

California Department of Fish and Wildlife
Environmental Enhancement Fund (EEF) Grant Program
Final Progress Report
Restoring Critical Habitat and Increasing Climate Resiliency in a Northern California Dune System

Date: 06/30/2026

Project Title: Restoring Critical Habitat and Increasing Climate Resiliency in a Northern California Dune System

Agreement No.: Q2275068

Grant Term: 10/12/2022 - 06/30/2026

Grantee: Friends of the Dunes

Invoice Submitted with this report: ☒ Yes ☐ No

Final Invoice #11048 submitted with this report.

FISCAL REPORT

Fund Source	Amount Awarded	Total Amount Invoiced
CDFW EEF Grant Funds	\$229,517	\$229,517
Cost Share	\$550,000	\$579,220.18
Agreement Totals	\$779,571	\$808,737.18

PROGRAM/TECHNICAL REPORT

Brief Summary of Work Performed October 12, 2022, to June 15, 2026

Friends of the Dunes, the U.S. Fish and Wildlife Service (USFWS), and other restoration partners successfully implemented a large-scale coastal dune restoration project at the Wadulh Unit of the Humboldt Bay National Wildlife Refuge (Fig. 1). The 200-acre project was designed to restore ecosystem function and biodiversity while increasing the resilience of the dune system to climate change and sea level rise. The CDFW EEF funded portion of the project focused on restoring approximately 40 acres of mid-stage lupine-invaded coastal dune habitat through manual removal of invasive yellow bush lupine and soil restoration, with passive recovery of native Dune mat species. Additional project components including European beachgrass removal in the foredune, late-stage lupine invaded backdune restoration using heavy equipment, revegetation of denuded areas with native dune species and long-term monitoring were funded by other entities. This report summarizes the CDFW EEF funded portion of the project.

Yellow Bush Lupine Removal and Invasive Species Management

The primary focus of this project was the removal of invasive yellow bush lupine (*Lupinus arboreus*), a species that has fundamentally altered ecosystem processes throughout Northern California dunes, including the Wadulh Unit of Humboldt Bay National Wildlife Refuge. Intentionally planted on Wadulh in the 1940s, yellow bush lupine spread unchecked across the site, transforming a formerly open dune system into a static, densely vegetated landscape. As a large, short-lived, nitrogen-fixing species, lupine significantly alters soil chemistry and structure by increasing nutrient availability, accelerating nitrogen cycling, accumulating a thick layer of organic duff, and facilitating the establishment of secondary invasive species. The dense shrub cover also stabilizes dunes, halting natural sand movement and disrupting the geomorphic processes necessary to maintain healthy coastal dune ecosystems. Any native Dune mat species present are eventually outcompeted as they evolved under the low nutrient conditions of uninvaded dunes.

Restoration efforts focused on manual removal of yellow bush lupine throughout 40 acres of the project area that were unsuitable for removal using heavy equipment due to remnant native vegetation. Retaining native vegetation allows for its expansion into cleared, treated sites, eliminating the need for revegetation. Contracted work crews and project staff used electric hand saws, Swedish axes, and hand tools to remove dense stands of lupine and associated invasive vegetation. Removed woody biomass was consolidated into brush piles for later burning under the supervision of USFWS fire personnel. Removed herbaceous vegetation was bagged and taken to a green waste facility.

By 2025, crews successfully completed removal of all standing yellow bush lupine throughout the restoration area. Because yellow bush lupine has a long-lived seed bank, periodic monitoring and treatment of new seedlings will continue as part of long-term management by USFWS, a standard practice after restoration.

Duff Layer Removal/Soil Restoration

As mentioned above, native dune plants, and the Dune mat community they make up, are adapted to nutrient-poor, dynamic sandy environments with summer drought, and are unable to compete effectively after yellow bush lupine, an ecosystem engineer, drastically alters soils. Enriched soils with greater organic matter and water holding capacity favor weedy species over natives even after lupine is removal. Restoration of soils through the removal of the organic duff layer returns the soil to conditions favorable to native species and significantly reduces the lupine and non-native seed bank.

Following lupine removal, restoration crews undertook an intensive effort to manually remove accumulated duff throughout the project area. Manual methods were required in order to retain relict native plants that were present. McLeods, Pulaskis, and other hand tools were used to scrape, loosen, and remove duff while minimizing impacts to native plants. Material was loaded into sleds, transported to pile sites, buried in excavated trenches, and capped with clean sand to prevent resprouting. This effort occurred over a two-year period. Because duff removal is labor intensive and slow, other invasive species, especially the annual grasses ripgut brome and rattlesnake grass, emerged from the duff layer in areas awaiting treatment and had to be controlled. Brush cutting and manual pulling (around native species) were used as a temporary measure to prevent more seed production before duff was removed.

Duff removal was highly successful. Within manually treated restoration areas, duff cover declined from 36% in 2023 to 12% in 2025 (Fig. 2). Remaining duff will be removed using matching funds in 2026/2027 and future monitoring is expected to show close to 100% elimination of duff. Monitoring also documented a dramatic reduction in invasive annual grasses from 23% to 2% cover in manually treated areas (Fig. 3). Removal of duff greatly reduced the annual grass and invasive weed seedbank. However, some of the annual grass seedbank remains and grasses will continue to be controlled using matching funds. Native Dune mat species are already recolonizing restored areas following lupine and duff removal (Figs. 4-5). At the time of the 2025 monitoring, native plant cover increases did not show up in monitoring results, probably due to a low sample size. However, qualitative observations show that native species cover in 2025 (Fig. 5), and an even greater increase should be detected in the 2026 native species, laying the foundation for long-term recovery of native plant and animal communities, improved biodiversity, and restoration of natural dune geomorphic processes.

Additional Activities Undertaken With Matching Funds

As discussed above, matching funds have been used to restore the more degraded portion of the backdune using heavy equipment, burying all vegetation and duff. This exposed a great deal of sand that could be mobilized and threaten adjacent private lands. For this reason, the goal of the project was to attain semi-stable dunes supporting the CDFW-ranked sensitive plant community Dune mat. To accomplish this, matching funds were used to strategically place arrays of sand fencing to stabilize the substrate enough to allow plants to establish. Approximately 280,000 dune perennials were grown by the local Samara Restoration native plant nursery from seed collected nearby. Plants were delivered by helicopter and planted out in winter 2025-6. Additional activities included the eradication of European beachgrass (*Ammophila arenaria*) from the foredune through the use of herbicides followed by a broadcast burn. This area was then replanted with the native American dunegrass (*Elymus mollis*) harvested from remnant stands on site. Matching funds were also used to carry out geomorphic monitoring by scientists from UC Santa Barbara.

There are two cost shares included with this grant. There is a \$200,000 cost share for U.S. Fish and Wildlife Service for the project, this included staff time as well as the needed purchase of a UTV for the project, totaling \$229,220.18. There is a cost share for a grant from the California Coastal Conservancy for \$350,000. At this time there is \$278,524 outstanding to spend with the grant, majority will be spent summer 2026. There are multiple additional grants supporting the restoration of the Wadulh Unit not including as cost share, but activities described above.

Conclusion

The project successfully achieved its primary restoration goals by completing large-scale removal of invasive yellow bush lupine across the restoration area. Removing and burying extensive accumulations of accumulated duff restored natural soil conditions as well as eco-geomorphic processes that support native plant and animal communities. Through coordinated partnerships and based on a 40-year history of research and dune restoration in the region, the project has substantially restored habitat quality, biodiversity, and ecological resilience across the restoration area. Ongoing monitoring will guide future management and ensure restoration goals are sustained as native dune communities continue to establish and expand.

Deliverables

Q2275068
Friends of the Dunes

Task	Description	Deliverables	Estimated Completion Dates	Status	% Complete	Date submitted to CDFW
1	Collect Seed and Grow Plants		09/2025	· Completed with matching funds	100%	
2	Remove Lupine		12/2024	· Complete	100%	
3	Remove Duff Layer		10/2025	· Complete	100%	
4	Plant Native Plants		02/2026	· Completed with matching funds	100%	
5	Biological Monitoring		12/2027	· Completed for DFW funded portion of project, will continue by USFWS	100%	
6	Project Management and Administration	Due within 30 days following each calendar quarter (March, June, September, December) following grant execution		· Complete	100%	
		Quarterly Invoices	Due within 30 days following each calendar quarter (March, June, September, December) after grant execution	· Complete	100%	

		Copies of Executed Subcontracts	Due with next Quarterly Progress Reports upon completion of Subcontracts	· Complete	100%	
		Copies of Permits	Dues with next Quarterly Progress Reports upon completion of Permits	n/a		
		Submit Project Data	06/15/26	· Complete	100%	
		Draft Final Report	06/15/26	· Complete	100%	
		Final Report	06/30/26	· Complete	100%	
		Project Close-out Summary Report	06/30/26	· Complete	100%	
		Final Invoice	06/30/26	· Complete	100%	

***If no, summarize in Problems/Delays and Lessons Learned section below**

Problems/Delays and Lessons Learned

The project encountered few delays and no real surprises. The methods had been previously tested experimentally and shown to be effective. The scale was the primary unknown factor, as this project represents the largest application of these methods to date in California or elsewhere. Through the effective use of multiple crews under the direction of a Restoration Manager and Biotech, work proceeded smoothly throughout the project. The biggest challenge was keeping the annual grasses under control as they emerged from the seed bank after lupine removal but before duff removal. There is a very short window for annual grass control (about 2 months) which lasts from after grasses emerge sufficient through seed maturation. This necessitated the use of multiple approaches to annual grass control. Using brushcutters as a stop-gap method to prevent seed set was a previously unused approach. Brushcutting is limited as a method in itself because it only prevents the current year's

contribution to the seed bank. Duff removal is the more permanent solution. Given the very time-consuming nature of the manual duff removal methods, brushcutting was an important tool, especially in the first spring after lupine removal. The grasses that were pulled or brushcut were raked, bagged, and disposed of at a green waste facility to prevent addition of nitrogen to the soils (and to some extent extracting usable nitrogen from soils). When pulling grasses by hand, if time ran short, grasses were grabbed and the tops ripped off (rather than pulling up the entire plant) to prevent seed dispersal. A new method was developed to use the brushcutter on grasses that were growing interspersed with native Dune mat species. The natives are generally shorter than the fruiting tops of the grasses, and the brushcutters were skimmed over the tops of the natives to cut off fruiting heads and kill seeds. In this case, no raking was conducted.

Project Benefits and Results

The project resulted in the restoration of eco-geomorphic processes to 40 acres of dunes degraded by invasive yellow bush lupine and associated invasive and non-native species. Remnant populations of native Dune mat species were still present, so native vegetation is returning on its own to these manually treated areas. Expansion of Dune mat cover is expected to continue, and long-term monitoring and adaptive management will be provided by staff at Humboldt Bay National Wildlife Refuge. Although only plants are being monitored, increased use by invertebrates and mammals has also been observed, a sign that plant-animal interactions and food chains are returning.

Estimated Co-benefits achieved to date

Wildlife Habitat Enhancement and Biodiversity Recovery

The restored habitat provides improved foraging, nesting, and movement opportunities for a wide range of wildlife species associated with coastal dune ecosystems, including native pollinators, other invertebrates, reptiles, small mammals, migratory and resident birds, and other species that depend on open dune habitats. Plant recovery is happening rapidly, and cover will continue to expand over the next five or so years, based on past restoration projects in the region. Qualitative observations indicate that invertebrate and mammal use is beginning to return as well. Pollinators, including the native solitary Silver Bee, have been observed. Past research has shown that yellow bush lupine is primarily pollinated by regional pollinators like bumblebees. The nearby Lanphere Dunes hosts over 40 species of solitary bees that are associated with native Dune mat species, using them for nectar and to provision their nests. Native wasps have been seen nectaring on newly established annual species, and their burrows observed in the sand. Pollen-consuming beetles are abundant, and the Acmon blue butterfly is visiting Dune mat flowers. Mammals or their tracks are increasingly sighted, such as the Western Deer Mouse, Striped skunk, and Black-tailed Jack Rabbit.

By restoring native vegetation structure and increasing plant diversity, the project contributes directly to long-term biodiversity conservation goals within the Humboldt Bay National Wildlife Refuge and the greater North Coast dune ecosystem.

Climate Resilience and Coastal Ecosystem Adaptation

The restoration of geomorphic processes is particularly important for climate resilience. Coastal dunes are expected to migrate in response to sea level rise. Increased frequency and intensity of erosion-producing storms has already been observed over the past decade at Wadulh. The dunes in this location have adequate accommodation space, and with biodiversity and physical processes intact, should be able to translate in response to sea level rise. The project builds upon previous restoration efforts within

the Humboldt Bay dune complex, where long-term monitoring has demonstrated that restored dune systems exhibit greater resilience through faster recovery from storm erosion. By restoring ecological processes rather than simply treating individual invasive species, the project provides enduring climate resilience benefits for both wildlife habitat and coastal landscapes.

Restoration of Ecological Function

A major ecological benefit of the project was the restoration of natural soil processes within the dune ecosystem. Decades of invasion by Yellow Bush Lupine and associated invasive species resulted in the accumulation of a thick organic duff layer that fundamentally altered soil chemistry and nutrient cycling. These nutrient enriched conditions favored invasive species while placing native dune plants, which are adapted to low nutrient environments, at a competitive disadvantage.

Removal and burial of the duff layer restored the nutrient poor sandy substrate characteristic of functioning coastal dunes. This restoration of soil conditions will provide long-term ecological benefits by reducing invasive species recruitment, improving native plant establishment, and supporting the recovery of natural dune succession processes.

Monitoring results indicate that removal of the duff layer significantly reduced invasive annual grass cover and depleted portions of the invasive seed bank, helping shift the site toward a more self-sustaining native plant community. The project therefore addressed not only the visible invasive vegetation but also the underlying ecological conditions that allowed invasions to persist.

Long-Term Conservation Value

The restoration completed through this project provides lasting conservation benefits that extend beyond the immediate treatment area. By removing invasive ecosystem engineers, restoring natural soil conditions, re-establishing native vegetation, and allowing natural dune processes to return, the project has substantially restored ecosystem integrity. The Wadulh site is part of a 7-mile-long stretch of dune-backed coastline, the majority of which has been restored, with additional restoration planned. Although there is no formal inventory, this appears to be the largest stretch of restored/planned coastal dunes in California and is truly an ecosystem scale project.

Summarize Benefits to Disadvantaged Communities (if applicable)

N/A

Objectives

Project Objective (as stated in Grant Agreement)	Objective met or exceeded? (Yes/No)*
1. Eradicate invasive yellow bush lupine over a 40-acre area of degraded coastal dunes through manual methods over two years (this area is too topographically steep to use heavy equipment). Herbicides will be used as needed on co-occurring non-native species but are ineffective as a treatment on lupine because only the leaves are affected, and	Yes

the branching system still needs to be removed. Any lupine resprouting will be less than	
2. Restore dune soils through the removal of the duff layer under and around lupine plants and burying duff in excavated areas over a two-year period.	Yes
3. Collect seeds and plant native dune mat species (1/4m ²) in areas of degraded dune mat and dune forest species in areas of degraded forest in the third year. Survival of dune plants will be 50% or replanting will occur.	Yes, through matching funds.
4. Restore geomorphic processes as measured using topographic profiles that record sediment deposition and deflation. Sediment transport will occur between the beach, foredune, and back dune.	Yes, through matching funds
5. Monitor changes to vegetation using a combination of qualitative and quantitative methods to measure success annually throughout the project. By the end of this Project, native dune mat will achieve 10% cover and will increase 40% by 5 years.	Yes, through matching funds, although native cover is expected to reach 10% by the end of 2026.

*If No, please explain in Issues and Lessons Learned section below

Issues and Lessons Learned

Included above in Delays and Lessons learned.

Additional report included more detailed information and results of all restoration activities at Wadulh Unit 2024-2025.

Relevant Pictures, Maps, Data for this Report



Figure 1. Location of the Wadulh restoration project and adjoining units of Humboldt Bay National Wildlife Refuge.

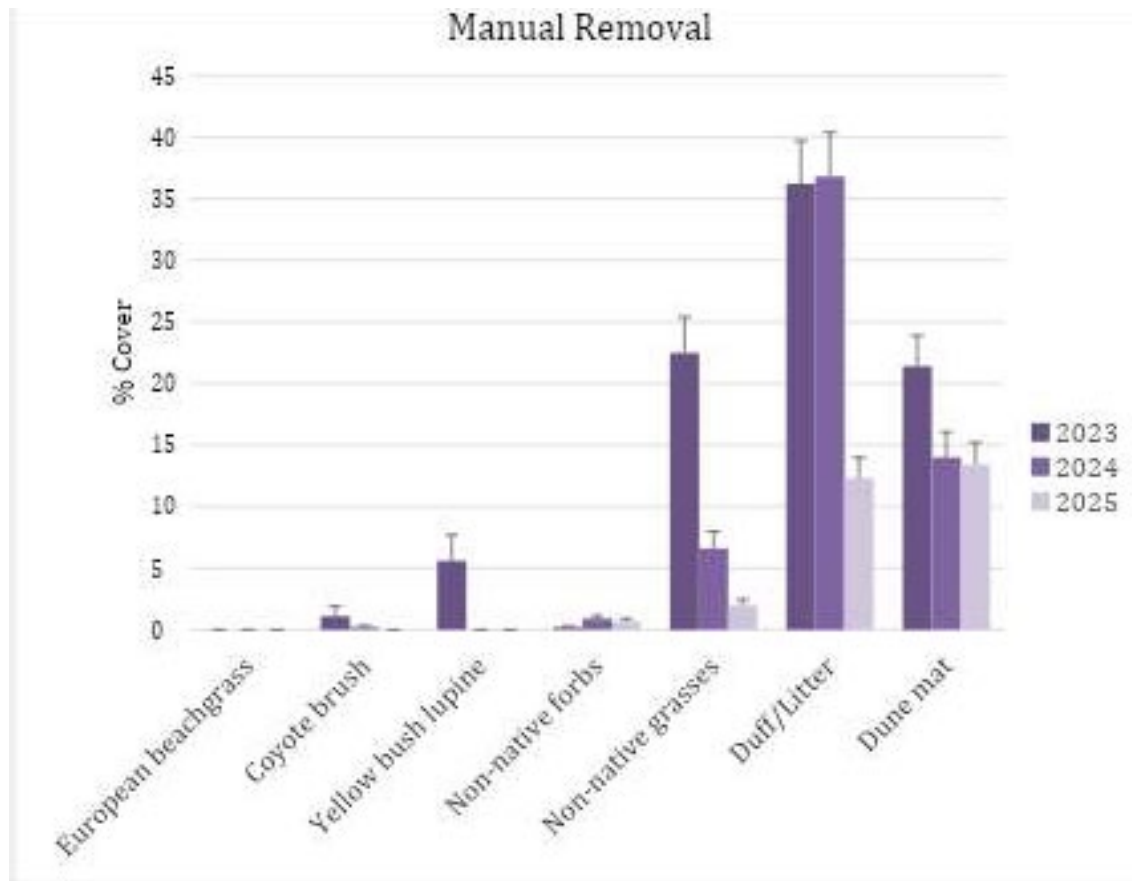


Figure 2. Percent cover of invasive vegetation, duff, and native vegetation between 2023 (pre-project) and 2025.



Figure 3. Examples of lupine-invaded dunes before restoration. On the lower right, the lupine have died out, leaving duff and annual grasses.



Figure 4. Examples of lupine invaded dunes after restoration. Photos were taken in August 2025. Vegetation is a mix of dune mat species that were present but suppressed, and newly “volunteering” plants responding to the creation of open space.