Effects of Artichoke Thistle Management on Grassland Regeneration in Wildcat Canyon Regional Park

Celia M. Rodriguez

ABSTRACT

Artichoke thistle is an invasive weed that can outcompete grassland vegetation species and reduce wildlife mobility by creating dense monocultures. Prior to EBRPD's management, artichoke thistle thrived in Wildcat Canyon and created widespread problems for the ecosystem. This research project seeks to combine historical photographs and follow up surveys to examine the grassland regeneration following the removal of artichoke thistle. Historic photographs aided in identifying three site locations that were once heavily covered in artichoke thistle. Line point transects were used to collect species composition trends. Artichoke thistle image cover decreased 15.95% over all sites surveyed and was no longer detected in present day imagery. Nonnative annual grasses (NNAG) were the most frequent and abundant functional group surveyed at all three sites. A reduction of artichoke thistle patches and a return of NNAG dominance suggests a recovery of grassland function.

KEYWORDS

Long-term management, invasive weeds, public land, rangelands

INTRODUCTION

Rangelands are vital ecosystems that support a variety of economic services and ecological processes. Rangeland ecosystems are characterized by dominant grasses and with varying communities of forbs, shrubs, and widely dispersed trees (EPA 2020). In the United States, rangelands form the largest land cover type, covering an estimated area of 770 million acres (EPA 2020). Unsuitable for agriculture, rangelands are primarily used for livestock grazing (Huntsinger and Oviedo 2014). Ecologically, however, rangelands serve as wildlife habitat and provide ecosystem services including water and air purification (EPA 2020). The Department of Energy has recognized rangelands as viable carbon sink due to their large land cover area in the U.S (Litynski et al. 2006). However, the valuable ecosystem services provided by rangelands are threatened by the introduction of invasive species.

Invasive plants are a global threat and pose many challenges to conversation managers. Introductions of invasive species have significantly increased in magnitude and initiated large-scale environmental, social, and economical shifts (Mooney and Huenneke 2005, Pimental et al. 2005, Van Kleunen et al. 2010). The introduction of an invasive species creates novel interactions, adding high uncertainty and variability to management programs (Maguire, 2004). These novel interactions can culminate in the creation of a novel ecosystem. A novel ecosystem system is defined as a system of native and introduced species living under new environmental conditions and new or altered disturbance regimes (Seastedt et al. 2008). In most ecological settings, simply removing the invasive species from a novel ecosystem does not guarantee successful recovery of the historic species composition (Hobbs et al. 2006). Although complete restoration is not always possible, adaptive and active management can still be used to mitigate the effects that invasive species have on the environment. An excellent example this type of adaptive management can be seen in the control of artichoke thistle in Wildcat Canyon Regional Park

In the Bay Area, the East Bay Regional Park District (EBRPD) has been a model for managing invasive species. Since 1980s, many management practices have been tested to reduce artichoke thistle's population including a combination of mowing, application herbicides, hand pulling, livestock grazing, and seed head removal. The integration of different treatment approaches increases the probability of successful weed management and eventual removal (Buhler et al., 2000, Kettenring and Adams 2011). Removal of artichoke thistle via mechanical treatments like mowing or hand pulling were proven to be ineffective due to artichoke thistle's ability to resprout vigorously from root tissue (Kelly and Pepper 1996). Intensive hand pulling to ensure all the roots are removed causes a great degree of soil disturbance and potentially creates a suitable environment for re-establishment of any artichoke thistle left behind (Marushia and Holt 2008). Labor and costs of these management treatments and the scale of the thistle coverage were also a factor (Brownfield, 1987). Without an approved biological control agent, herbicide application has become the primary mode of removal. Currently, a mix of Garlon (Corteva agriscience, 2020) and Milestone (Dow AgroSciences, 2020) is used to treat artichoke thistle in Wildcat Canyon (Pamela Beitz, *personal communication,)*. This combination of herbicides is also effective at suppressing other species of thistles and other weeds that have the potential to germinate before native grasses. Although mechanical treatments cannot remove artichoke thistle, they can still be used as a preventative treatment. Seed head removal is a mechanical treatment used to limit the amount of seeds that fall into the soil thereby reducing the seed bank over time (Kirby 1989). Seed head removal has similar labor and resource concerns as hand pulling or mowing, but it does not have the same resprouting risks. Through integrating mechanical and chemical treatments, Wildcat Canyon has seen a significant reduction in artichoke thistle. Although the changes are noticeable to the naked eye, data on specific vegetation regeneration has not been studied.

The purpose of my research was to quantify the regeneration patterns of vegetation following the historic removal of artichoke thistle in Wildcat Canyon. My objectives were to i) compare historical coverage of Artichoke Thistle to present coverage in Wildcat Canyon, ii) resurvey sites that were historically heavily covered with artichoke thistle, and iii) examine the vegetation types that have regenerated at those sites. I hypothesized that management of artichoke thistle had been effective at restoring grassland habitat and ecological function within Wildcat Canyon. I predicted a decrease in current artichoke thistle coverage compared to pre-management coverage and an increase in overall site plant species richness.

METHODS

Study Site

I conducted my study in Wildcat Canyon Regional Park. Wildcat Canyon is located in the East Bay hills and extends from Berkeley to Richmond, California. The 2,489-acre park is owned and managed by EBRPD. This region experiences a Mediterranean climate, characterized by wet, cool winters and hot, dry summers. Average annual temperature is 16° C and the region receives and average of 2 inches of rainfall a year with the majority rain events occurring during winter months (NOAA 2020). Rangeland ecotypes present in Wildcat Canyon include oak woodland, California annual grasslands, chaparral, and riparian systems. Livestock grazing is present in the park. Recreation is also an important component to the function and management options in Wildcat Canyon.

Study species

Artichoke thistle (AT), *Cynara cardunculus,* is an invasive plant that is actively invading California's rangelands. Artichoke thistle's preference for disturbed soils, high fecundity, and ability to outcompete native grasses are why the California Invasive Plant Council classify it as CalEPPC A-1 or "highly impactful" (Cal-IPC 2006). The growth form of AT changes the vertical structure of grasslands creating obstacles for wildlife and livestock mobility. AT can reach heights greater than even the largest grazers and is covered in long spines that can injury wildlife and livestock (Kelly and Pepper 1996). High plant fecundity and a high grazing avoidance by livestock and wildlife can allow plant populations to overtake an area, reducing other grasslands species richness (Thomsen et al. 1986, Cal-IPC 2006, White and Holt 2005).

Site locations and photograph comparison

To quantify past artichoke thistle, I analyzed historic aerial photography. Historic photos were on 35mm film taken from a helicopter by Nancy Brownfield, Integrated Pest Specialist at EBRPD. I digitized photographs using a 35mm/IX240 film microscope (Nikon 2001). The oblique angle at which the photographs were taken, limited the type of analysis that could be conducted. Exact percent AT abundance and landscape cover could not be calculated, so pixel analysis provided an estimation.

To be considered for possible site location identification and digitization, the photographs had to meet several criteria:

1. Photographs had to have distinguishing features. This usually included a trail, vegetation patterns, or a note on the film indicting where it was taken.
2. Artichoke thistle coverage had to be in dense patches. I could then assume artichoke thistle cover was 100% as a baseline and then compare it to present-day cover. I also assumed that all vegetation surveyed did not exist prior to treatment.
3. It had to digitize properly. Several photographs when digitized showed signs of deterioration or over-exposure and therefore could not be used.

Once digitized, I began my site location process. In total, I selected 23 photographs for site identification. I grouped photographs that were of the same location together, but at different angles and noted several distinct features. I used Parkvue, the EBRPD's ArcGIS portal, to locate and georeferenced the sites. I identified and located three sites, (Figure 1) shows the site locations in Wildcat Canyon.

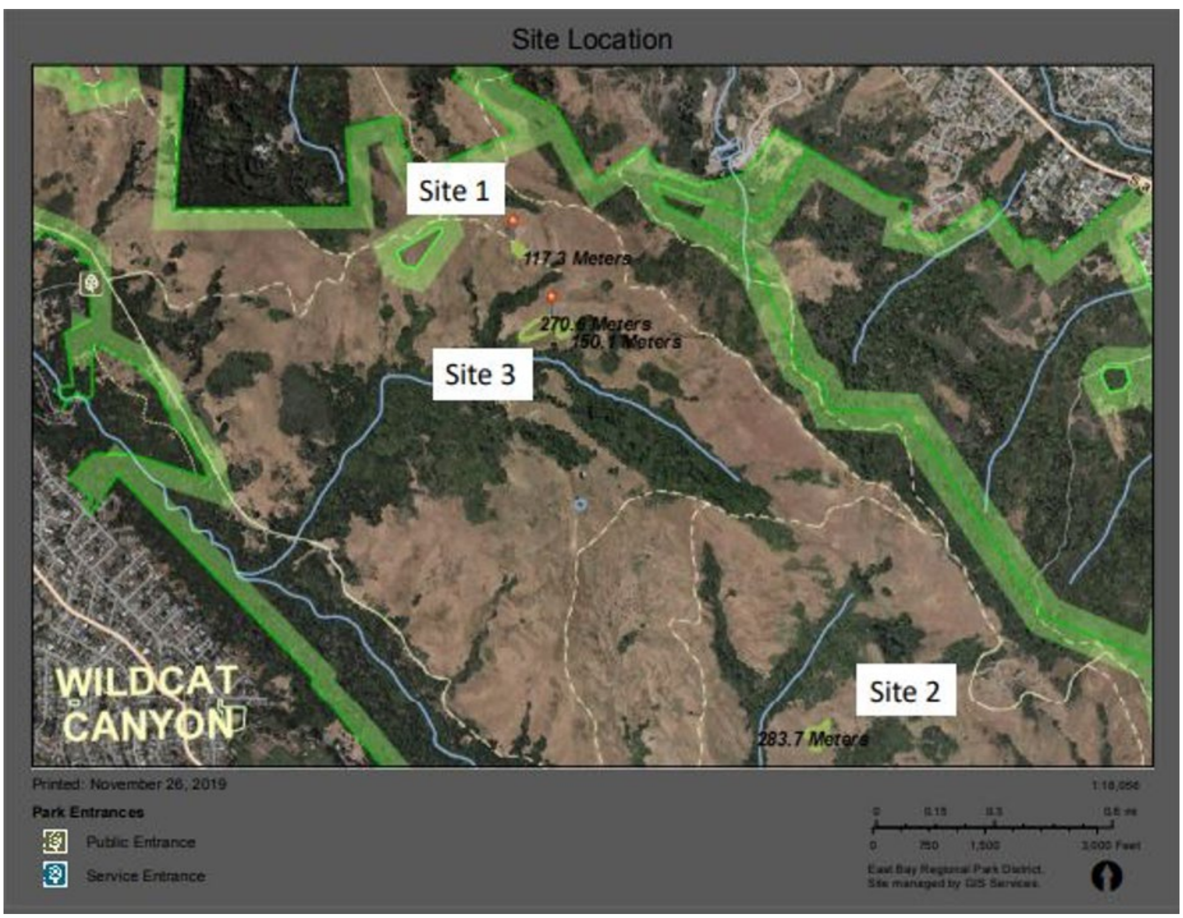

Figure 1: Locations of each size and approximate parameters of each patch.

Image cover

After I located the 3 sites in Parkvue, I conducted a photo pixel analysis to compare the historical coverage of artichoke thistle to present day coverage. I used image cover as a proxy for estimating the coverage of artichoke thistle. Clark and Hardegree (2005) defined image cover as the ratio of the number of pixels of a specific cover type relative to the total number of pixels. I used Adobe Photoshop to trace and isolate the artichoke thistle patches at each site and for each time period (Adobe Creative Cloud Photoshop Team 2020). I used artichoke thistle's silvery foliage color to differentiate it from other vegetation. After I outlined the artichoke thistle polygons, I used the histogram function to determine the number of pixels in each polygon. Then I recorded total pixels and selected patch pixels in excel.

Survey methods

To characterize plant community regeneration, I conducted a vegetation survey at two times during the winter of 2019 and spring of 2020. I conducted a pilot field survey on 12/18/19, with the assistance of EBRPD botanist, Michele Hammond, to establish an early season baseline. I used a 20-meter line transect and randomly generated transect bearings (Kent 2012). I placed 0.5m x 0.5m plot quadrats placed on every other meter mark to measure the presence or absence of artichoke thistle (Higgins et al. 2012, Coiffait-Gombault et al., 2012). Using the same transect, I dropped a pin at every meter and recorded the first object the point touched to measure species relative abundance (Kent 2012). Because winter growth may not represent all species present, I conducted two additional surveys to describe later season growth that was not visible on 12/18/19. I repeated these methods to resurvey Site 1 and site 3 on 05/04/20. On this date, I restricted my data collection and only recorded species abundance. I then created a species list for both sites (see Appendix A and B for species list).

Species identification

I identified plants using a variety of methods. For the initial survey conducted in December, most plants were identified by Michele Hammond of EBRPD. Because early season growth makes species level differentiation challenging, we identified vegetation genus and further categorized plants by functional groups. If definitive species-level identification was possible, we recorded both genus and species. For later surveys, I used the *Field Guide for Common California Rangeland and Pasture Plants* (Forero et al., 2016) and Calflora (Calflora 2020) to identify most of the plants sampled. If I was uncertain about my identification, I took several photographs and verified my identifications with EBRPD staff. I also noted if dead litter, bare ground, and livestock feces were present.

Data analysis

After completing vegetation surveys, I uploaded the vegetation to excel. I organized data based on plant functional groups. I classified plants as: non-native annual grass (NNAG), native grass (NG), non-native perennial forb (NNPF), non-native annual forb (NNAF), artichoke thistle (AT), invasive weed (IW), and non-vegetative material (NVM). I used these categories because they are the most common functional types observed in Wildcat Canyon. If a plant species was listed by the EBRPD as an invasive weed, I classified the species as an invasive weed, instead of its functional group (McKaskey et al. 2017). I did this, to determine if other problem weeds were occupying the space after removing artichoke thistle.

For site 1, I calculated the frequency and relative abundance of each functional group using the equations (Kent, 2011):

a) $$f = \frac{the\ number\ of\ quadrats\ with\ the\ target\ specied}{the\ total\ number\ of\ quadrats}$$

b) $$a = \frac{the\ number\ of\ pin\ hits\ for\ each\ functional\ group}{the\ total\ number\ of\ pin\ hits}.$$

RESULTS

Image Cover

Each site had a decrease in polygon size and showed a complete lack of AT foliage in the present-day images. The historical patch size of artichoke thistle compared to Google Earth satellite images taken in December 2020 shows a complete elimination of large AT patches (Table 1).

Table 1: Patch outlines of the historical coverage of artichoke thistle. Present day images did not have any discernable artichoke thistle patches.

Before Treatment	**After Treatment**
Site 1	**Site 1**
	
Site 2	**Site 2**
	
Site 3	**Site 3**
	

Photographic analysis showed a general decrease in artichoke thistle percent image cover over time with some variation in the magnitude of change. Site 3 had the largest patch size and site 1 had the smallest patch size. Before treatment site 1 had a cover of 3.7%, site 2 had a cover of 5.5%, and site 3 had a cover of 6.7%. After treatment, all sites had no visible large patch that could be detected in the imagery. In total, artichoke thistle image cover decreased 15.92% across all three sites (Figure 2*)*. Similar to patch size results, site 3 had the greatest decrease (-6.7%) and site 1 had the least change in image cover (-3.7%).

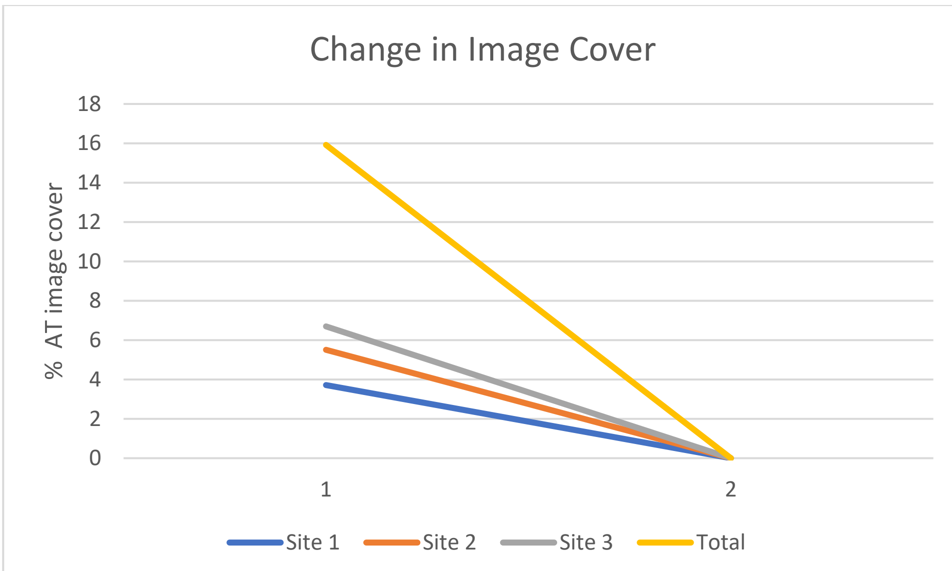

Figure 2. Decrease of artichoke thistle percent cove at all three sites. Site 3 had the greatest decrease in patch size.

Species composition: winter survey

My winter survey had a species composition that was similar to my hypothesis. In the winter survey, nonnative annual grasses had the highest frequency (100%) and abundance (0.85) at both sites surveyed. Nonnative annual forbs were the next dominant functional groups with a frequency of 5.55% (*Figure 3)*. Both Artichoke thistle and native grasses were absent. The one invasive weed found was *Heminthotheca echinioides*; however, the frequency was low compared to the other functional groups.

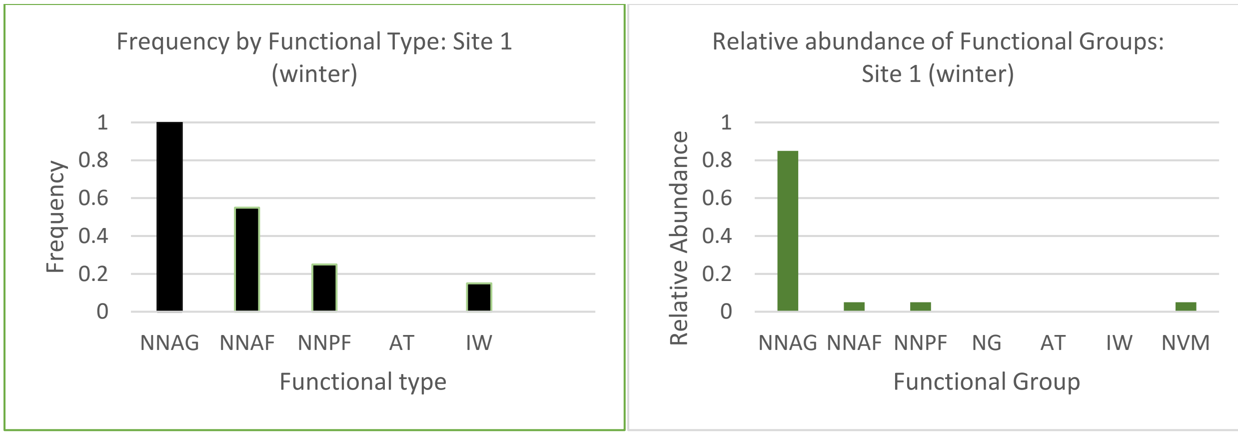

Figure 3: NNAG the greatest frequency and relative abundance for the winter survey of site 1. No artichoke thistle was surveyed. Natives were not present. Organized by functional groups: non-native annual grass (NNAG), native grass (NG), non-native perennial forb (NNPF), non-native annual forb (NNAF), artichoke thistle (AT), invasive weed (IW), and non-vegetative material (NVM).

Species composition: spring surveys

Spring surveys showed a similar dominance of non-native annual grass (NNAG) and lack of artichoke thistle that was observed in the winter survey. Invasive weeds (IW) relative abundance was the same for both sites (0.15). Site 1 had an increase in NNPF, while NNPG and NVM stayed constant when compared to the winter survey. Between the two sites, species composition varied slightly (figure 4). Some common annual grasses found at both sites were *Avena fatua, Carduus pycnocephalus,* and *Helminthotheca echioides* (Appendix 1A and 1B). Cow feces was the most common NVM. It is important to note that site 3 was actively being grazed, despite the fact that no NVM was recorded.

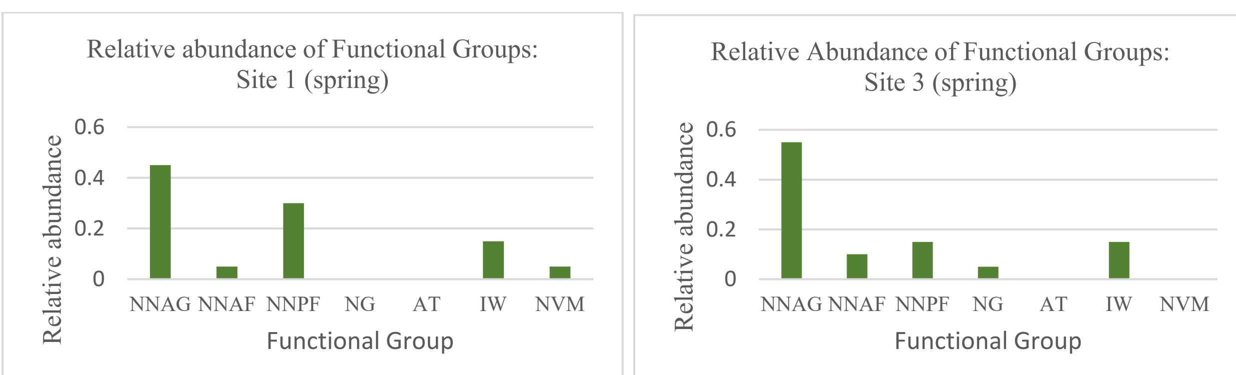

Figure 4: Spring surveys show a dominance of NNAG, however, NNPF increased in site 1 from the winter survey. The relative abundance of IW increased from the winter surveys.

DISCUSSION

Invasive weed management is an important element to maintaining the functionality of California's grasslands. EBRPD's goal to control and eventually eradicate artichoke thistle from Wildcat Canyon has made notable progress since its inception. The results of my study show a regeneration other grassland species that were once crowded out by artichoke thistle. Although this progress shows a positive recovery of grassland following it is important to remember that management of artichoke thistle must continue and monitored.

Decrease in artichoke thistle over time

A complete loss of large dense patches suggests that management has been successful at removing artichoke thistle at every site, but management is still needed to treat isolated populations. Although a specific management technique cannot be definitively tied to the removal of large patches, the accumulation of management techniques has succeeded in reducing artichoke thistle in all of these sites. Kelly and Pepper (1996) saw similar results in their 3-year experiment using herbicide application and seed head removal to remove artichoke thistle from Los Peñasquitos Canyon Preserve in San Diego, CA. The isolated plants posed the greatest threat to progress and were often more difficult to reach due to hidden, remote locations. This is the current situation in Wildcat Canyon. Isolated populations in remote locations or populations on adjacent properties with infestation require continual management until artichoke thistle is completely eradicated. This eradication must be followed by long-term monitoring.

Regeneration and species composition

Without the artichoke thistle covering the study sites, regeneration can and did occur as shown by the high abundance of other functional groups. The lack of native grass species in the species composition was to be expected considering that competitive reseeding did not take place and a dominance of non-native annual grass species is common in California's annual grasslands (Bakker and Berendse 1999, Gornish and Ambrozio dos Santos 2015). The low abundance of NG highlights the limitation of perennial grasses. Native perennial grasses are often limited by low recruitment when they are competing against fast seed producing NNAG (Seabloom et al., 2003). Low recruitment combined with the disturbance of artichoke thistle could have favored NNAG dominance. A low abundance of IW suggests that the current management plan has also effectively controlled other invasive weeds that could have moved in as the artichoke thistle abundance was declining. Using an herbicide mixture that includes Milestone which treats hemlock, thistles, and mustards positively impacted the regeneration of Wildcat Canyon's grassland species.

Management implications

As progress continues to be made in the control of the artichoke thistle population, it is important that management continues to be consistent. This artichoke thistle problem has spanned over several decades and the remaining patches in the park could potentially take another couple of decades to be fully removed from Wildcat Canyon. There is a risk of recolonization if any artichoke thistle is left given its weedy characteristics (Kelly and Pepper 2005, Cal-IPC 2006). The remaining patches of artichoke thistle need to be treated with the same amount of persistence and adaptability as the removed patches. However, even if artichoke thistle is fully removed, monitoring must continue. Artichoke thistle is found across the Bay Area and even in private properties adjacent to the park (C. Rodriguez *personal observation)* so a reintroduction is possible. Continuing monitoring can prevent another, or in general, any colonization of invasive weed.

Exploring different monitoring techniques that mitigate time and cost inputs can decrease the likelihood of a recolonization. Using satellite imagery or accessible citizen science applications can provide more avenues for monitoring and prevent another artichoke thistle problem.

Limitations

My research had several limitations that need to be addressed. First, the oblique angle of the photographs creates a geometric distortion that prevents calculating artichoke thistle cover directly (Lu and Li 2010). However, the image cover definition used standardizes the measurement of comparison. The lack of artichoke thistle in the surveys and species list also support my change image cover results. Secondly, the timing of my surveys greatly influenced the vegetation results and may have overrepresented annual grasses due to their early growing season (Bartolome 1979).

The increase in NNPF from winter to the spring survey shows the importance of properly timing vegetation surveys to target species. Considering artichoke thistle remains in its early season growth a rosette stage until well before I conducted my second survey suggests that timing would not have influenced detecting artichoke thistle.

Future directions

The progress of artichoke thistle control is a successful case study for large scale regeneration programs. Evaluating the process, planning, and resources for this project can provide insight into other invasive weed problems rangelands are facing. Examining effective monitoring techniques for invasive weeds is vital for the next phrase of artichoke thistle management. Looking beyond Wildcat Canyon, incorporating artichoke thistle studies from across the Bay Area would provide valuable information about landscape-level changes and barriers to invasive weed management.

Conclusion

Grassland species can be easily displaced by invasive weeds. Rangelands are at risk of becoming novel ecosystems if nothing is done to control invasive weeds. Wildcat Canyon Regional Park was once on this track due to the extensive artichoke thistle coverage, but it has undergone intensive management in order to prevent shifts in vegetation composition. Through management, artichoke thistle has reduced in coverage and is successfully restoring its grassland features and processes. This successful management shows that regeneration of grassland species is possible and serves as an inspiration to other invasive weed management problems.

ACKNOWLEDGEMENTS

Patina Mendez, Leslie McGinnis, Samuel Evans, and Jessica Heiges were all vital in the completion of this project. I would like to thank Leslie for her encouraging words and dedication over this past year. I would also like to thank East Bay Regional Park staff and my mentor Pamela Beitz for creating a supportive learning environment that strengthened my passion for rangeland ecology and management, Michele Hammond for taking the time to help me with my pilot study field survey, and my editing cohort "Its lit": Melissa Jaffe, Ursula Harwood, and Augustus Clements.

I am thankful for my family, Juan Juarez, Veronica Faure, and Emily Ortiz, for being by my side through this entire journey. Finally, I want to thank my mom, Rebecca Cluff, who molded me into the person I am today and who is always in my heart.

REFERENCES

Adobe Creative Cloud Photoshop Team. 2020. Adobe Photoshop version 21.1.2. Adobe Creative Cloud. San Jose, CA, USA.

Baker, H.G. 1989. Sources of the Naturalized Grasses and Herbs in California Grasslands. Pages 29-38 *in* Mooney, H.A., L.F. Huenneke. 2005. Grassland structure and function: California annual grassland. Kluwer Academic Publishers. AH Dordrecht, The Netherlands.

Bakker J.P. and F. Berendse. 1999. Constrains in the restoration of ecological diversity in grasslands and heathland communities. Trends in Ecology and Evolution 14: 10.1016/S0169-5347(98)01544-4.

Bartolome, J.W. 1970. Germinant and Seedling Establishment in California Annual Grassland. Journal of Ecology 67: 273 – 281.

Beitz, Pamela. 2020. East Bay Regional Park District.

Brownfield, N. 1987. Artichoke Thistle Management in Wildcat Canyon. *East Bay Regional Park District*

Buhler, D.D., M. Liebman, J.J. Obrycki. 2000. Theoretical and practical challenges to an IPM approach to weed management. Weed Science 48.

Cal-IPC [California Invasive Plant Council]. 2006. IPCW Plant Report: *Cynara cardunculus.* Berkeley, CA, USA.

Calflora. DATE. Information on wild California plants. Calflora. <https://www.calflora.org/>

Clark, P.E., S.P. Hardegree. 2005. Quantifying Vegetation Change by Point Sampling Landscape Photography Time Series. Rangeland Ecology and Management 6: 10.2111/04-111R2.1

Coiffait-Gombault, C., E. Buisson, T. Dutoit. 2012. Are old Mediterranean grasslands resilient to human disturbances? Acta Oeoclogica 43: 86-94.

EPA [Environmental Protection Agency]. 2020. Agriculture Pasture, Rangeland, and Grazing. EPA, Washington, D.C., USA.

Forero, L., J. Davy, S. Barry, J. Bartolome, S. Larson. 2016. Field Guide for Common California Rangeland and Pasture Plants. University of California Agriculture and Natural Resources.

Gornish, E.S., P. Ambrozio dos Santos. 2015. Invasive species cover, soil type, and grazing interact to predict long-term grassland restoration success. Restoration Ecology 24.

Higgins, K.F., K.J. Jenkins, G.K. Clambey, D.W. Uresk, D.E. Naugle. 2012. Vegetation Sampling and Measurement. From the SelectedWorks of Robert Klaver: 381-409.

Hobbs, R. J., S. Arico, J. Aronson, J. S. Baron, P. Bridgewater, V. A. Cramer, P. R. Epstein, J. J. Ewel, C. A. Klink, A. E. Lugo, D. Norton, D. Ojima, D. M. Richardson, E. W. Sanderson, F. Valladares, M. Vila, R. Zamora, and M. Zobel. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography 15:1–7.

Huntsinger, Lynn, Jos, and Oviedo. 2014. Ecosystem Services are Social–ecological Services in a Traditional Pastoral System: the Case of California's Mediterranean Rangelands. The Resilience Alliance. http://dx.doi.org/10.5751/ES-06143-190108.

Kent, M. 2012. Vegetation Description and Data Analysis: A practical approach. John Wiley & Sons Ltd. West Sussex, UK.

Kirby, S. 1989. The Feasibility of Managing Artichoke Thistles in Wildcat Canyon. Thesis, University of California, Berkeley, California, USA.

Kittenring, K.M., and C.R. Adams. 2011. Lessons learned from invasive plant control experiments: a systematic review and meta-analysis. Journal of Applied Ecology 48: https://doi.org/10.1111/j.1365-2664.2011.01979.x

Leiva, M.J., F.S. Chapin III, R. F. Ales. 2006. Differences in species compostion and diversity among Mediterranean grasslands with different history – the case of California and Spain. Ecography 20: https://doi.org/10.1111/j.1600-0587.1997.tb00351.x

Litynski, J. T., S. M. Klara, H. G. Mcilvried, and R. D. Srivastava. 2006. The United States Department of Energys Regional Carbon Sequestration Partnerships program: A collaborative approach to carbon management. Environment International 32:128–144.

Lu P., Z. Li. 2010. A method of obtaining ice concentration and floe size from shipboard oblique sea ice images. IEEE 48: 10.1109/TGRS.2010.2042962

Maguire, L. A. 2004. What Can Decision Analysis Do for Invasive Species Management? Risk Analysis 24:859–868.

Marushia, R.G., J.S. Holt. 2008. Reproductive strategy of an invasive thistle: effects of adults on seedling survival. Biological Invasions 10: https://doi.org/10.1007/s10530-008-9234-1

McKaskey, C., C. Brierley, P. Beitz. 2017. East Bay Regional Park District Integrated Pest Mangement: Invasive Weed Identification Guide. EBRPD, Oakland, CA, USA.

Mooney, H.A., L.F. Huenneke. 2005. Grassland structure and function: California annual grassland. Kluwer Academic Publishers. AH Dordrecht, The Netherlands.

Nikon. 2001. Super Coolscan 4000ED (LS-4000 ED) version 3.1.2. Nikon Corporation. Minato City, Tokyo, Japan.

NOAA [National Ocean and Atmospheric Administration. 2020. Average Precipiation and Temperature levels for Richmond, CA. Maryland, USA.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52:273–288.

Seabloom, E., W.S. Harpole, O.J. Reichman, and D. Tilman. 2003. Invasion, competitive dominance, and resource use by exotic and native California grassland species. Proceedings of the National Academy of Sciences 100: 10.1073/pnas.1835728100

Seastedt, T. R., R. J. Hobbs, and K. N. Suding. 2008. Management of novel ecosystems: are novel approaches required? Frontiers in Ecology and the Environment 6:547–553.

Van Kleunen, M., E. Weber, M. Fischer. 2010. A meta-analysis of trait difference between invasive and non-invasive plant species. Ecology Letters 13: https://doi.org/10.1111/j.1461-0248.2009.01418.x

White, V.A. & Holt, J.S. (2005) Competition of artichoke thistle (*Cynara cardunculus*) with native and exotic grassland species. Weed Science, 53, 826–833.

APPENDIX A: Species list for site 1

Table 1A. The species list for site 1 from spring vegetation survey. Most species at the site are annual herbs. *Baccharis pilularis* was the only California native species observed.

SITE 1: SPECIES LIST		
Species	**Duration and Life form**	**Native (Y/N)**
Avena fatua	Annual grass	N
Baccharis pilularis	Shrub	Y
Brassica sp.	Annual herb	N
Brome hordeaceus	Annual grass	N
Brome sp.	Annual grass	N
Carduus pycnocephalus	Annual herb	N
Conium maculatum	Perennial herb	N
Geranium dissectum	Annual herb	N
Helminthotheca echioides	Annual herb	N
Hordeum sp.	Annual grass	N
Lolium multiflorum	Annual grass	N
Medicago polymorpha	Annual herb	N
Rumex acetosella L.	Perennial herb	N
Silybum marianum	Annual herb	N
Vicia sp.	Annual herb	N

APPENDIX B: Species list for site 3

Table 1B. Species list for site 3 from spring survey. Functional groups are distributed evenly amongst the species recorded. *Stipa pulchra* and *californica* are two natives found. Site 3 had a higher species count compared to site 1.

SITE 3: SPECIES LIST		
Species	**Duration and Life Form**	**Native (Y/N)**
Avena fatua	Annual grass	N
Bellardia trxago	Annual herb	N
Brassica sp.	Annual herb	N
Brome hordeaceus	Annual grass	N
Brome sp.	Annual grass	N
Carduus pycnocephalus	Annual herb	N
Circium vulgare	Perennial herb	N
Danthonia californica	Perennial grass	Y
Geranium dissectum	Annual herb	N
Helminthotheca echioides	Annual herb	N
Hordeum sp.	Annual grass	N
Lolium multiflorum	Annual grass	N
Lotus corniculatus	Perennial herb	N
Plantago lanceolata	Perennial herb	N
Rumex acetosella L.	Perennial herb	N
Stipa pulchra	Perennial grass	Y
Trifolium hirtum	Annual herb	N
Vicia sp.	Annual herb	N

APPENDIX C: Site 1 Photographs

Appendix C: Site photograph for site 1. Taken on 05/04/2020 at the western edge of the historical polygon. The artichoke thistle patch has since been replaced with non-native grasses.

APPENDIX D: Site 3 photograph

Appendix D: Site photograph for site 3. Taken 05/04/2020 at the southern edge of the historical polygon. There was no artichoke thistle present.