Lanphere Adaptation Site,
Humboldt Coastal Resilience Project
2024 Report on Vegetation

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INTRODUCTION

The Humboldt Coastal Resilience Project was funded by the California State Coastal Conservancy and Ocean Protection Council to better understand and prepare for the effects of sea level rise and climate change in the coastal barrier dune systems of the Eureka littoral cell in northern California (Fig. 1). The Lanphere Adaptation Demonstration Project (Adaptation Site) is one component of a larger research and planning effort. The Adaptation Site consists of a stretch of foredunes within Humboldt Bay National Wildlife Refuge that was previously invaded and stabilized by invasive European beachgrass (*Ammophila arenaria*). The purpose of the demonstration site was to examine the morphodynamic and ecological responses of the foredune to the removal of *Ammophila* followed by replanting with three distinct vegetation types composed of native plant species of differing morphologies. The project tests how restoration to native vegetation affects foredune resiliency.

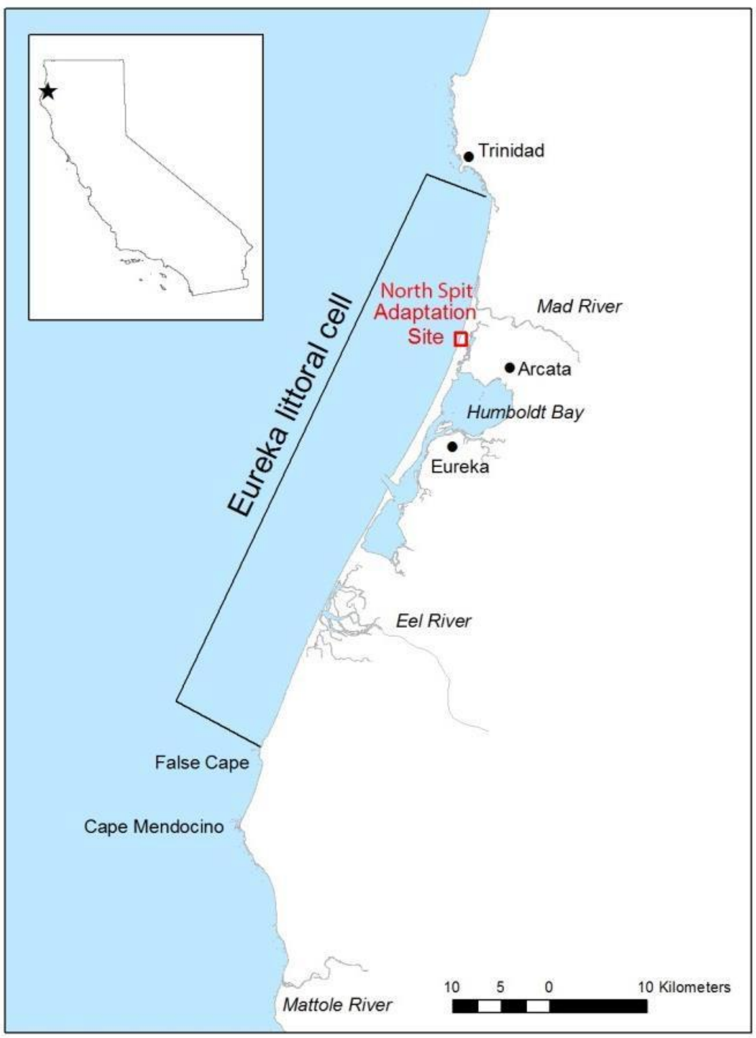


Figure 1. Location of the North Spit Adaptation Site and Eureka littoral cell.

This report summarizes resultsof the vegetation component of the project fromAugust 2015-August 2024. Morphodynamic response has been analyzed and discussed in Hilgendorf et al. (2022).

METHODS

Experimental Design

The Adaptation Site was divided into fourapproximately equal areas that were randomly assigned to one of three treatments or a control (Fig. 2). Following the removal of *Ammophila arenaria*, the three treatment types were planted with different configurations of native species (Table 1), although density of plantings was held constant at approximately 1 plant/m^2.

Table 1. Planting treatments.

Treatment Name	Density *Elymus* hills/4m^2	Density Dune mat divisions/4m^2	Density of seed planting holes/m^2	Total density/4 m^2
Elymus mollis	4	0	0	4
Dune mat	0	2	0.5	4
Dune mat-*Elymus*	1	1	0.5	4

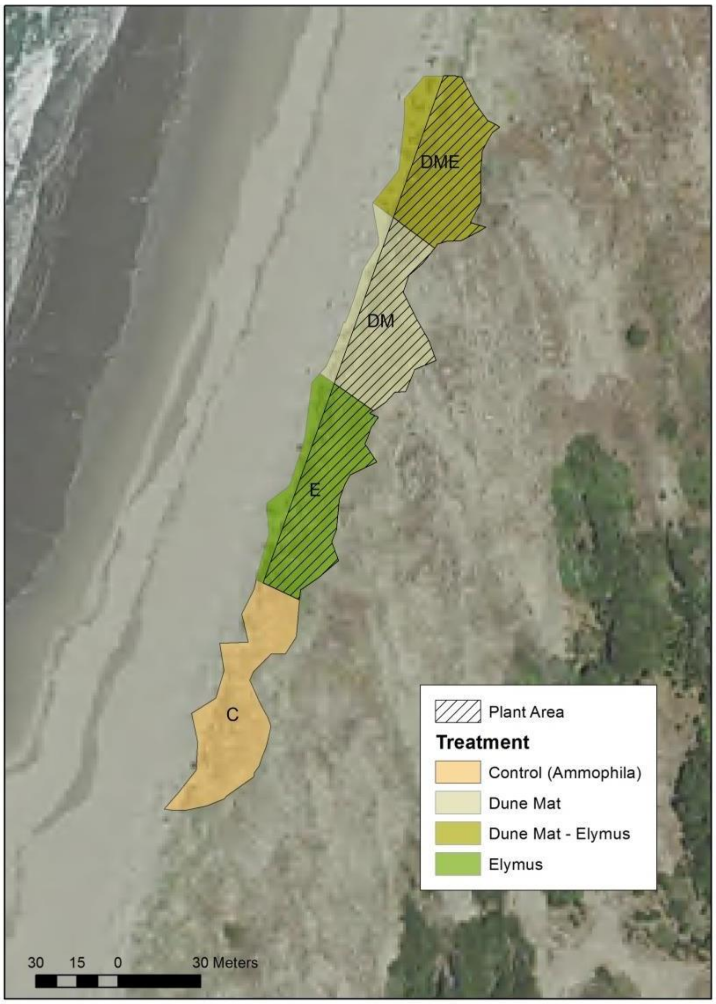


Figure 2. Location of control and three treatments, showing planted areas, overlain on the original *Ammophila* footprint.

Vegetation Monitoring

Vegetation cover by species and percent bare sand was sampled prior to *Ammophila* removal to establish a baseline, and for the ability to detect any changes over time that occur in the control (untreated *Ammophila*). Shore normal transects were spaced 10 m apart along the length of the Adaptation Site using a random start. A 0.5 m x 0.5 m gridded quadrat was placed at 10 m intervals along transects throughout the *Ammophila* footprint. The quadrat had a total of 25 gridded intersections. A pin was dropped at each intersection and the proportion of hits by the top-most species at each intersection was used as a proxy for cover (with a minimum of 4% precision). Annual monitoring was carried out in July or August, 2016-2024, except for 2021. The August 2017 – July 2024 sampling utilized a random rather than systematic sampling design. A total of 32 plot locations were selected randomly within each treatment area using the Create Random Points tool in ArcGIS Pro. A 1-m buffer was first established around the edges of the treatment area to avoid edge effects.

Photopoints

To provide supporting qualitative data, permanent photopoints were established throughout the Adaptation Site in 2016 prior to restoration. Photopoints are taken annually in July-August (Appendix A).

RESULTS

Vegetation Response

1. Total Cover

Change in total cover for each treatment over time is shown in Fig. 3. Total cover, which includes all species present, is a variable of interest given that cover of any kind has the potential to slow sand transport. As expected, there was no significant difference in cover among the three treatments prior to vegetation removal (ANOVA p=.30). At the end of the first summer following removal (August 2016) substantial *Ammophila* resprouts were still present, along with some relict or volunteer dune mat species, and there were significant differences among treatments (Kruskal-Wallis p<.05). Multiple comparisons showed that the Dune mat-*Elymus* treatment had higher cover than both the Dune mat and *Elymus* treatments (p<.05). Revegetation occurred in winter 2016-2017, however by August 2017 trends were similar with the Dune mat-*Elymus* treatment again distinguished as significantly higher in cover than the Dune mat treatment (p=.03). At this time (August 2017), mean cover in the Dune mat-*Elymus* treatment was equivalent to reference conditions as previously measured in intact dune mat on the adjacent Lanphere Dunes Unit (Pickart 2013). From August 2018 on, total cover was no longer significantly different among treatments, except for 2020 when the Dune mat-*Elymus* treatment was again significantly higher than other treatments (p<.01). In 2024 the three groups were not significantly different (Figure 4, Anova, p=0.17).

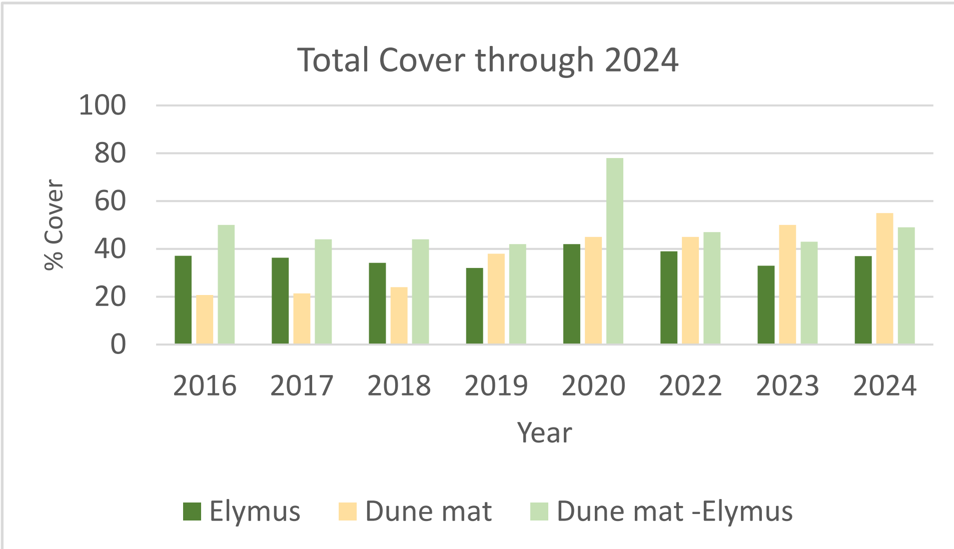


Figure 3. Percent cover (total of all species comprising three vegetation types) by treatment and year. *Ammophila* was gone by 2017. Planting with native species took place in Dec. 2016 - Jan. 2017. Remedial planting of *Elymus* took place in 2023.

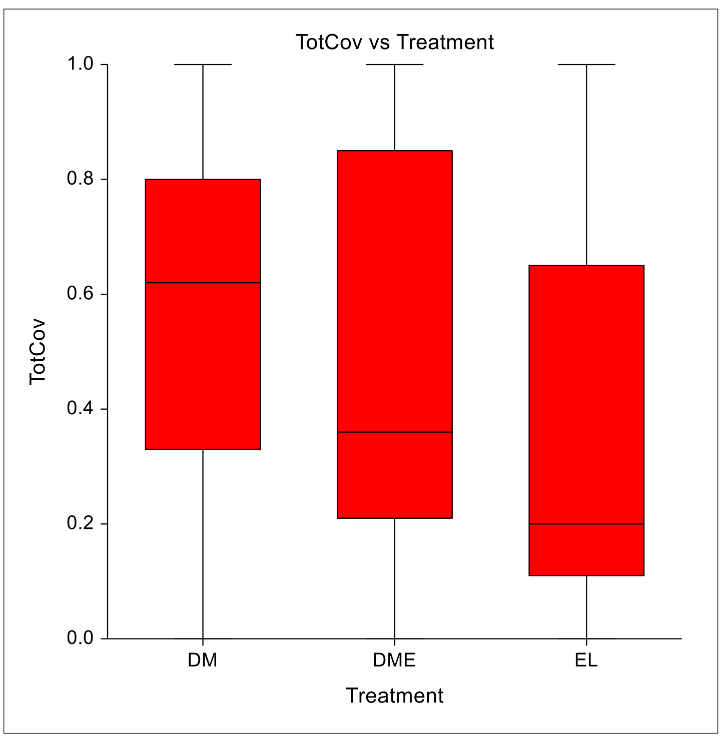


Figure 4. Box plots showing difference in median and quartiles for total cover among treatments in 2024. DM = Dune mat, DME = Dune mat – *Elymus*, EL = *Elymus.* Means were not significantly different.

In 2024 both the dune mat treatment and Elymus treatments had reached the mean cover of n reference sites (40% and 37% respectively. However, the majority of the *Elymus* treatment area consisted of dune mat species.

Total cover of dune mat was also examined for all treatments combined (Fig. 5). The graph shows the steady increase in dune mat cover over time. An ANOVA (p<.001) and Duncan's multiple comparison test (p<.05) showed that the later years were significantly higher in cover than the earlier years (Table x). The current year, 2024, was significantly different than the greatest number of years including early and recent years.

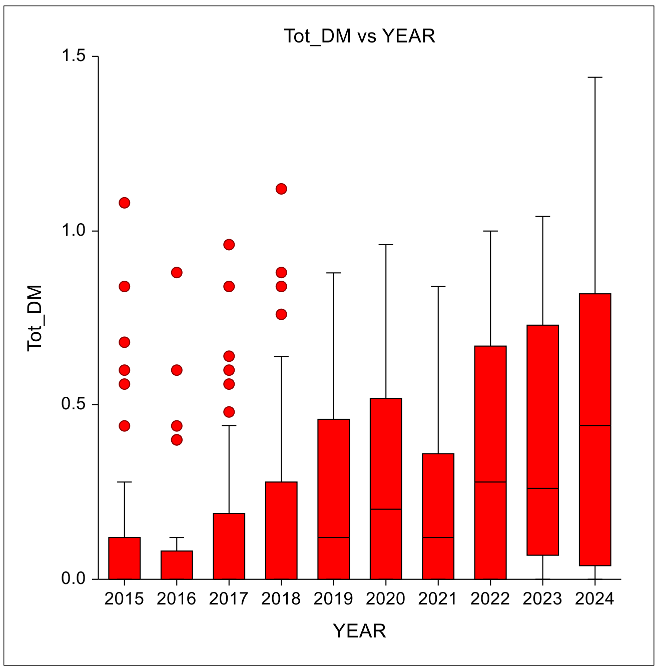


Figure 5. Box plots, showing median and quartiles, illustrate the increase in dune mat cover over time.

Table 2. Results of Duncan's Multiple Comparison Test

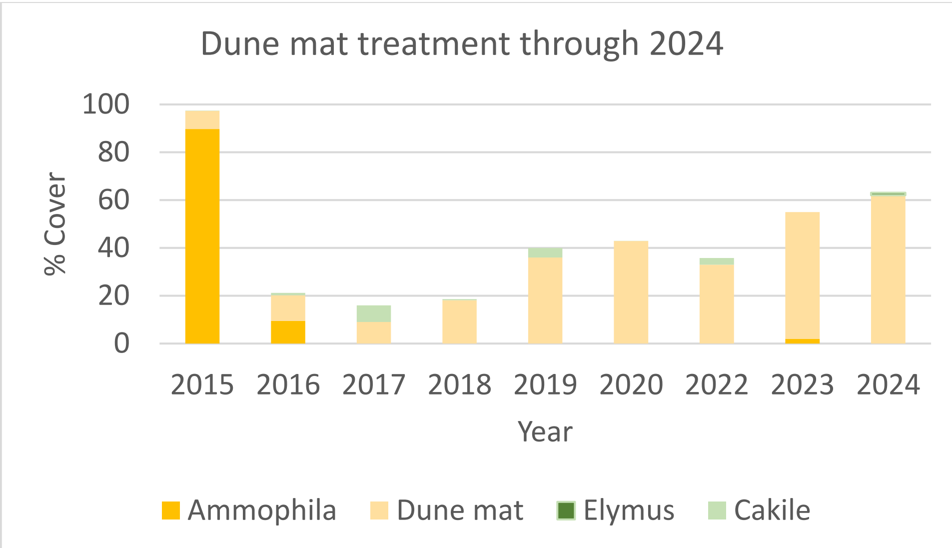
Group	Count	Mean	Different From Groups
2015	52	0.115	2022, 2023, 2024
2016	34	0.091	2020, 2022, 2023, 2024
2017	48	0.136	2022, 2023, 2024
2018	50	0.175	2024
2019	29	0.243	2024
2020	25	0.294	2016
2021	29	0.226	2024
2022	48	0.364	2015, 2016, 2017
2023	30	0.376	2015, 2016, 2017
2024	66	0.473	2015, 2016, 2017, 2018, 2019, 2021

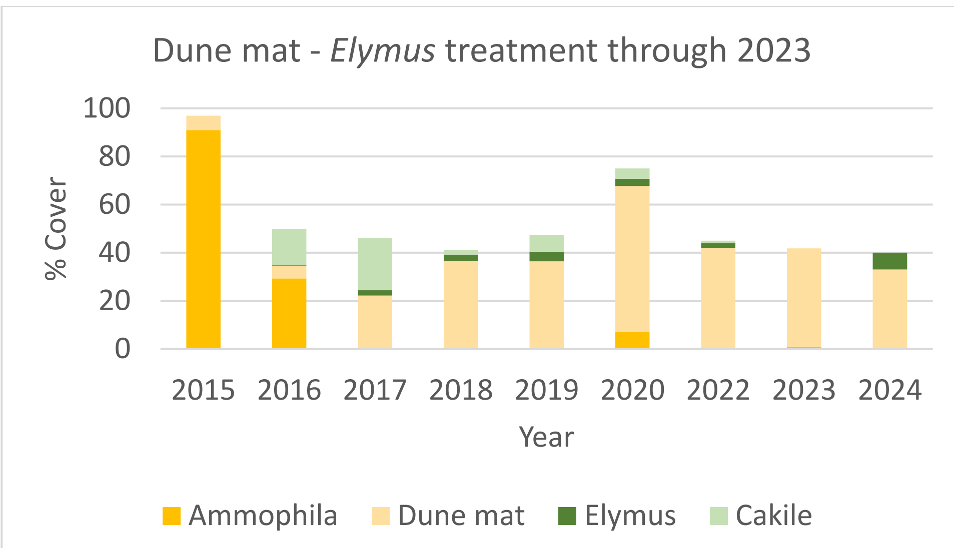
Species Composition

Between August 2015 and August 2016, the proportion of *Ammophila* in treatment areas declined dramatically due to control efforts (Fig. 6). *Cakile* spp. appeared in treated areas. In past projects, this non-persisting species has functioned as a nurse coverduring restoration. By August 2017, the *Ammophila* component of 2016 cover had been replaced by a combination of dune mat, *Elymus* and *Cakile* spp. (Fig. 6). By August 2018*, Cakile* had declined significantly. *Elymus* was most prevalent in the *Elymus* treatment, while dune mat was dominant in both the Dune mat and the Dune mat – *Elymus* treatment. In 2020 *Cakile* was a minor species, having dropped out as natives colonized. The *Elymus* treatment declined in cover between 2020 and 2023, as did *Elymus* as a species in the *Elymus* treatment. This reduction was observed to be primarily due to burial/deflation, as some slipfaces became more active (see photopoints in Appendix). Additionally, *Elymus* in many areas was replaced by dune mat. A remedial *Elymus* planting was carried out in 2023 and by 2024 cover in the *Elymus* treatment was 37%. However, the majority of that cover was comprised of dune mat species (32%) compared to *Elymus* (5%) (Fig. 6).

DISCUSSION

Total cover in two of the three planting treatments declined between 2020 and 2023, and *Elymus* in particular declined in cover. Observations on the site indicate that this cover reduction was due to mobilization of sand where slipfaces were present, particularly in the *Elymus* treatment (see photopoints 46, 47 and 56 in Appendix). These slipfaces appear to be a legacy effect of the *Ammophila*-built foredune which was noticeably steeper in the *Elymus* treatment area. Over time, these slipfaces are beginning to stabilize due to vegetation colonizing from the base or sides. Dune mat species are present in all 3 treatments, despite not having been planted in the *Elymus* treatment. Recruitment from off site has occurred, as shown by the addition of new species over time. In the first two years, cover was influenced by relict/volunteer species, with the Dune mat-*Elymus* treatment showing the highest cover pre-planting and for two subsequent years. As the site has matured, it has shifted toward dominance of Dune mat, with *Elymus* continuing to decline. *Elymus* was observed growing well elsewhere on the Lanphere and Ma-le'l Dunes, indicating that the pattern on the Adaptation site was not due to a regional trend. Based on these results, if *Elymus* is desired, it should be planted as it will not disperse on to the foredune from adjacent populations. It is recommended, however, that the density of *Elymus* planting should be increased. In the remedial planting in 2024 density was 1 hill (two culms)/.5m^2. It would be useful to conduct an experiment testing for the most effective density of *Elymus* for trapping sand.





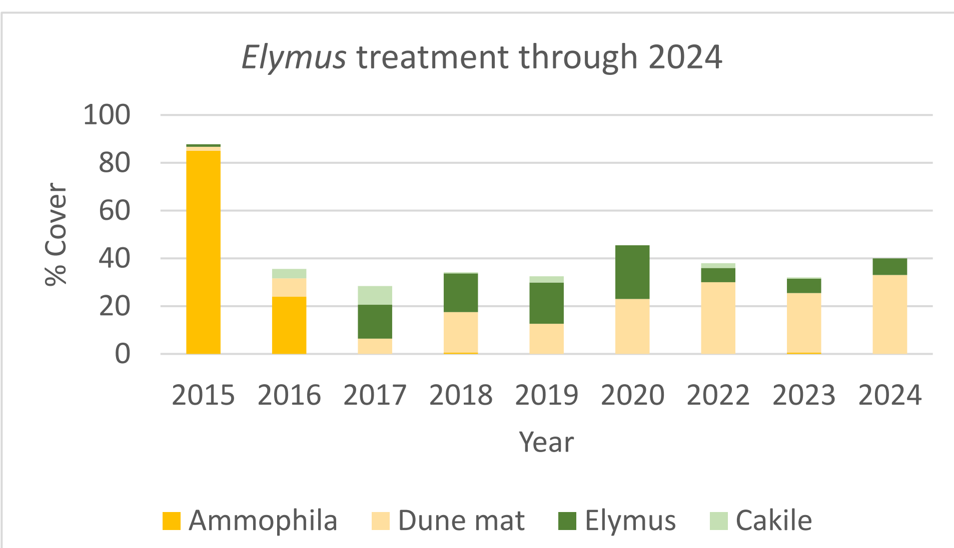


Figure 6. Graphs for each treatment type: Dune mat top, Dune mat-*Elymus* left, and *Elymus,* bottom, showing amount and proportion of vegetation in four groups: *Ammophila*, dune mat species, *Elymus*, and *Cakile* spp. by year.

CONCLUSIONS

The Lanphere Adaptation Site has successfully demonstrated the role of vegetation and morphodynamics in restoring both biodiversity and climate resilience to a foredune previously stabilized by *Ammophila arenaria*. Morphometric results are summarized in Hilgendorf et al. 2022). This report documents the recovery of vegetation which assisted in the return of resilience. In general, *Elymus mollis* was less successful in propagating post-introduction that dune mat species. However, there was abundant dune mat to the east and north of the site, and casual observations suggest that much of the vegetation that established on the Adaptation Site volunteered. An exception is Poa macrantha. This species was planted using divisions and it established and flourished rapidly. The species is a good candidate for foredune re-planting. Refer to the companion report documenting the Bair Adaptation site for additional information on vegetation response to *Ammophila* removal on the foredune (Pickart 2025).

ACKNOWLEDGEMENTS

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APPENDIX