this project is to determine if changes in vegetation correspond with the managed of grazed ranches.

I used the mapping protocols from the 1940s, 1960s, and 1990s maps to ensure the maps were comparable over time. (Keeler-Wolf 2003, Keeler-Wolf et al. 2003, Schirokauer et al. 2003, USGS and NPS 2016). I compared vegetation coverage by searching these papers for minimum percent shrub cover to determine the transition from shrub land to grassland (USGS and NPS 2016, Yu et al. 2006). Grasslands are characterized as having less than 15% shrub cover, open scrub/grasslands are characterized as having 15-50% shrub cover, and dense coastal scrublands are characterized as having greater than 50% shrub cover. Shrub cover is the most important distinction to compare, given that most the vegetation on these ranches is grassland and shrubland.

Additionally, I researched historical ranch information to compare and identify any correlations between the historical context of each ranch and vegetation changes over time. I used Dewey Livingston's "Ranching on the Point Reyes Peninsula" to inform my historical analysis (Livingston 1994). Using this resource, I could identify who owned and leased each ranch from the 1850s, if the ranch specialized in dairy or beef, and when ranches transitioned from dairy to beef operations (Livingston 1994). With this information, I could identify how ranching operations have developed over time and how they may coincide with vegetation changes.

Site Selection Methods

To select my sites and determine percent cover of vegetation change, I obtained ranch GIS data from the Bartolome lab at Berkeley to outline ranching boundaries. I compared these ranch boundaries to those in the historic ranch boundary map in Livingston's book (Livingston 1994). I included ranches as study sites if they had similar boundaries across all decades included in my study, from the 1940s to the 1990s. The final ranches included in my study are A through N Ranch, Home Ranch, and Pierce Ranch. Once my managed ranches were selected, I clipped the vegetation data from all three years to each ranch boundary, resulting in 16 separate ranch study sites. I used GIS to calculate the percent cover of each vegetation type within the boundaries. This was done for the 1940s map, 1960s map, and 1994 map.

Data Analysis

Within these ranch boundaries, I analyzed the mean percent cover of grassland, open scrub/grassland, and dense coastal scrub. These vegetation types showed the relationship between grassland and shrub cover, which showed the greatest change over time and is of most interest to the ranches. I expect a strong correlation between ranch location and the various vegetation changes because my sites are distributed across a large area with various climatic factors influencing the results. I ran an ANOVA using a Generalized Additive Model (GAM) to analyze the differences between beef and dairy operations and between 1940s, 1960s, and 1990s data, so I could understand which variable had a stronger effect on vegetation change. The GAM model is beneficial because it does not assume linear relationships between my dependent and independent variables.

RESULTS

Fine-Scale Study

Species Area Relationship Curve

From the nested study design method, I constructed a Species Area Relationship (SAR) curve (Figure 4). This curve starts at the initial sample point for each transect and expands to the last quadrat of each transect, averaged across all sites. The SAR curve for both grazed and ungrazed areas follows a very similar trend, indicating that plant species have similar distributions regardless of cattle presence. The curve also shows that grasslands are well mixed, given that more than half of the species within each site are found in the first meter quadrat.

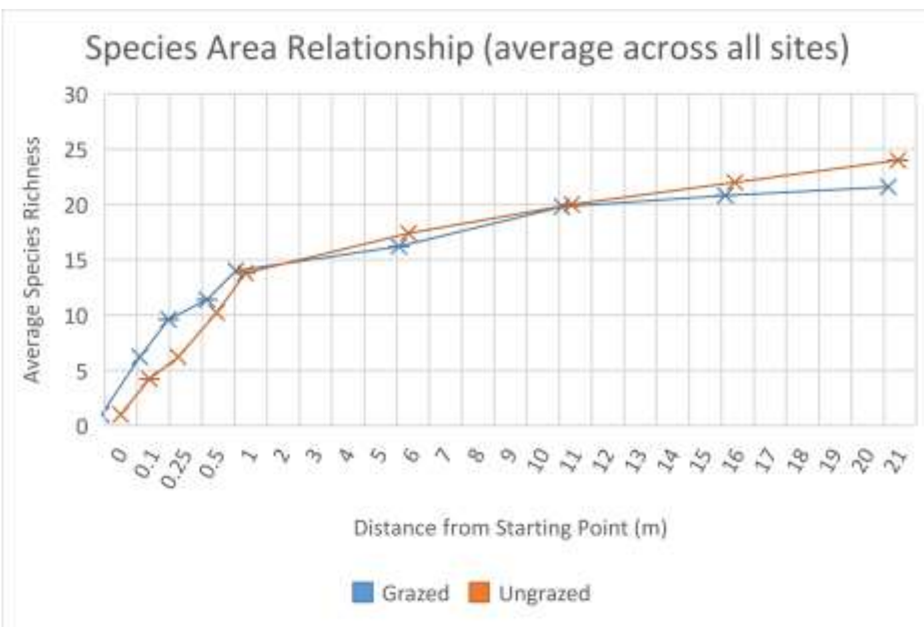


Figure 4:
The average SAR curve of grazed and ungrazed grasslands. Both grazed and ungrazed areas follow a similar SAR curve, indicating that they have similar distribution of species

Species Richness

I analyzed the species richness of plants in grazed and ungrazed grasslands to identify if grazing promotes or prevents plant diversity. Due to the time of data collection, many of my species were not identifiable to the level of genus and species. However, all species were identifiable as unique species. From my five total sites, I found 45 plant species on the grazed sides of the fence and 54 plant species on the ungrazed side. Site 6 had the highest species richness of all grazed (24 species) and ungrazed sites (33 species), and site 3 had the lowest species richness of all grazed (19 species) and ungrazed sites (15 species) (Figure 5). Ungrazed areas have much more variance than grazed areas and a wider spread of plant species results.

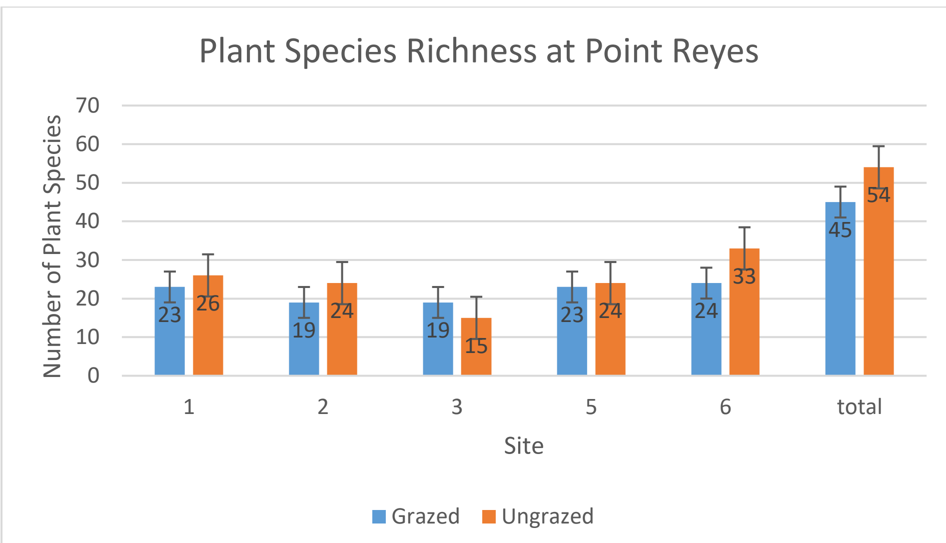


Figure 5: Plant species richness for grazed and ungrazed areas of Point Reyes, showing the total species richness and then broken down by site collected. The error bars represent standard error.

Using a Generalized Linear Model with a Poisson distribution, I found that species richness was not significantly correlated with grazing (P = 0.4112). Grazing does not have a significant impact on plant species richness, but it is interesting to note that grazed quadrats had an average of 13.5 plant species per quadrat while ungrazed quadrates had an average of 12.6 plant species per quadrat (Figure 6). At the quadrat level, there is a general trend for grazed sites to have more species. However, as Figure 5 shows, at the site level there is a general trend for ungrazed sites to have a higher species richness. This may indicate that most of the species that contributed to overall species richness in ungrazed sites were uncommon and not found frequently at the quadrat level.

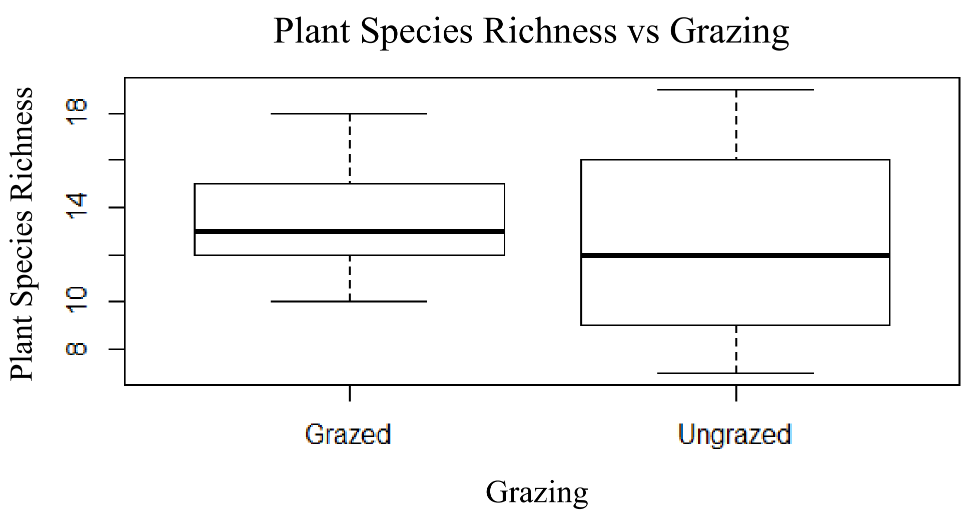


Figure 6: Box plot of plant species richness difference based on grazing

Native Species Richness

I analyzed the native species richness of plants in grazed and ungrazed grasslands to identify if grazing promotes or prevents native plant diversity. From the data collected, 19% of plant species in the grazed areas were native, while 14% of plant species in the ungrazed side were native. However, 24% of plant species on the grazed side and 22% of plants on the ungrazed side were unidentifiable as native or non-native. Not all species were identifiable as native or non-native due to dry conditions at the time of collection. Thus, the significance of this data is likely to be inaccurate, by may show a general trend. Site 6 had the highest native species richness of all grazed (7 species) and ungrazed sites (9 species), and site 3 had the lowest species richness of all grazed (1 species) and ungrazed sites (1 species) (Figure 7).

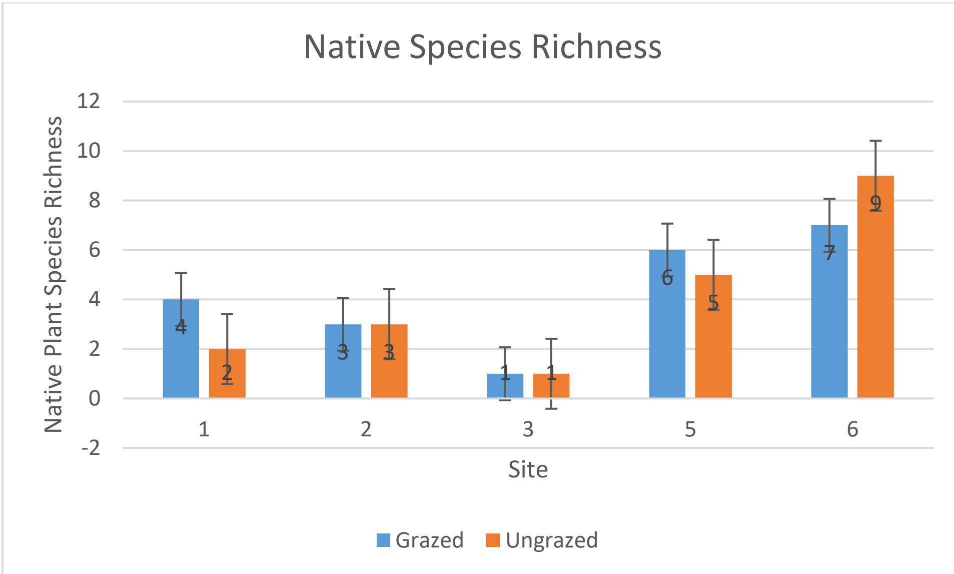


Figure 7: Native Plant species richness for grazed and ungrazed areas of Point Reyes, showing the total species richness and then broken down by site collected. The error bars represent standard error

Using a Generalized Linear Model with a Poisson distribution, I found that species richness was not significantly correlated with grazing (P = 0.06807). While no significant difference was found between grazed and ungrazed sites, there was a nearly significant result of P = 0.06807. In grazed sites, there was an average of 2.56 native plant species per quadrat, and in the ungrazed sites there was an average of 1.8 native plant species per quadrat (Figure 8). Overall, across all sites, 12 unique native species were found in ungrazed sites and 10 unique native species were found in grazed sites, yet there was a greater percentage of natives in the grazed sites versus the ungrazed sites. At a quadrat level, there was a trend of finding more native species in grazed sites. This could indicate that native species are more evenly distributed in grazed sites versus ungrazed sites.

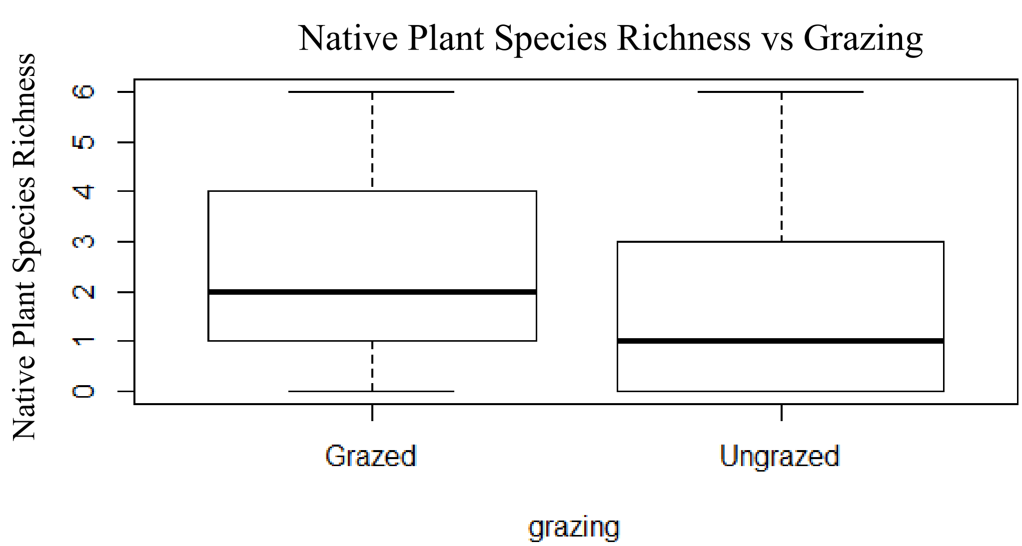


Figure 8: Box plot of native plant species richness difference based on grazing

To better inform Point Reyes management, I also isolated two key species, *Stipa pulchra*, a native grass, and *Holcus lanatus*, an exotic grass, which are of interest to the Parks Service. *Stipa pulchra* was present in 54% of the quadrats. Using a Chi Squared test, I found that *Stipa pulchra* was not significantly correlated, but nearly correlated, with grazing (P = 0.0861). Grazed sites had an average of 0.64 species of *Stipa pulchra* per quadrat while ungrazed sites had an average of 0.44 species of *Stipa pulchra* per quadrat. The NPS should consider that *Stipa pulchra*, a native perennial grass, may favor grazed lands.

Holcus lanatus was present in 38% of the quadrats. Using a Chi Squared test, I found that *Holcus lanatus* was not significantly correlated with grazing (P = 0.1024). Grazed sites had an average of 0.28 species of *Holcus lanatus* per quadrat while ungrazed sites had an average of 0.48 species of *Holcus lanatus* per quadrat. The NPS should consider that *Holcus lanatus*, an exotic perennial grass, may favor ungrazed lands. The frequencies of these two key species should be further studied to expand on these preliminary results.

Broad-Scale Study

Within these ranch boundaries, I analyzed the mean percent cover of grassland, open scrub/grassland, and dense coastal scrub to understand how management type (beef, dairy, or none) and time may influence change in shrubland vegetation. Overall, there was a 45% decrease in grassland and a 33% increase in open scrub/grassland between the 1960s and the 1990s (Figure 9). It is important to understand that management type and time also may be correlated, given that all ranches started as dairy ranches in the 1940s, some transitioned to beef ranches in the 1960s and 1990s, and some were taken out of production in the 1990s (Figure 9). Therefore, I only compared 1960s and 1990s data for the ranch management type to get more accurate results, given that there were no beef ranches in the 1940s. The significance of these results may still be altered because no ranches were taken out of production in the 1940s or 1960s.

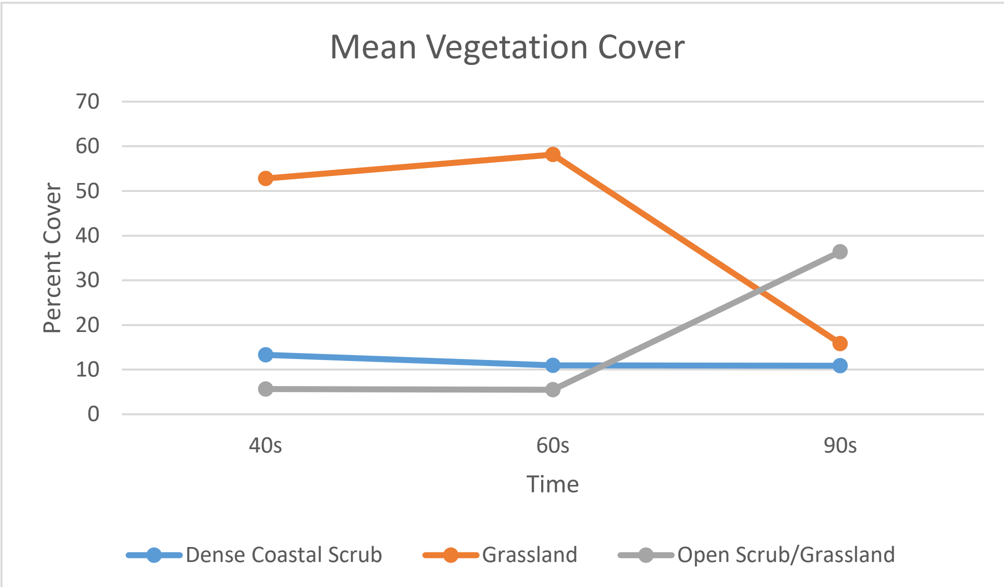


Figure 9: Average vegetation changes in percent cover across all study ranches over time. Only three vegetation types are shown for simplicity. These vegetation types show the greatest percent change and show the relationship between grassland and shrubland

Grassland

Using a Generalized Additive Model, I found that grassland vegetation changes were significantly correlated with management type ($P = 0.02632$) and date ($P < 2.2\times e^{-12}$). While management type was significant (Figure 10), the date seems to be much more strongly associated with vegetation change than management type. In the 1940s, grassland cover was at 56%, in the 1960s it was 62%, and in the 1990s it was 17%. Between the 1960s and the 1990s has the largest change in grassland cover, decreasing by 45% (Figure 11). The date of the maps, rather than management changes at individual ranches, are much more correlated with vegetation change. Because management type has a much weaker correlation, the changes in management at a few individual ranches cannot adequately explain why vegetation changes occur at a broad scale in the 1990s.

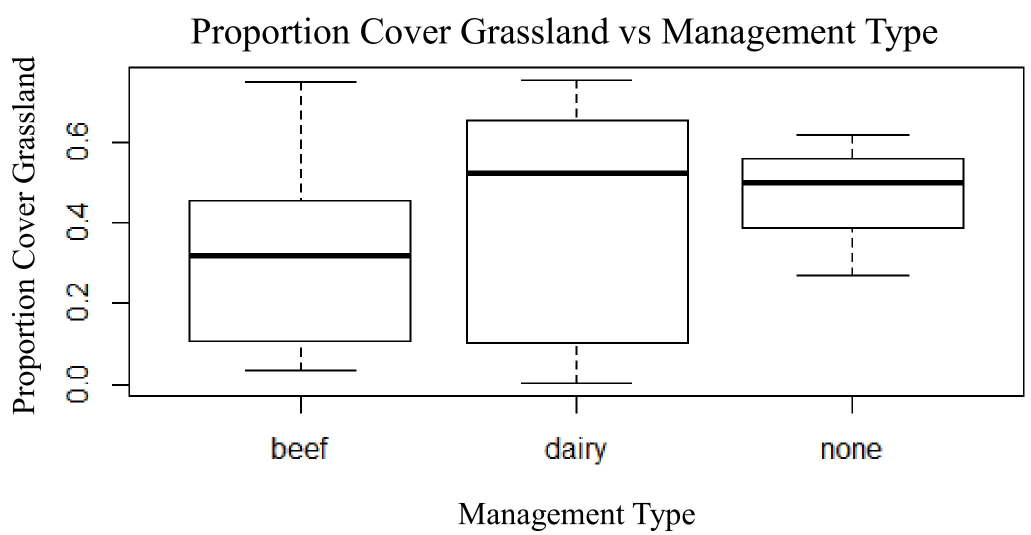


Figure 10: Box plot of proportion cover of grassland based on management type

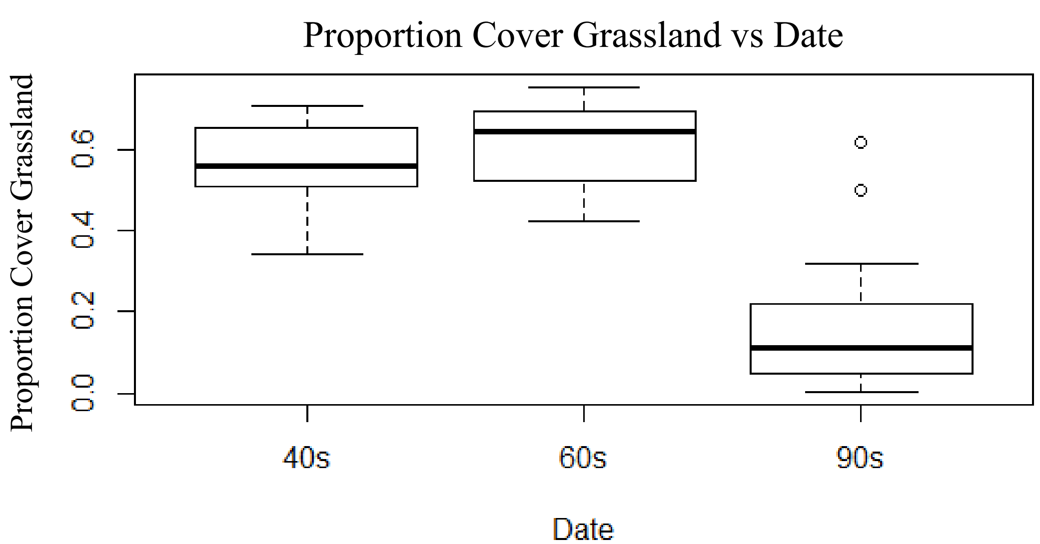


Figure 11: Box plot of proportion cover of grassland based on date

Open Scrub/Grassland

Using a Generalized Additive Model, I found that open scrub/grassland vegetation changes were not significantly correlated with management type (P = 0.3484) (Figure 12). However, open scrub/vegetation changes were significantly correlated with date ($P < 4.85 \times e^{-10}$). In the 1940s, open scrub/grassland cover was at 6%, in the 1960s it was 6%, and in the 1990s it was 39%. Between the 1960s and 1990s had the largest change in open scrub/grassland cover, increasing by 33% (Figure 13). This is consistent with grassland changes, indicating that open scrub/grassland, with moderate shrub cover, may be replacing grassland with sparse shrub cover.

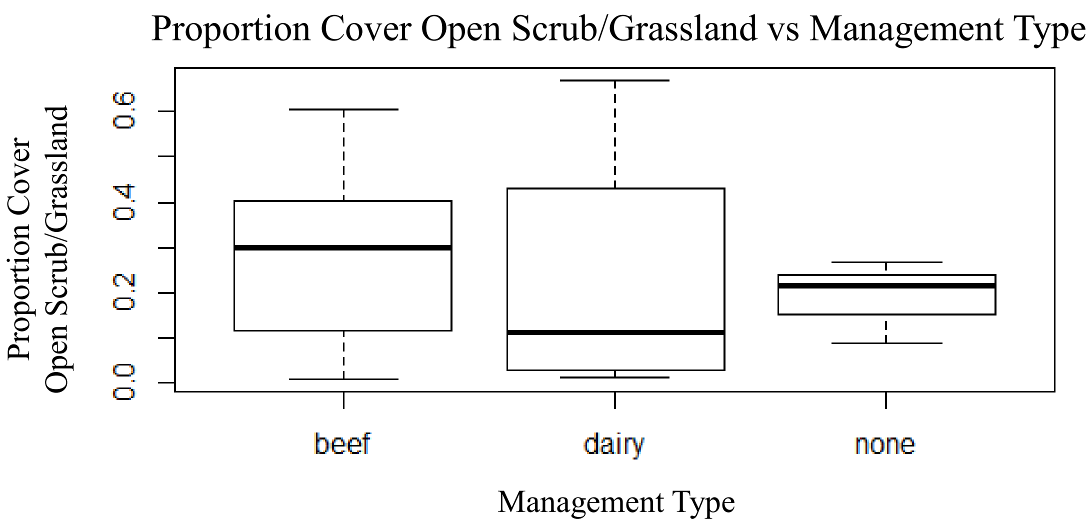


Figure 12: Box plot of proportion cover of open scrub/grassland based on management type

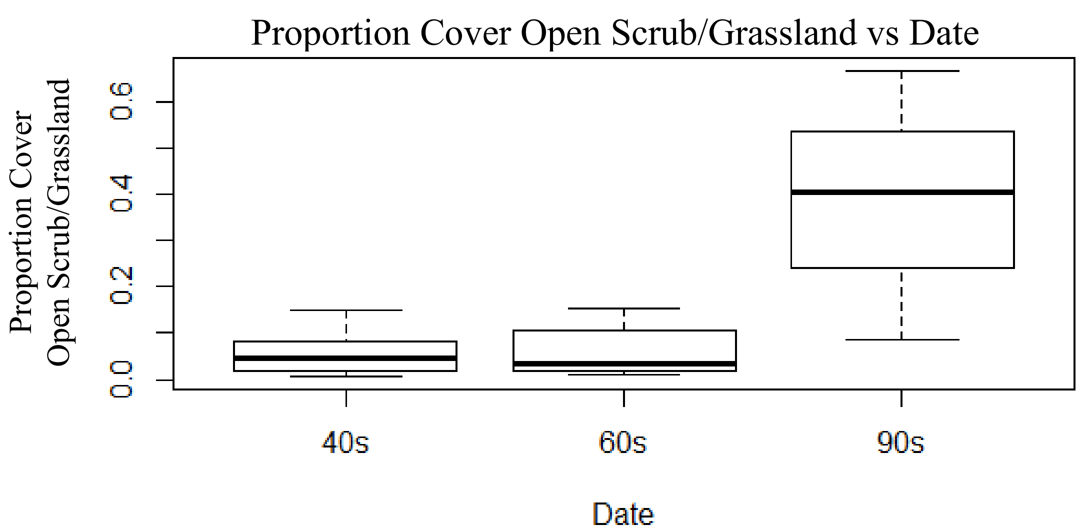


Figure 13: Box plot of proportion cover of open scrub/grassland based on date

Dense Coastal Scrub

Using a Generalized Additive Model, I found that dense coastal scrub vegetation changes were significantly correlated with management type (P = 0.0001631) but not significantly correlated with date (P = 0.1543). In this case, management type was significant. Beef ranches had an average of 9% dense scrub cover, dairy ranches had an average of 11% cover, and ranches with no management had an average of 26% cover (Figure 14). Ranches with no management seem to be more correlated with dense scrub. However, this management type only appeared in the 1990s, so this may be inaccurate to compare. Also, given that dense coastal scrub changes very little over time, this correlation with management type is not reflected at a broad scale. In the 1940s, open scrub/grassland cover was at 14%, in the 1960s it was 12%, and in the 1990s it was 12% (Figure 15). The percent cover of dense coastal scrub is not changing significantly over time in the same way as grassland and open scrub/grassland.

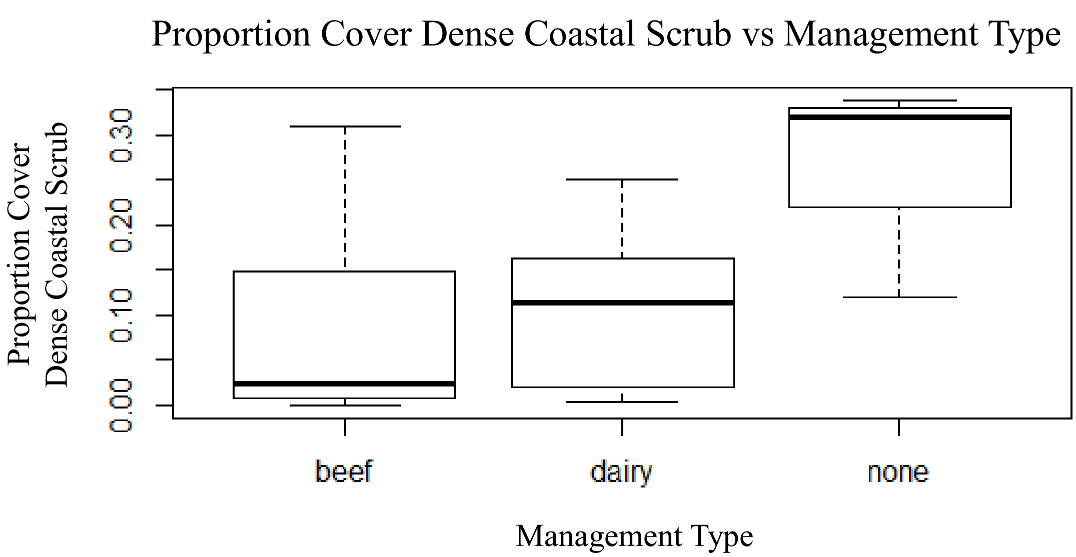


Figure 14: Box plot of proportion cover of dense coastal scrub based on management type

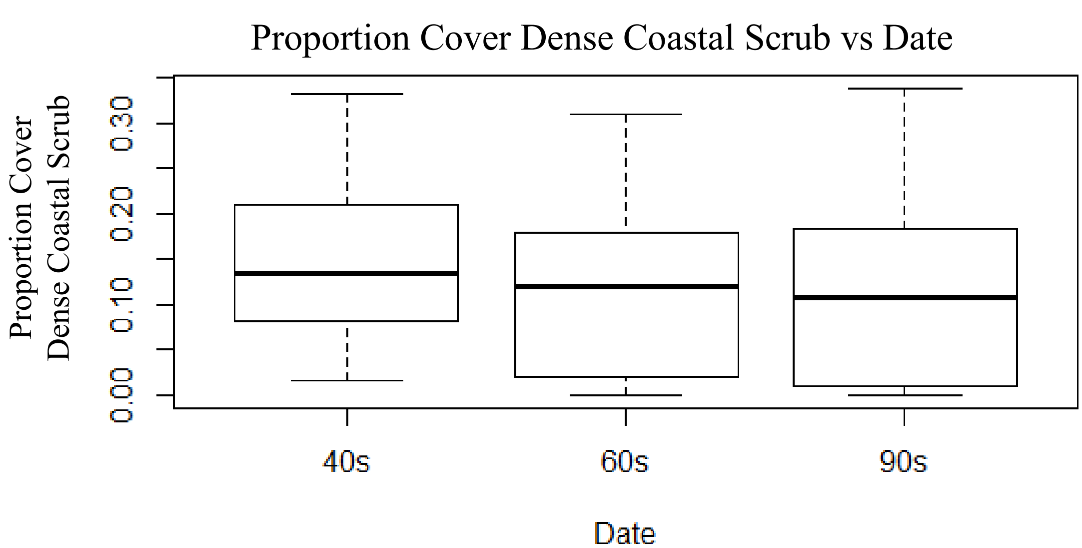


Figure 15: Box plot of proportion cover of dense coastal scrub based on date

DISCUSSION

At a fine-scale, I found that species richness among grazed and ungrazed sites was not significantly different, indicating that grazing does not have a measurable effect on biodiversity protection or degradation at my sites. At a broad-scale, I found that shrub encroachment became widespread between the 1960s and 1990s, which cannot be explained by individual ranch management changes. The rapid expansion of shrubs restricts the amount grazing land available to ranchers and transforms the land from its historic use. Using two spatial scales allows me to more fully understand shifting plant diversity over time across a large protected landscape. Individual plant diversity is important for understanding community structure and richness within grassland communities**.** Vegetation cover and change gives insights into how vegetation communities can shift over time, and how these different communities may support different levels of biodiversity and cultural use. My findings point out the importance of using a historical and multi-scale analysis to understand how the National Parks Service and ranchers might better work together to protect biodiversity and ranching livelihoods.

Fine-Scale Study

I found non-significant differences in species richness between grazed and ungrazed plots, indicating that grazing and ranching does not alter grassland plant communities. However, non-significant trends did emerge. Across sites, there was a slight trend that ungrazed areas had higher species richness. Yet at a quadrat level, grazed areas had a higher average species richness. This indicates that many species found only in ungrazed areas may not be widespread and are found infrequently. Additionally, *Stipa pulchra*, a native plant species, was more likely to be found in grazed areas versus ungrazed areas. A non-native grass, *Holcus lanatus*, which is a key species monitored by Point Reyes, was found at a greater frequency in ungrazed areas, indicating that grazing decreases its presence. These trends are only slight, given that many of the species found were unidentifiable as native or non-natives.

When the NPS bought the land in 1962, widespread grazing restrictions were implemented to protect plant diversity and restrict invasive species growth (Shook 1990). However, from my results, grazing restriction does not significantly impact plant diversity. To view grazing as a source of degradation to plant communities may be an invalid claim, and discontinued grazing has a large effect on the livelihoods of ranchers who forfeit their land or live precariously on renewed leases (Juutinen et al. 2008, Knapp et al. 2015). There are mixed results from scientific studies of grazing impacts on biodiversity (Bokdam and Gleichman 2000, Marty 2005, Schwabe et al. 2013, Deng et al. 2014b, Seifert et al. 2014, Bartolome et al. 2014). Studies which used biomass and plant height as a measure of grassland community health stated that grazing had a negative influence. Other studies acknowledge that shorter plant height could open space for more diverse species to grow. My findings focus on species richness rather than height and biomass, which led to my conclusion that grazing is not harmful or helpful to grassland communities. Without conclusive findings that grazing exclosures are an effective way to protect plant diversity, the restriction of grazing land may be more detrimental to ranchers than beneficial to plant species.

Broad-Scale Study

Grazed land experience an average of 33% shrubland increase in the 30 years between 1965 and 1994; the NPS accumulated the land in 1970, indicating a possible connection between land rights and management and shrub cover. Grazing restriction is also correlated with shrub cover increase (Cipriotti and Aguiar 2012). The expansion of shrub cover in a short period of time can eliminate diverse grassland species and restrict grazing land for cattle ranchers (Cipriotti and Aguiar 2012, Kesting et al. 2015).

While individual ranches switched from dairy to beef operations between 1965 and 1994, the percent increase of shrub encroachment on beef ranches was nearly identical to that of dairy ranches. Although dairy and beef ranchers have different management techniques and graze their cattle for a different number of years, these techniques seem to have little effect on broad-scale vegetation changes. The widespread nature of shrub encroachment at Point Reyes indicates a large-scale change that influenced shrub encroachment. State accumulated land can be negatively perceived by ranchers as threatening to their operations, and short-term leases can impose precarious living situations on a generational operation (Juutinen et al. 2008, Knapp et al. 2015). The NPS takeover of the land and limits placed on traditional ranching may have altered ranch management and led to widespread shrub increase (Mullen 2015).

Synthesis

The trend towards broad-scale shrub encroachment after the NPS took the land and the non-significant changes in plant diversity after 10 years of grazing exclusion indicates that grazing does not greatly impact vegetation community structure and may prevent against shrub growth over a long time period. Grazing was present at Point Reyes for about 160 years, and the land was converted to a national seashore in efforts to protect the biodiversity of the land (Dudley 2013). While the categorization of "National Seashore" is meant to indicate that grazing and biodiversity would be protected, tensions between rangers and ranchers still exist (Phillips and IUCN World Commission on Protected Areas 2002, Juutinen et al. 2008). Some ranching areas were taken out of production entirely because of the NPS, while others switched from dairy to beef ranching at various point in time. In general, ranchers have a lack of trust in state management and feel that imposing restrictions to protect biodiversity threatens their livelihood (Knapp et al. 2015). These findings suggest that rancher operated land can simultaneously protect plant diversity and rancher livelihood, but the relationships between the NPS and the ranchers must be evaluated to ensure that ranchers have adequate access and ownership to the land.

LIMITATIONS AND FUTURE DIRECTIONS

While identifying plant diversity changes from two spatial scales added a helpful layer of analysis to this study, the two components of this research could be expanded upon. For a stronger fine-scale comparison, additional sites could be selected and sampled. While there are currently insignificant differences between grazed and ungrazed sites, expanding the selection of sites could heighten the small differences that were seen. For the broad-scale study, future analysis could expand the time frame of the study into the 21st century with additional mapping efforts. Future studies should focus on bringing this analysis into the 21st century, both by expanding the length of time that exclosure sites are restricted from grazing and to add another time-step to the broad-scale analysis. Additionally, research into the social history of the land should be expanded upon. It would be a useful component to interview ranchers to provide more context to how the land takeover may have altered rancher management practices.

BROADER IMPLICATIONS

The NPS purchase of the land seems to correlate greatly with broad-scale vegetation changes, which brings into question who is best suited to operate land slated for environmental protection**.** Point Reyes was made a Category V National Seashore, meaning that the cultural ranching history of the land should be preserved as an aspect of the park (Phillips and IUCN World Commission on Protected Areas 2002). Yet grazing exclosure practices not only left ranchers landless, but also seemed to correlate with widespread shrub encroachment. Leaving the ranchers in charge of the land as they had been in the past could be more effective at preserving grassland communities and just as effective at promoting plant diversity. This can be achieved by expanding ranching leases from 5 years to a few decades, giving ranchers more ownership over the land.

ACKNOWLEDGEMENTS

Thank you to everyone who helped me write this paper. Patina Mendez, Kurt Spreyer, and John Battles for teaching our class. Dylan Chapple and Abby Cochran for their office hours and paper edits. Eva Malis, Alison Haddad, Alex Goetz, and Reina Carissa for their moral support and peer edits. Janet Lalor and Maddie Lalor for their field work assistance. Felix Ratcliff for his invaluable mentorship and time commitments to my project. James Bartolome and Roxanne Foss for their support from the UC Berkeley Bartolome lab. Dylan Voeller, Benjamin Becker, and Samuel Kraft for their support and for sharing data from Point Reyes National Seashore. To the CNR Travel Grant program for funding my field study. And finally, the Spring 2017 ESPM 175A/B class of outstanding Environmental Scientists for their hard work and moral support.

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