Spring 2023

Prevalence of Hesperevax sparsiflora var. brevifolia (short-leaved evax) at Ocean Ranch, Humboldt County, California: exploring the effects of disturbance

Shelby DiQuirco
Humboldt State University, sld27@humboldt.edu

Matthew Estrada
Humboldt State University, me134@humboldt.edu

Alana T. Fraley
Humboldt State University, atf24@humboldt.edu

Alexander D. Smith
Humboldt State University, ads115@humboldt.edu

PREVALENCE OF *HESPEREVAX SPARSIFLORA* VAR. *BREVIFOLIA* (SHORT-LEAVED EVAX) AT OCEAN RANCH, HUMBOLDT COUNTY, CALIFORNIA: EXPLORING THE EFFECTS OF DISTURBANCE

Shelby DiQuirico, Matthew Estrada, Alana Fraley, Alex Smith

Hesperevax sparsiflora var. *brevifolia* at Ocean Ranch, CA. Photo by Alana Fraley (2023).

Ecological Restoration Capstone (ESM 455)

Department of Environmental Science & Management

California State Polytechnic University Humboldt

May 2023

Table of Contents

1. ABSTRACT

The prevalence of special-status plants within a landscape can be an indicator of the ecological health of that site, and therefore inform restoration efforts and post-restoration monitoring. *Hesperevax sparsiflora* var. *brevifolia* (short-leaved evax) is a special status species found within the Ocean Ranch unit of Humboldt, California. A primary threat to native plant communities are invasive plant species. Coastal dune ecosystems are largely dominated by invasive species, including *Ammophila arenaria* (European beachgrass). To work towards the eradication of *A. arenaria*, the California Department of Fish and Wildlife utilized treatment combinations of herbicide and prescribed fire at Ocean Ranch in the fall of 2022. We worked with the California Department of Fish and Wildlife (CDFW) to study the density and abundance of *H. sparsiflora* var. *brevifolia*, proximity to *A. arenaria*, soil compaction, and distance to the road within specified areas. We estimated a total of 14,354,293 *H. sparsiflora* var. *brevifolia* individuals in the polygons we measured. We found that the further from *A. arenaria*, the greater the likelihood of *H. sparsiflora* var. *brevifolia* individuals. However, our findings showed that the number of individuals and distance to the road was not a significant relationship, and the relationship between the number of individuals in burned versus unburned quadrats was not significant. This project can serve to monitor the establishment of special-status species to observe the success of recent restorative treatments and to guide future restoration.

2. INTRODUCTION

2.1 Special-Status Plants and Restoration

The prevalence of special-status plants within a landscape can be an indicator of the ecological health of that site, and therefore inform restoration efforts and post-restoration monitoring. Due to the effects of climate change, ecological restoration becomes of greater importance as ecosystems with native plant composition and proper ecological functions in place are more resilient to the impacts of climatic shifts (Simonson et al., 2021). One way to measure the effectiveness of restoration efforts is to evaluate the prevalence of native, special-status, endangered, or threatened species prior to and following restoration (Wilkins et al., 2003).

A primary threat to native plant communities are invasive plant species. Invasives are believed to be one of the main causes of biodiversity loss, disrupting ecosystems across the world (Weidlich et al., 2020). Coastal dune ecosystems are considered to be vulnerable ecosystems and should have high priority status for restoration according to the International Union for Conservation of Nature (Marchante et al., 2011). The coastal dune ecosystems of Humboldt County, California are largely dominated by invasive species, including *Ammophila arenaria* (European beachgrass) (Pickart et al., 1998).

2.2 Restoration Goals: Ocean Ranch

One of the main goals of California Department of Fish and Wildlife's Ocean Ranch Unit in Humboldt County, California is to restore the natural dune community and its ecological processes, and to improve the habitat for native, state and federally listed, and special-status species (GHD, 2021). Most of the Ocean Ranch area was historically estuarine salt marsh (J.

Ray, pers. comm., 2023). Between 1916 and 1946, the site and surrounding area was converted from the native saltmarsh; it was diked and drained for agricultural use as pastures (GHD, 2021). As a result, tidal salt waters no longer inundated land that was previously in the tidal reach (GHD, 2021). Land use and the increased population growth of non-native species, including *Spartina densiflora* (dense-flowered cordgrass) and *A. arenaria*, led to an increased need for restoration on this site (J. Ray, pers. comm., 2023). The dunes restoration methods at Ocean Ranch focus on the eradication of *A. arenaria* through treatment combinations of herbicide and prescribed fire (Figure 1) (J. Ray, pers. comm., 2023). Monitoring the establishment of special-status species is one of the methods being employed to measure the success of these treatments.

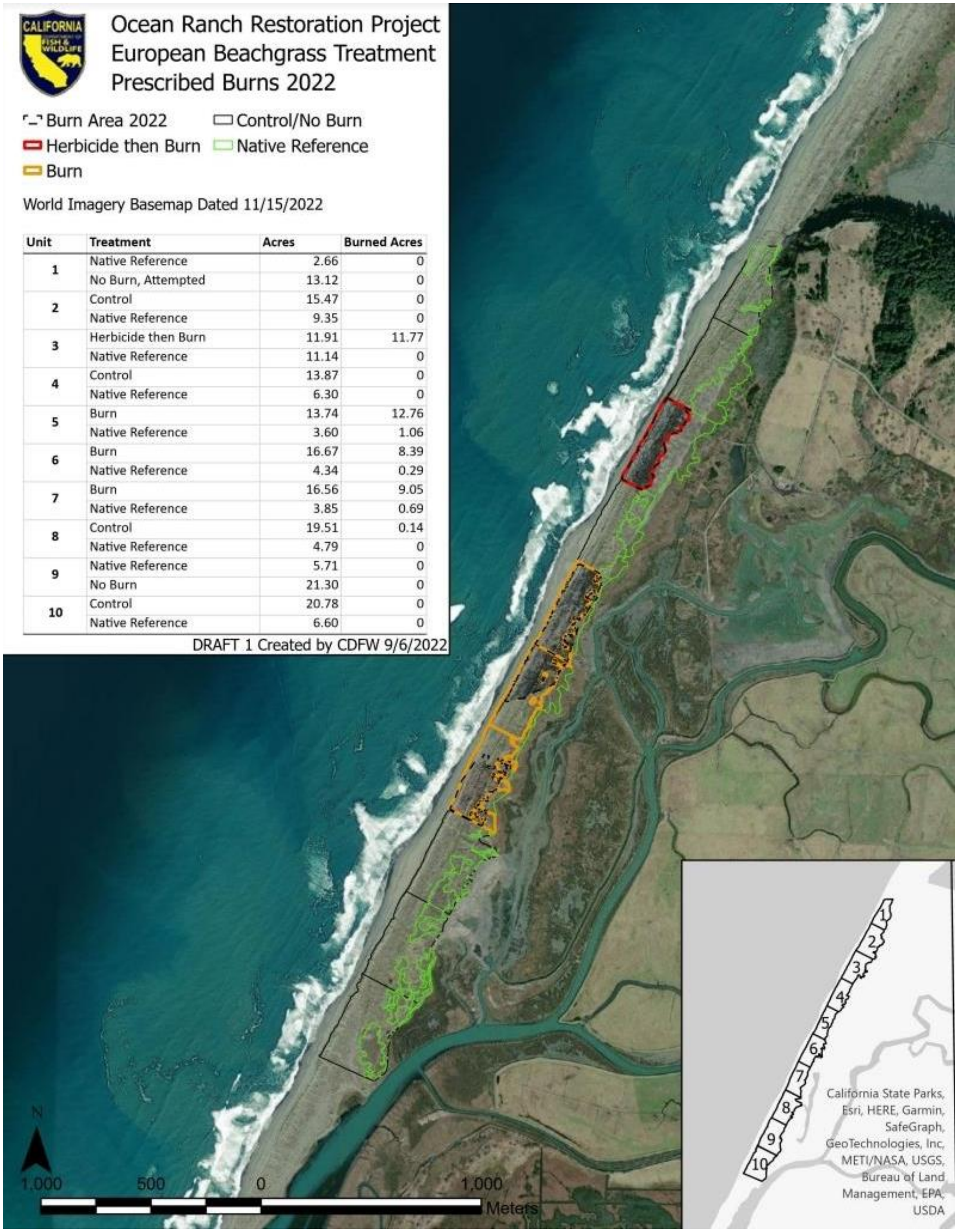

Figure 1. Ocean Ranch treated polygons. Burned, unburned, burned and herbicides added (source: CDFW).

Hesperevax sparsilfora var. *brevifolia* (short-leaved evax) has a rarity status of 1B, meaning that the species is rare throughout its range; most species within this ranking have declined significantly over the past century (Pacific Coast Fish, Wildlife and Wetlands Restoration Association, 2018). *Hesperevax sparsiflora* var. *brevifolia* is found within the Ocean Ranch area, occurring within approximately 26 acres of the site (Eicher et al., 2018). Short-leaved evax is a caulescent, green plant with obovate to orbicular shaped leaves, and is a special-status plant found in the sandy bluffs and immediate coast in northwestern California and southwestern Oregon (Morefield, 1992).

The first objective of this study is to estimate the density and abundance of *H. sparsiflora* var. *brevifolia* at Ocean Ranch following the application of the herbicide Imazapyr and prescribed burns in the fall 2022 season. Another study objective is to measure physical variables associated with the prevalence of *H. sparsiflora* var. *brevifolia*: 1) proximity to *A. arenaria*, 2) soil compaction, and 3) distance to road, to guide future restoration and conservation efforts related to this species. This study is intended to compare pre-treatment special-status species populations to the current, or post-treatment populations. This study will also allow us to test our hypothesis that the density and abundance of *H. sparsiflora* var. *brevifolia* will be greater in compacted areas near the road, further from *A. arenaria,* and in areas that were treated with herbicide and prescribed fire in the fall of 2022.

3. METHODS

3.1 Study Area

The Ocean Ranch Unit is approximately 933 acres in size and is located within Humboldt County, California, north of the mouth of the Eel River (GHD, 2021) (*Figure 2*). The unit is located at latitude 40.6923487, longitude -124.2736717, to the west is the Pacific Ocean, to the north is Table Bluff, to the east is McNulty Slough (*Figure 2*) (GHD, 2021). The whole unit was acquired by CDFW in 1986, and restoration activities began in 1991 with the removal of grazing activities on the land (GHD, 2021). Restoration on site included a 1994 levee breach that resulted in a return to saltmarsh in some areas, sediment excavation and slope management beginning in 2015, the 2021 fish relocation and dewatering, various methods for invasive removal (including chemical and mechanical) and various maintenance and monitoring plans (Loomis, 2021; GHD, 2021).The Ocean Ranch Unit is located on Wiyot ancestral land, historically the land supported around 2000 inhabitants and after a tumultuous history of dispossession and limited access much of that ancestral land is now co-managed by the tribe and owned by private owners (Erikson et al., 2022). The USDA Web Soil Survey determined the area to be made up of two main soil types: Samoa-Clambeach complex soils, which make up the dunes, and Oxyaquic Udipsamments-Samoa complex (USDA, 2018). All data were collected by the authors on March 21st and 29th of 2023.

Figure 2: Ocean Ranch Unit and study area location in northwestern California (inset map) and relative to South Humboldt Bay (source: PCFWWRA).

Our study area is not the entirety of the Ocean Ranch Unit, rather we studied areas with the presence of invasive *A. arenaria*, compaction, and various restoration efforts (K. McDonald, pers. comm., 2023). Portions of our study areas were recently treated with either a combination of herbicide and prescribed burning, or prescribed fire only by CDFW in cooperation with Cal Fire applied October 2022 (GHD, 2021; K. McDonald, pers. comm., 2023). The treatment had varying effects, a few years after the treatment areas returned to being invaded by *A. arenaria* to different degrees; this is largely impacted by the proximity to untreated areas (K. McDonald, pers. comm., 2023). Our community partner Kelsey McDonald, an Environmental Scientist at the California Department of Fish and Wildlife (CDFW), provided polygons representing the areas of interest on the site (*Figure 3*).

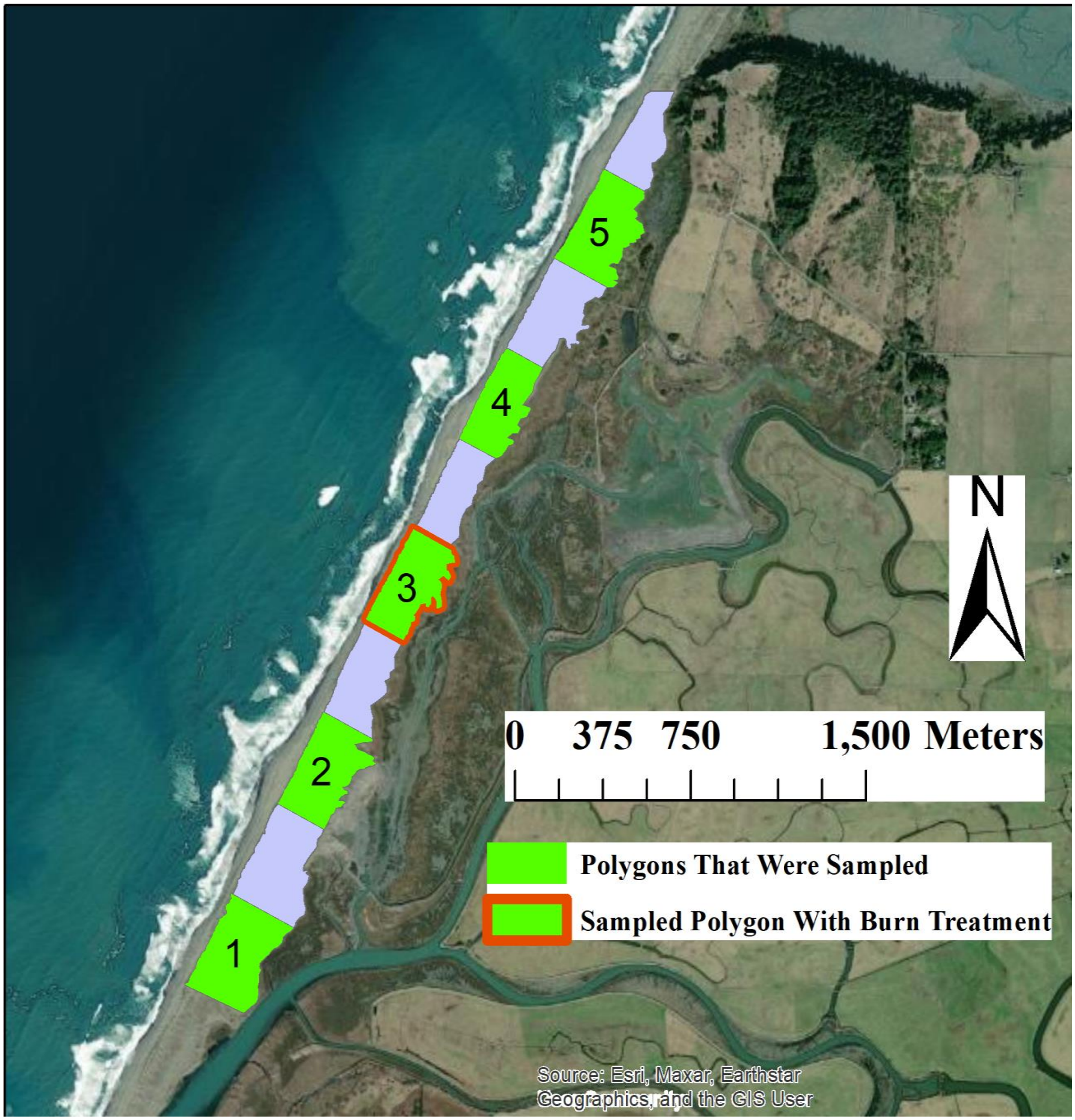

Figure 3: Map showing polygons sampled within the Ocean Ranch Unit (green). Our study area consisted of every other polygon beginning with the southernmost polygon (1-5). Polygon 3 with the red outline indicates a prescribed burn treatment (source: K. McDonald, pers. comm., 2023). Map made by Matt Estrada using ArcMap version 10.8.1.

3.2 Site Preparation and Species Data Collection's

We began our data collection by preparing our tools and technology. We used a ¼ m^2 quadrat, 50 meter foresters tape, various flags, and our smartphones or iPads for data collection in the field. To begin with, we prepared maps using the phone application ArcGIS Field Maps (version 23.1.0) with the provided polygons. On site, we used an Excel sheet to record information within our quadrats, accessed on our mobile phones.

Our first day of data collection was performed on March 22, 2023, all data obtained at Ocean Ranch were collected using the same method. In the field we began with the southernmost polygon (Polygon 1 in *Figure 3*), and collected data in every other polygon (1-5). In each polygon we placed a flag at the southeastern end of the polygon, along the road. We then used a random number generator to generate a number between 1 and 100 to determine the starting location for our first transect (*Figure 4*). Transects were placed every 50 meters along the road *(Figure 4*).

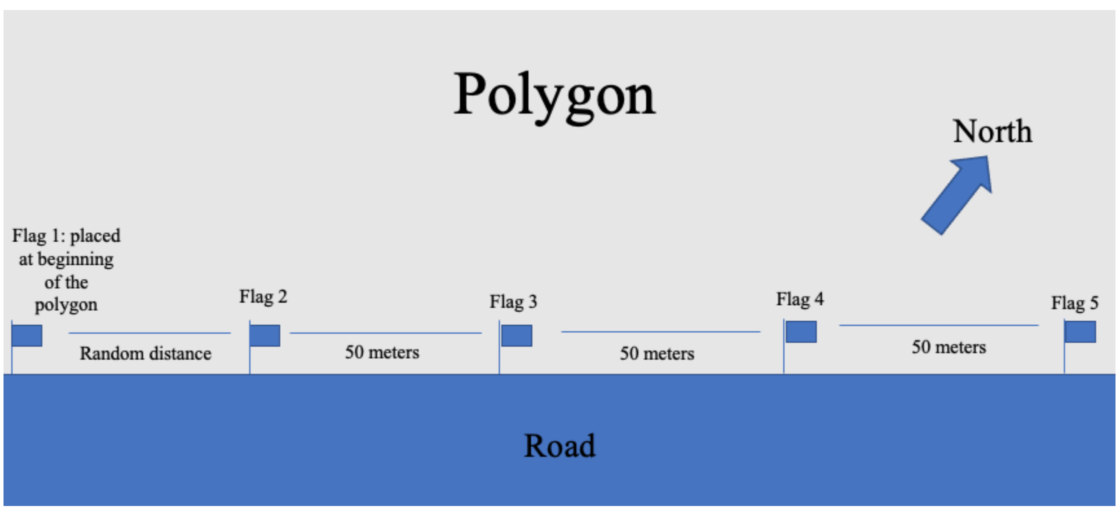

Figure 4: Schematic of how we placed our flags for our transect, the view is from above looking (from the road) roughly to the northwest (towards the ocean) (Figure by Shelby DiQuirico, 2023).

Forty-meter long transects were laid in an east-west (towards the ocean) perpendicular to the road at each of the five starting locations (*Figure 4*). Quadrats were placed every 10 meters along each transect *(Figure 5*). The location of each quadrat was recorded using a handheld GPS unit. At each quadrat the, distance to the road, transect #, transect distance, number of *Hesperevax sparsiflora* var. *brevifolia*, comments on compaction and burn status, and other notes were recorded. We then separated into two groups of two individuals and each collected data from two more polygons each (total of five polygons). We collected data in twenty quadrats in each polygon (*Figure 5)*, resulting in a total of 100 quadrats total.

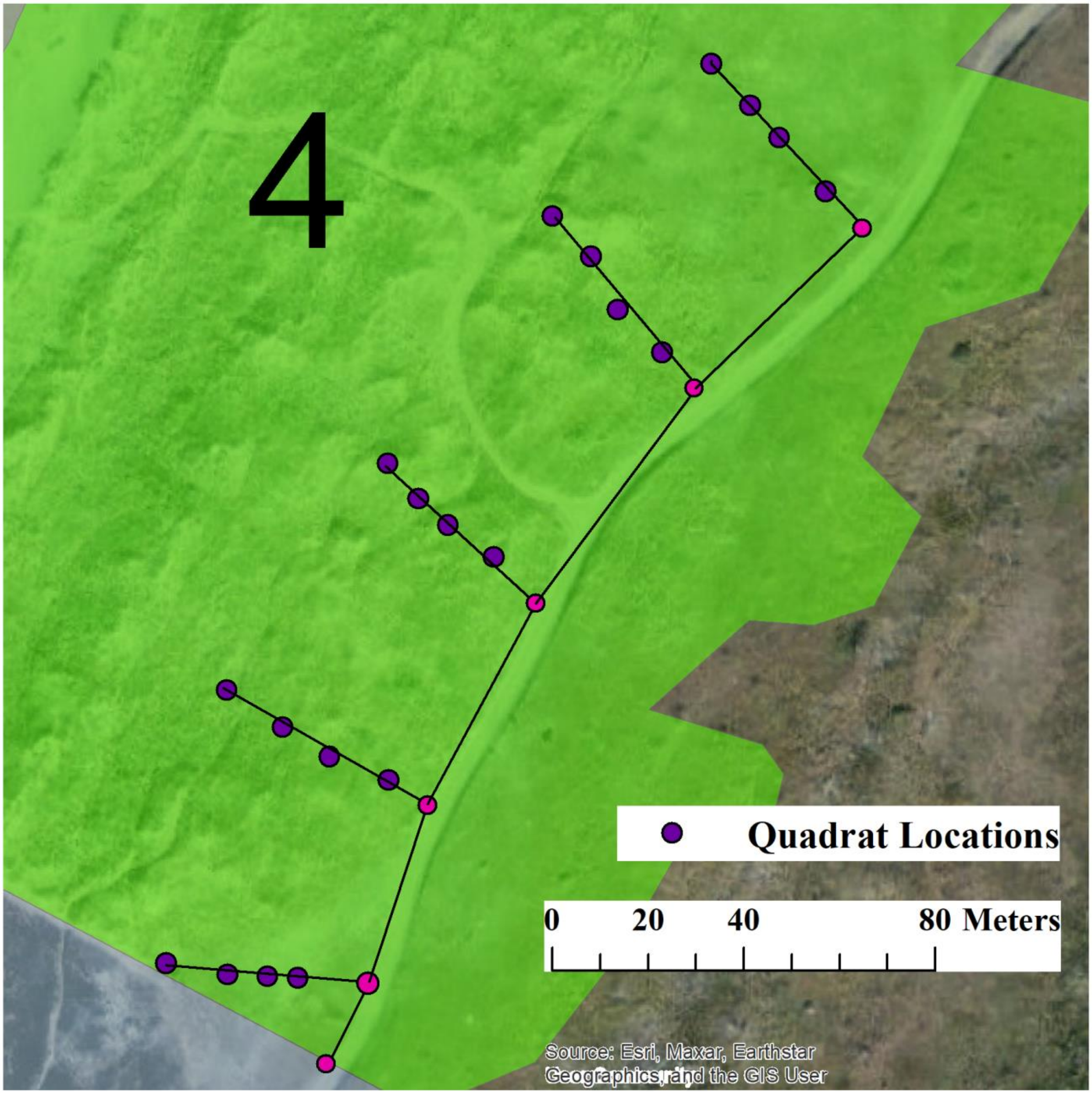

Figure 5. Example of transect layout within a polygon. In polygon four, the twenty quadrat, locations are indicated by purple circles. The other four polygons had similar transect patterns, with the only difference being the initial random measurement from the southeast corner of the polygon. Map made by Matt Estrada using ArcMap version 10.8.1.

3.3 Disturbance Data Collection

The remainder of our data were collected on March 29th, 2023, this day was focusing on the variables of compaction and distance to invasives. We collected data within polygon three, the center polygon (*Figure 3*). We began by laying out the same transect lines from our first field day, and comparing this with our georeferenced maps on our phone to ensure accuracy. We then determined the presence or absence of compaction by using visual cues (e.g., tire tracks and commonly used pathways), physical cues (e.g., determining soil density by touch using the pointer finger and thumb on dominant hand), and looking at nearby vegetation (e.g., looking for tampering, or species we knew to be sensitive to compaction). The data collected was in a yes compaction is present, or no compaction is not present format and we made this determination on the west side of the tape at each increment. Following this, we measured the distance (meters) from each quadrat to the nearest *A. arenaria* individual, measuring directly from the 10m, 20m, 30m, and 40m mark (*Figure 6)* and recorded this information into our excel sheet.

4. RESULTS

The density of *H. sparsiflora* var. *brevifolia* found within each polygon (*Figure 6)* varied with the smallest value being 0, and the largest being 80.2 individuals per square meter (*Table 1*). The total estimated population of *H. sparsiflora* var. *brevifolia* within the five sampled polygons is approximately 14,354,293 individuals (*Table 1).*

Table 1: Hesperevax sparsiflora var. *brevifolia* density per square meter and the total density per polygon were measured in March of 2023 at Ocean Ranch Unit (Humboldt County, CA). Refer to *Figure 5* for orientation and relative locations of polygons 1-5.

Polygon	***H. sparsiflora* var. *brevifolia* Density per square-meter**	**Total Area of Polygon (square-meters)**	**Total Individuals of *H. sparsiflora* var. *brevifolia* per Polygon**
1	41.4	110,803	4,587,245
2	2	98,338.61	196,677.2
3	6.4	85,064.92	544,415.5
4	0	81,625.09	0
5	80.2	112,543.1	9,025,955

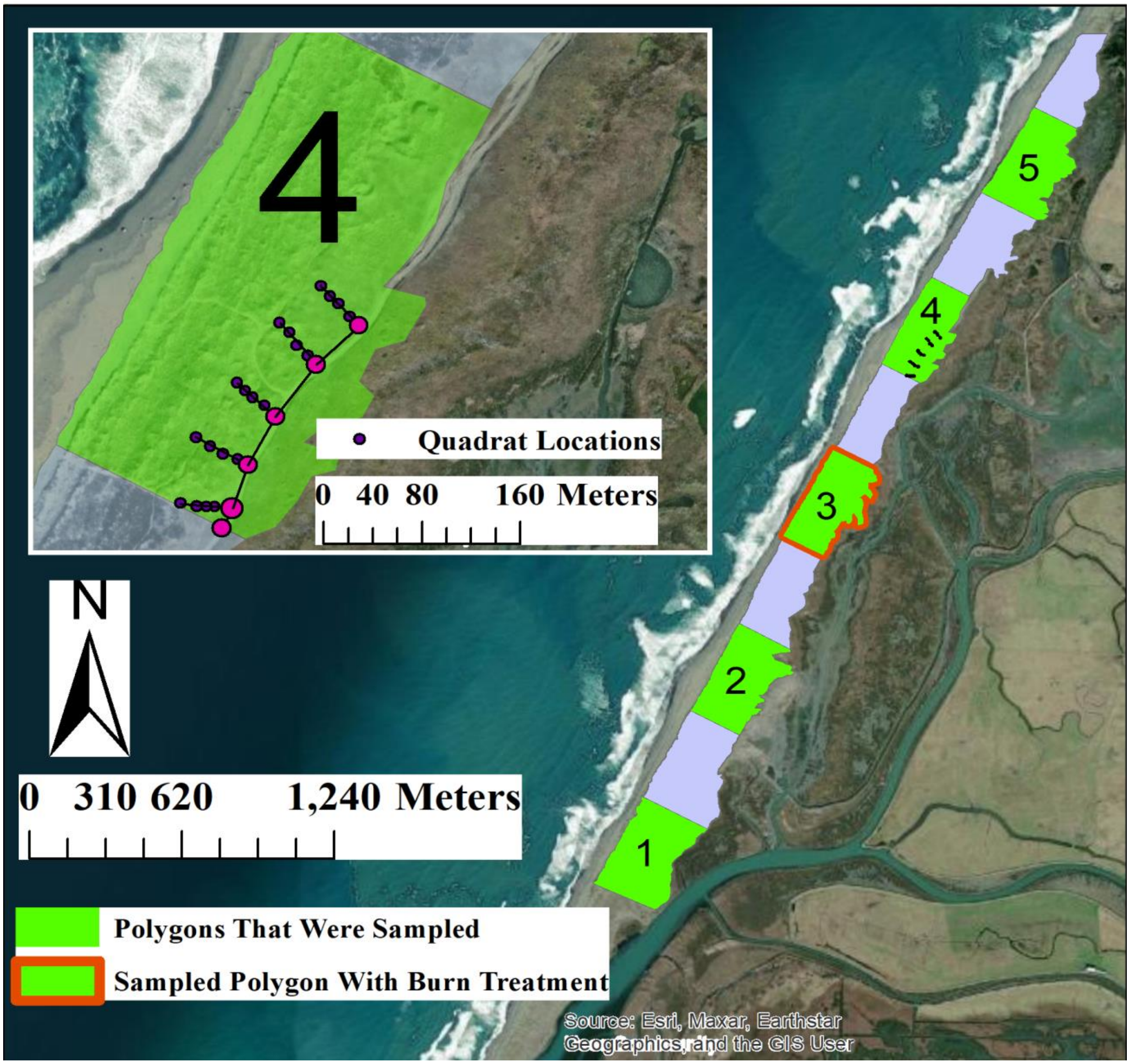

Figure 6: Map showing the total site and inset showing transects and quadrat locations. Map made by Matt Estrada using ArcMap version 10.8.1.

The relationship between the number of *H. sparsiflora* var. *brevifolia* individuals and distance to *A. arenaria* was found to be significant ($p < 0.01$) (*Figure 7*). The greater the distance from *A. arenaria*, the greater the likelihood of *H. sparsiflora* var. *brevifolia* occurring (*Figure 7).*

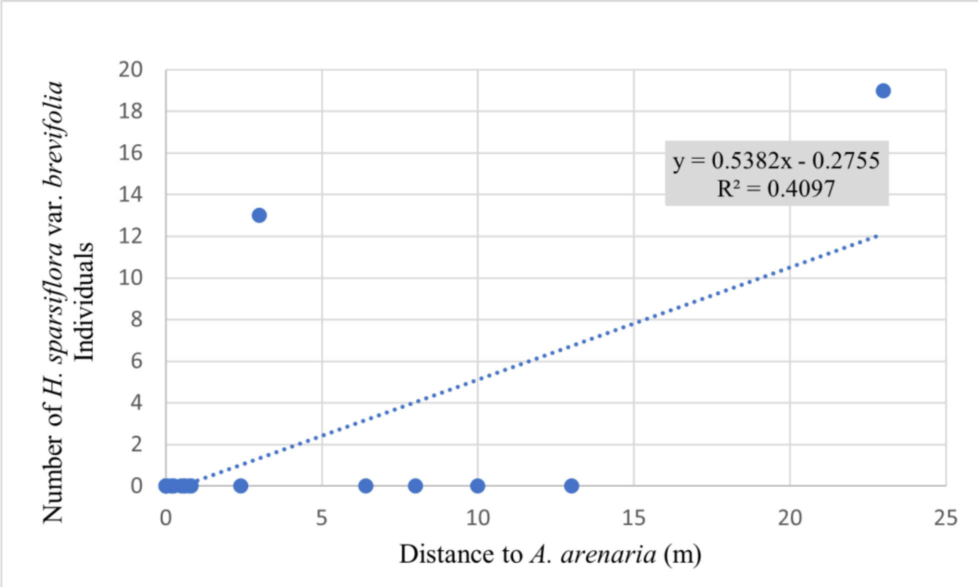

Figure 7: Regression comparing distance to *A. arenaria* (x-value) and number of *H. sparsiflora* var. *brevifolia* individuals (y-value) yielded p-value=0.00236.

The relationship between the number of *H. sparsiflora* var. *brevifolia* individuals and distance to the road was not significant (p-value > 0.05) (*Figure 8*). However, the two highest sampled values of *H. sparsiflora* var. *brevifolia* individuals were found between ten and twenty meters from the road. A two-tailed t-test assuming unequal variances comparing presence of compaction to presence of *H. sparsiflora* var. *brevifolia* was found to be insignificant (p = 0.19).

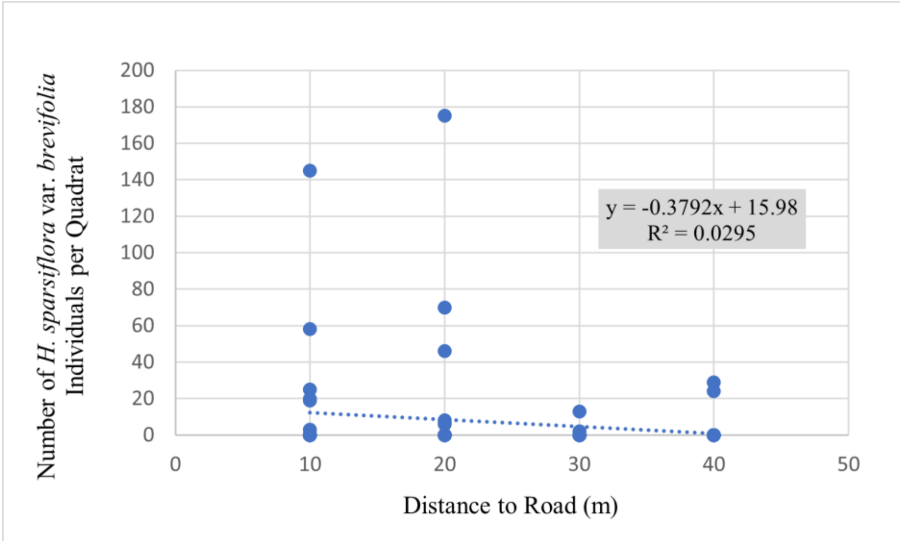

Figure 8: Regression comparing distance to the road (x-value) and number of *H. sparsiflora* var. *brevifolia* individuals (y-value), yielded a p-value of 0.0875.

The relationship between the number of *H. sparsiflora* var. *brevifolia* individuals in burned versus unburned quadrats was not significant (p-value > 0.05). There was an average of 7.725 *H. sparsiflora* var. *brevifolia* individuals in unburned areas and an average of 1.6 individuals in burned areas (*Figure 9*).

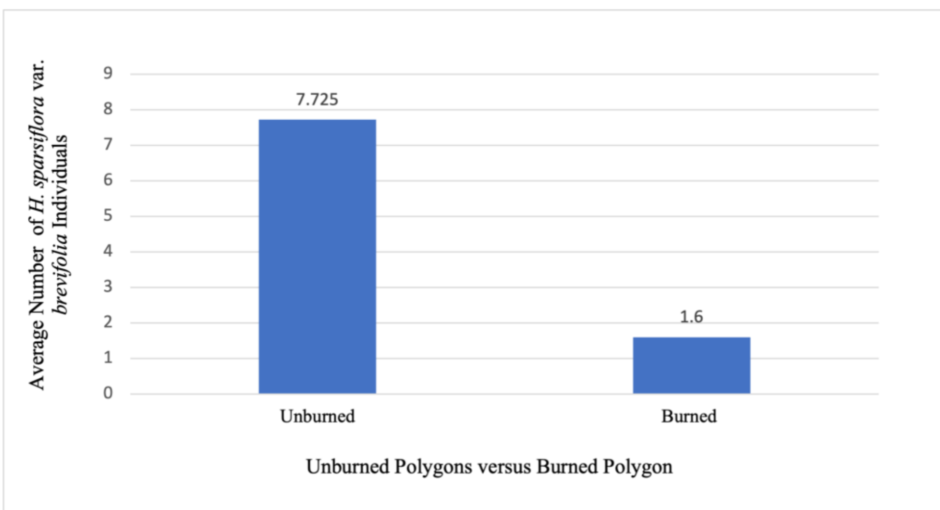

Figure 9: Compares the average number of *H. sparsiflora* var. *brevifolia* individuals in the burned polygon (polygon 3) and unburned polygons. The t-test, which was a Two-Tailed T-Test Assuming Unequal Variances, gave us a p-value of 0.08261.

5. DISCUSSION

5.1 General Findings

We hypothesized that the density and abundance of *H. sparsiflora* var. *brevifolia* would be greater in compacted areas near the road, further from *A. arenaria*, and in areas that were treated with herbicide and prescribed fire in 2022. We estimate there to be about 14.3 million *H. sparsiflora* var. *brevifolia* within our studied polygons at Ocean Ranch in Humboldt County, California.

Our findings showed that there is no significant relationship between *H. sparsiflora* var. *brevifolia* presence and distance to the road (*Figure 8*). In the field however, we observed that *H. sparsiflora* var. *brevifolia* is often found along the road side. In addition to this, the highest values of *H. sparsiflora* var. *brevifolia* sampled were found between ten and twenty meters from the road, and lesser amounts *H. sparsiflora* var. *brevifolia* were found within distances greater than twenty meters. In addition to this, our results showed that generally where there is compaction, *H. sparsiflora* var. *brevifolia* is more likely to be found (*Figure 8*). Therefore, it can be assumed that since areas close to the road are compacted, there will often be a greater presence of *H. sparsiflora* var. *brevifolia* along the road.

The relationship between *H. sparsiflora* var. *brevifolia* presence and distance to *A. arenaria* was found to be significant (*Figure 7*). *H. sparsiflora* var. *brevifolia* is most prevalent in areas containing little to no *A. arenaria*. In the field, we observed that *H. sparsiflora* var. *brevifolia* was typically found on the eastern side of the polygons and completely absent on the western side. This phenomenon may be due to greater *A. arenaria* presence within the western portions of the polygons as well as greater compaction to the east.

Our study did not find a statistically significant relationship between the burn treatment and density of *H. sparsiflora var. brevifolia* (*Figure 9*). This is likely due to the lack of burned polygons sampled within the study area, and additional data collection may be needed to determine the effect of the burn treatment. There is a significant inverse relationship between the density of *H. sparsiflora var. brevifolia* and the presence of *A. arenaria*. Burning treatments to reduce cover of *A. arenaria* may lead to increased establishment and abundance of *H. sparsiflora var. brevifolia* within suitable habitat.

We encountered a few issues, including that our attempt to measure compaction rates was halted due to the fact that we were provided an incomplete penetrometer set. Also, our results regarding the relationship between the number of *H. sparsiflora* var. *brevifolia* individuals and distance to both the road and *A. arenaria* may have been skewed due to large amounts of zeros sampled within the quadrats. Linear Regression is not the best statistical method when posed with many zeros, and additional exploration of the distribution of the data and appropriate statistical modeling methods is recommended for any similar research in the future.

5.2 *A. arenaria* in relation to *H. sparsiflora var. brevifolia*

The results showed that there is a significant relationship between the distance from invasive *A. arenaria* and density of native *H. sparsiflora* var. *brevifolia* (*Figure 7*). Upon investigating the different sites, we found that there could be multiple reasons for that finding. A small annual plant such as *H. sparsiflora* var. *brevifolia* may be easily shaded out by a taller dense-growing perennial grass such as *A. arenaria*, thus stunting the ability for seedlings to grow (Hacker et al., 2011; Lu et al., 2021). Additionally, a study of *A. arenaria* showed that the invasive species can lead to changes in the soil microbial community (Elgersma, 2011). Another characteristic of the *A. arenaria* that could explain a lack of *H. sparsiflora* var. *brevifolia* is how dense the clusters of the invasive species can get (Pickart, 1997). The large stature of *A. arenaria* and its habit of forming dense populations of multiple plants means that it forms a blockade that could prevent the small *H. sparsiflora* var. *brevifolia* from spreading via wind (Davies & Sheley, 2017). Dense growth of *A. arenaria* may be responsible for the lack of *H. sparsiflora* var. *brevifolia* in the area otherwise the suitable habitat with lightly compacted sandy soil, and therefore removal of *A. arenaria* has the potential to increase the abundance of *H. sparsiflora* var. *brevifolia* (*Figure 7*).

5.3 Insights from our work

If we were to conduct this study again, we would implement many changes. We would prefer to take quadrat assessment starting at the beginning of each polygon to the end of each polygon every 25 meters, moving from South to North, covering the entire polygon. This is because there are large clusters of the target species close to the road. We would also change the increments to every five meters rather than every ten meters to have a better picture of the site (*Figure 5).* This change is due to the fact that as we walked ten meters into each polygon to reach our first point, we would often pass patches of *H. sparsiflora* var. *brevifolia* that did not fall under our chosen methods and thus were not measured for this study. In addition to this change, we would also extend the transect length by twenty meters to increase the coverage area. This change is to make sure that if there is any of the target species further west or not, it will be recorded and help to show distribution. Lastly, if we were to redo this study, we would have investigated and compared more of the burned areas to the unburned (Shumack et al., 2017). We did not have access to the prescribed fire map (*Figure 1*) until after the data was collected, so we only surveyed one polygon that was treated with prescribed burn (polygon 3) and the other 4 were in untreated areas (polygons 1, 2, 4, and 5). Knowing which specific polygons were burned, we would have implemented more focus on the comparison of the polygons treated by burning and not burning to lessen the errors that we found in our data and strengthen our comparisons.

5.4 Management Recommendations

At the present moment, CDFW is aware of the presence of *A. arenaria* and is actively working on eradication. CDFW selected some polygons to be burned with one of them being sprayed with herbicide before the burn treatment (*Figure 1*) (Hyland et al., 2005). The sample size of the burned area is much smaller than the unburned areas, it is hard to compare the two with this drastic difference in size. Helping to form early successional microhabitats is likely to help *H. sparsiflora* var. *brevifolia* gain a foothold within the site (Pardini et al., 2015). It is crucial to constantly assess the dunes to decide on the best course of action (Horando et al., 2010). We recommend that this treatment continue as we have found a negative relationship between the presence of *A. arenaria* and density *H. sparsiflora* var. *brevifolia (Figure 7).*

The removal of *A. arenaria* is an ongoing process that many other agencies are participating in along the coast. The goal is that as the populations of this invasive species are curtailed, more native plant species populations will be established and increased. As more *A. arenaria* is removed from the coasts, more efforts will have to be made for plant surveying afterwards to observe what grows in its place. Testing the correlation of rare plant abundance with the presence of invasive plants, restoration treatments, and physical habitat features may help guide future restoration that aims to increase populations of special-status species.

6. ACKNOWLEDGEMENTS

We deeply appreciate the guidance and aid given to us by Dr. Alison O'Dowd. We thank Kelsey McDonald and James Ray at CDFW for their support and guidance as community partners. Comments and reviews by Dr. Alison O'Dowd, Scott Estepa, Dellaina Morse, Verenice Sanchez, Aidan Jack Murphy, Leila Rahimi and Magdalena Villasenor were extremely helpful throughout the project. Additionally, we thank the Cal Poly Humboldt Forestry Stockroom for the loan of necessary tools.

7. LITERATURE CITED

Davies, K., & Sheley, R. (2007). Influence of Neighboring Vegetation Height on Seed Dispersal: Implications for Invasive Plant Management. Weed Science, 55(6), 626-630. doi:https://doi.org/10.1614/WS-07-067.1

Eicher, McDonald, Farro. (2018). *Special Status Plant Survey for the Ocean Ranch Restoration Project.* California Department of Fish and Wildlife

Elgersma, K.J., Ehrenfeld, J.G. (2011). Linear and non-linear impacts of a non-native plant invasion on soil microbial community structure and function. Biol Invasions 13, 757–768. https://doi.org/10.1007/s10530-010-9866-9

Erickson, Z. J., Boston, K., Dockry, M. J., & John-Pascal Berrill. (2022). Listening to indigenous voices, interests, and priorities that would inform tribal co-management of natural resources on a california state university forest. *Forests, 13*(12), 2165. doi:https://doi.org/10.3390/f13122165

GHD (2021). Ocean Ranch Restoration Project - Environmental Impact Report. Eureka, CA.

Hacker, S.D.; Zarnetske, P.; Seabloom, E.; Ruggiero, P.; Mull, J; Gerrity, S, and Jones,C. (2011). Subtle differences in two non-native congeneric beachgrasses significantly affect their colonization, spread, and impact. Oikos, 121(1),138–148. https://www.jstor.org/stable/41409027

Honrado, J., Vicente, J., Lomba, A., Alves, P., Macedo, J. A., Henriques, R., Granja, H.and Caldas, F. B. (2010). Fine-scale patterns of vegetation assembly in the monitoring of changes in coastal sand-dune landscapes – Web Ecol. 10: 1–14. https://ptflora.up.pt/img/publicacoes/83/Web_Ecol.10.1-14.pdf

Hyland T., Holloran, P., (2005). Controlling European beachgrass (*Ammophila arenaria*) using prescribed burns and herbicide. California Department of Parks and Recreation. https://people.ucsc.edu/~kholl/migrated/envs160/holloran&hyland.pdf

Loomis C (2021). Fish Relocation and Dewatering Report Ocean Ranch Unit 2021. California Department of Fish and Wildlife.

Marchante, H., Freitas, H. and Hoffmann, J.H. (2011), The potential role of seed banks in the recovery of dune ecosystems after removal of invasive plant species. Applied Vegetation Science, 14: 107-119. https://doi.org/10.1111/j.1654-109X.2010.01099.x

Morefield, J. D. (1992). Resurrection and Revision of Hesperevax (Asteraceae: Inuleae). *Systematic Botany*, *17*(2), 293–310. https://doi.org/10.2307/2419524

Lu, D., Liu, B., Ren, M., Wu, C., Ma, J., & Shen, Y. (2021). Light Deficiency Inhibits Growth by Affecting Photosynthesis Efficiency as well as JA and Ethylene Signaling in Endangered Plant *Magnolia sinostellata*. Plants, 10(11). https://doi.org/10.3390/plants10112261

Pacific Coast Fish, Wildlife and Wetlands Restoration Association (2018). Special Status Plant Survey for the Ocean Ranch Restoration Project (DU Project No. US-CA-398-4). Final report prepared for the California Department of Fish and Wildlife and Ducks Unlimited, Inc.

Pardini E., Vickstrom K., Knight T. (2015). Early Successional Microhabitats Allow the Persistence of Endangered Plants in Coastal Sand Dunes. PLoS ONE 10(4): e0119567. https://doi.org/10.1371/journal.pone.0119567

Parsons, & Becker, B. H. (2021). Invasion by *Ammophila arenaria* alters soil chemistry, leaving lasting legacy effects on restored coastal dunes in California. Invasive Plant Science and Management, 14(2), 75–91. https://doi.org/10.1017/inp.2021.16

Pickart, A.J., Miller, L.M. and Duebendorfer, T.E. (1998). Yellow Bush Lupine Invasion in Northern California Coastal Dunes I. Ecological Impacts and Manual Restoration Techniques. Restoration Ecology, 6: 59-68. https://doi.org/10.1046/j.1526-100x.1998.00618.x

Pickart, A. J. (1997). Control of European beachgrass (*Ammophila arenaria*) on the west coast of the United States. In California Exotic Plant Pest Council Symposium.

Shumack S., Hesse P., Turner L. (2017). The impact of fire on sand dune stability: Surface coverage and biomass recovery after fires on Western Australian coastal dune systems from 1988 to 2016, Geomorphology, Volume 299, 2017, Pages 39-53, ISSN 0169-555X, https://doi.org/10.1016/j.geomorph.2017.10.001.

Simonson, Miller, E., Jones, A., García-Rangel, S., Thornton, H., & McOwen, C. (2021). Enhancing climate change resilience of ecological restoration — A framework for action. *Perspectives in Ecology and Conservation*, *19*(3), 300–310. https://doi.org/10.1016/j.pecon.2021.05.002

Soil Survey Staff, Natural Resources Conservation Service, U.S Department of Agriculture. Web Soil Survey.

Weidlich, E., Flórido, F., Sorrini, T., Brancalion, P. (2020). Controlling invasive plant species in ecological restoration: A global review. *J Appl Ecol*. 2020; 57: 1806–1817. https://doi.org/10.1111/1365-2664.13656

Wilkins, S., Keith, D.A. and Adam, P. (2003). Measuring Success: Evaluating the Restoration of a Grassy Eucalypt Woodland on the Cumberland Plain, Sydney, Australia. Restoration Ecology, 11: 489-503. https://doi.org/10.1046/j.1526-100X.2003.rec0