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Habitat Assessment of Suitable Areas for Three Rare Plant Species (Layia carnosa, Erysimum menziesii, and Gilia millefoliata) in the Barr Parcel on Friends of the Dunes Property

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Photographs of *Layia carnosa*, *Erysimum menziesii*, and *Gilia millefoliata* by Almond Dodge.

Applied Ecological Restoration Capstone (ESM 455)

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ABSTRACT

Native rare plants are an important component of ecosystems. It is critical to preserve these species because it facilitates growth of native plants. Ecological restoration provides the necessary conditions to encourage native plant growth. *Gilia millefoliata, Erysimum menziesii*, and *Layia carnosa* are three rare plants found on the Friends of the Dunes property in Arcata, CA. In this assessment, we surveyed these three rare plants and came up with a management plan for the Barr Parcel on the Friends of the Dunes property. Friends of the Dunes recently acquired the Barr Parcel and are waiting for restoration permits for this site. The objectives of this project were to locate and plot locations of three rare plant species, create three informative maps that display the extent of the current habitat for these three rare species, and prescribe a feasible management plan for each of the three rare species that encourages successful propagation and re-colonization throughout their natural habitat. We found that all three rare plants were present and abundant on the Barr Parcel. Recommended management includes invasive species removal, increased disturbance for *Layia carnosa*, and increased signage for *Erysimum menziesii* and *Gilia millefoliata* to encourage growth.

INTRODUCTION

Dune Ecosystems

Preservation of native species in dune ecosystems is essential. Dune ecosystems are highly sensitive and impacted by human interaction and climate change (Seabloom et al., 2013). Historically, dune habitats in Humboldt County consist of native foredune grasslands, dune mats, dune swales, moving dunes, and coniferous dune forests (U.S.F.W. Humboldt, 2020). These ecosystems are also a great economic benefit; coastal zones generate 30% of the nation's jobs (National Research Council, 1999). Native species tend to create more biodiversity in dune ecosystems because they have higher success at colonizing other native plants compared to invasive species (Crutsinger et al., 2010). For example, if the dune ecosystem is dominated by an invasive non-native such as European beachgrass (*Ammophila arenaria)*, then the native plant abundance is diminished. Considering the sensitivity of dunes, economic benefit, and non-native species dominance; it is important to protect dunes ecosystems along the coast of Humboldt County, California.

Land Use History

The land use history of the Humboldt Bay area includes many anthropogenic impacts due to European colonization and subsequent mismanagement. The Humboldt Bay area is located within the ancestral territory of the Wiyot people, who inhabited this land for thousands of years prior to European contact and still live here today (Simpson, 2019). Spanish colonization in Humboldt County began in the 1700s and by 1806 European settlement began (Humboldt Bay Harbor, 2020). European settlement resulted in the extraction of resources such as timber and

land conversion for agriculture, lumber mills, city buildings, and commercial trade centers (Humboldt Bay Harbor, 2020). Invasive *Ammophila arenaria* was introduced to the northern region of Humboldt Bay in 1901 by the Vance Redwood Company and in the 1960s it was planted to prevent sand movement along the railroad system (U.S Fish and Wildlife, 2005). The railroad system in Humboldt County has not been in use since the 1990s, but there are still homeowners that are concerned with sand movement on their properties (U.S Fish and Wildlife, 2005). Dune stabilization has been ingrained in local community sentiment since the 1960s and many local residents think that *A. arenaria* should not be removed from dunes because it stabilizes the dunes (U.S Fish and Wildlife, 2005). However, dune stabilization and vast monocultures of *A. arenaria* outcompetes essential native plant species including rare and endangered species (U.S Fish and Wildlife, 2005).

Friends of the Dunes

Friends of the Dunes is a non-profit land trust with a mission focused on the conservation of coastal environments. The organization started in 1982 and currently manages 118 acres of coastal dunes on the Manila/Samoa peninsula in the city of Arcata in Humboldt County, California (Coastal Conservation, 2020). Friends of the Dunes partners with local area land managers to conduct restoration, education programs, and guided walks (Friends of the Dunes, 2020). With these local partners Friends of the Dunes developed a program called “Dune Ecosystem Restoration Team” (DERT) (Friends of the Dunes, 2020). This program holds restoration events once a month that involves hand-pulling non-native invasive plants within their property boundaries (Friends of the Dunes, 2020).

Stakeholders

There are several stakeholders associated with the coastal dunes located on the Manila/Samoa peninsula in Humboldt County, California. The biggest stakeholder is Friends of the Dunes, who have been working for years on ecologically restoring these coastal dunes. Other stakeholders include agencies and land managers in the area that have worked in partnership with Friends of the Dunes in restoration and education efforts. These partners include Humboldt Bay National Wildlife Refuge, Bureau of Land Management, Manila Community Services District, Center for Natural Lands Management, etc. (Coastal Conservation, 2020). Humboldt State University (HSU) students and faculty are also stakeholders, who have conducted research projects, field trips, and labs on these dunes. Lastly, the neighboring landowners are also stakeholders in this project, as they have voiced both their concerns and support regarding restoration of the dunes.

Project Objectives

Conservation of rare and endangered species requires accurate and up-to-date distribution and locational maps that can inform restoration and conservation measures. Friends of the Dunes identified three rare plant species to prioritize for restoration and conservation. In order to assist with this goal, the objectives of our project were to:

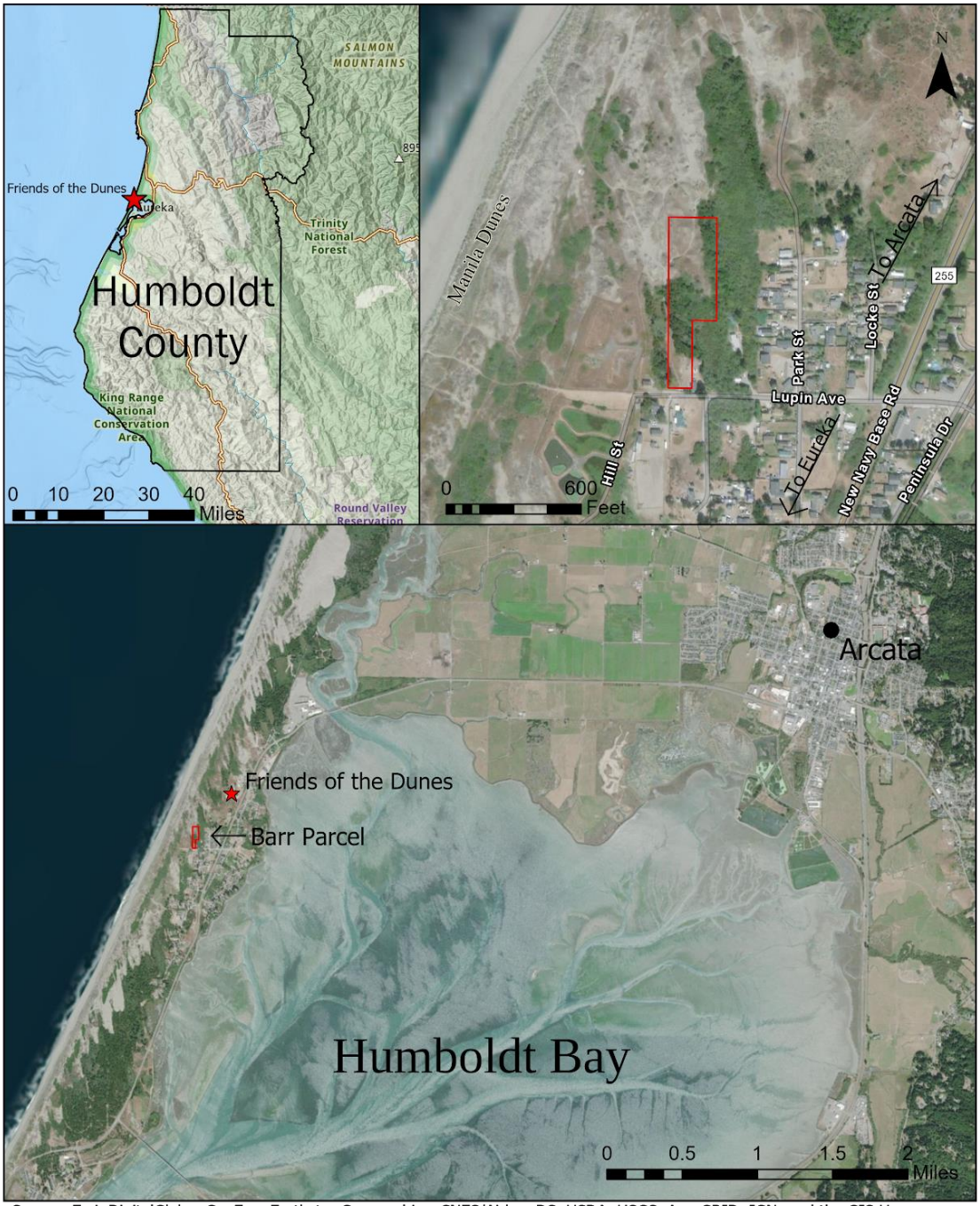
- Locate and plot locations of three rare plant species (*Layia carnosa*, *Erysimum menziesii*, *Gilia millefoliata*) within the Barr parcel owned by Friends of the Dunes in Manila, California;
- Create three informative maps that display the extent of the current habitat for these three rare species; and

- Prescribe a feasible management plan for each of the three rare species that encourages successful propagation and re-colonization throughout their natural habitat.

METHODS

Site Description

The study site for this project is part of a dune ecosystem. The site is located within the 'Barr parcel,' which is located on the southern end of the Friends of the Dunes property in Manila, California (Figure 1). This site contains a grove of shore pine (*Pinus contorta* ssp. *contorta*), as well as many native dune plants. Plant species include seaside buckwheat (*Eriogonum latifolium*), coastal sagewort (*Artemisia pycnocephala*), sand verbena (*Abronia latifolia*), and coast goldenrod (*Solidago spathulata*). Many of these plants are pollinated by solitary bees (Friends of the Dunes, 2020). The dune ecosystem also provides habitat for snowy plover (Friends of the Dunes, 2020). The Barr parcel is the most recently acquired portion of Friends of the Dunes property and was privately owned prior to the acquisition. Friends of the Dunes plans on incorporating the Barr parcel into their preexisting restoration plan (D. Ryman, pers. comm., 2020).



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community, Sources: Esri, USGS, Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Figure 1: The Barr Parcel is in Humboldt County at the north end of the Samoa/Manila peninsula on the western half of Humboldt Bay.

Environmental Setting

Climate

The Samoa/Manila peninsula in Humboldt County, California is located in a rainy temperate zone (Evenson, 1959). The average annual temperature in Eureka, California is 53 degrees Fahrenheit (Climate-Data, 2020). The temperature is highest in August with an average of 58.6 degrees Fahrenheit and the lowest in January at 47.8 degrees Fahrenheit (Climate-Data, 2020). The average rainfall annually is 42.4 inches, being highest in January at 7.4 inches and the lowest in July at 0.2 inches (Climate-Data, 2020). Most of the rainfall in this region falls between October and May, with a prolonged summer dry period (Climate-Data, 2020).

Soils/Geology

Our study site is located within the Humboldt Coastal Zone and the soil mainly consists of sand. Specifically, this region's soil composition is 65% Samoan complex, 30% Clam beach, and 5% minor components (NRCS, 2020). The soil profile has mostly plant material in the O layer followed by sand in the remaining lower levels. This area generally has 0-50% slopes and the elevation varies from sea level to 70ft asl (NRCS, 2020). The prominent parent material is Eolian and marine sand from multiple sources on the Pacific (NRCS, 2020).

Invasive/Native/Rare Species

This section describes a few of the notable plant species and pollinators present at our study site. The plant species include some of the invasive, native, and rare plants found at the dunes within the Barr parcel.

Non-native Invasive Dune Plant Species

Ice plant (Carpobrotus chilensis)

Ice plant (*Carpobrotus chilensis*) (*Figure 2)* is an invasive non-native species that is very common throughout coastal California (Invasive to Avoid: Iceplant, 2020). *Carpobrotus chilensis* inhabits several ecosystems and is extremely prevalent in dune and beach environments (Invasive to Avoid, 2020). *Carpobrotus chilensis* is a succulent shrub in the family Aizoaceae that creates dense mats, restricting spread of natives (Baldwin, 2012). It also reduces soil pH and has a negative impact on water availability for native species (Ditomaso et al., 2013). *Carpobrotus chilensis* is widespread throughout the dunes and its spread has displaced the three rare species targeted in our study, as well as other native dune species. Fortunately, Friends of the Dunes has committed a lot of staff and volunteer time to eradicating ice plant throughout their property, so our project site is only mildly affected by ice plant invasion at this time.

Figure 2: Carpobrotus chilensis. Photos courtesy of commons.wikimedia.org (left) and flickr.com (right).

Yellow bush lupine (*Lupinus arboreus*)

Yellow bush lupine (*Lupinus arboreus*) (*Figure 3)* is native to central and southern California but is invasive to northern California coastal dunes (Yellow Bush Lupine, 2020). Like other *Lupinus* species, *L. arboreus* is a nitrogen-fixer. It colonizes the open dune mat areas and, due to increased nitrogen, allows native and invasive species to move into dune mat areas that

they would otherwise be unable to grow (Yellow Bush Lupine, 2020). Increased nitrogen in the soil is problematic since *L. arboreus* can drastically change the plant community and displace natives that need the dune mat section of the dunes to thrive (Yellow Bush Lupine, 2020). Friends of the Dunes hosts an annual volunteer event called the "Lupine Bash" to help stop the spread of yellow bush lupine and eliminate the existing individuals on their property.

Figure 3: Lupinus arboreus. Photos courtesy of commons.wikimedia.org (left) and flickr.com (right).

European beach grass (*Ammophila arenaria*)

Ammophila arenaria (*Figure 4)* is a perennial clumping grass in the family Poaceae and is the most problematic invasive species present on the Manila/Samoa dunes (*Ammophila arenaria* Profile, 2018). *Ammophila arenaria* creates many issues for the surrounding dune ecosystem. First, *A. arenaria* spreads much quicker than native plants in the area, making it easy to colonize any open sand and disturbed areas (Ditomaso et al., 2013). Second, like other invasive species, once *A. arenaria* is introduced, it outcompetes other natives, such as American dune grass (*Elymus mollis*), creating a monoculture (Ditomaso et al., 2013). Lastly, *A. arenaria* grows in very dense stands, changing the overall geomorphology of the dune system (California

State Parks, 2020). The dense root and vegetative growth of *A. arenaria* prevents sand from moving naturally to the interior dunes, changing the structure and ecology of the dunes as a whole (State Parks, 2020). This facet of *A. arenaria* also creates steep, unnatural slopes that run parallel to the ocean on the primary dune (*Ammophila arenaria* Profile, 2018). Friends of the Dunes have dedicated countless volunteer hours removing *A. arenaria* and have done a successful job of eliminating it from many areas of the dunes, but *A. arenaria* still remains throughout areas of the dunes that they own and manage, including the Barr parcel. There is concern that removing *A. arenaria* and allowing for the natural movement of sand throughout the dunes will have impacts on neighboring properties (D. Ryman, pers. comm., 2020).

Figure 4: Ammophila arenaria. Photos courtesy of commons.wikimedia.org (left) and uk.wikipedia.org (right).

Himilayan blackberry (*Rubus armeniacus*)

Rubus armeniacus (*Figure 5)* is an invasive shrub in the *Rosaceae* family. It originated from Eurasia and is highly invasive, displacing many native species, including the California blackberry (*Rubus ursinus*). One of the main reasons that it is such a strong competitor is because it can easily grow to overtop native species, shading them out from sunlight and restricting their growth.

Figure 5: Rubus armeniacus. Photos courtesy of Jeremy Cashen (left) and commons.wikimedia.org (right).

Native and Rare Dune Plant Species

Dark-eyed gilia (*Gilia millefoliata*)

Gilia millefoliata (*Figure 6*) is a rare annual herb that grows on coastal dunes and is confined to western North America in Oregon and California (Dark-eyed Gilia, 2020). *Gilia millefoliata* is in the family Polemoniaceae and blooms with small violet flowers from April to July (CNPS Inventory, 2020). *Gilia millefoliata* propagates through seed and is dispersed by the wind (California Native Plant Society, n.d.). *Gilia millefoliata* is not currently listed as threatened or endangered federally, but statewide in California it is ranked as 1B, which means that it is rare throughout its range and has declined significantly over the century (California Native Plant Society, n.d.).

Figure 6: Gilia Millefoliata. Photos courtesy of Almond Dodge (left) and en.m.wikipedia.org (right).

Menzies' wallflower (*Erysimum menziesii*)

Menzies' wallflower (*Erysimum menziesii*) (*Figure 7)* is an endangered plant that is a succulent biennial to perennial with bright, densely clustered, yellow flowers in the family Brassicaceae (Menzies' Wallflower, 2020). *Erysimum menziesii* is federally and state listed as an endangered species and labeled as critically imperiled (U.S.F.W. Menzies', 2020). The flowers of *Erysimum menziesii* bloom from February to April and its habitat extends from the mouth of the Mad River to the southern tip of the Samoa peninsula in the Humboldt bay area (Menzies' Wallflower, 2020). *Erysimum menziesii* is very distinct from other angiosperms in that it is monocarpic and only produces one fruit in its life, after which it dies (Menzies' Wallflower, 2020). Also, the basal rosette of *Erysimum menziesii* may persist and take as long as eight years to flower (Menzies' Wallflower, 2020). Unfortunately, Menzies' wallflower does not have a persistent seed bank and the survival rate for seedlings is very low (U.S.F.W Menzies', 2020). Furthermore, the population is also at risk from a fungus in the area that causes white rust disease

(U.S.F.W. Menzies', 2020). The current population of *Erysimum menziesii* is estimated at around 30,000 plants, which is a substantial increase since 1989 and due to comprehensive restoration work (U.S.F.W. Menzies', 2020).

Figure 7: Erysimum menziesii. Photos courtesy of Almond Dodge.

Beach layia (*Layia carnosa*)

Beach layia (*Layia carnosa*) (*Figure 8)* is a succulent annual herb and belongs to the family Asteraceae. *Layia carnosa* is listed as endangered federally and statewide in California (Beach Layia, 2020). Humboldt County boasts the largest populations and acreage of occupied habitat of *Layia carnosa* (Beach Layia Species Profile, 2020). *Layia carnosa* is currently found growing in and around Humboldt County at Freshwater Lagoon, Mad River Dunes, Samoa/Manila peninsula, South Spit, Eel River Wildlife Area, and the mouth of the Mattole River (Beach Layia Species Profile, 2020). The inflorescence of *Layia carnosa* is a radiate capitulum with white ray flowers and yellow disc flowers (Beach Layia, 2020). The number of flower heads vary from one to over 100 depending on the fertility and conditions of the area it is growing (Beach Layia Species Profile, 2020). *Layia carnosa* colonizes sparsely vegetated, newly

created bare sand areas, making it resilient for disturbance (Beach Layia Species Profile, 2020). *Layia carnosa* thrives around trails and on the side of sandy roads (Beach Layia Species Profile, 2020).

Figure 8: Layia carnosa. Photos courtesy of Almond Dodge.

Bee Species in the Dunes

Bees are a necessary component of dune ecosystems, as they are the key pollinator for most of the plant species in this ecosystem. There are about 40 different species of bees (including solitary and colonial bees) that visit the Manila dunes area when the dune plants are flowering (Van der Meer, 2020). Honey Bees (*Apis mellifera*) and bumblebees (*Bombus vosnesenskii*) are the two groups of colonial bee that you can find at the dunes (Van der Meer, 2020). Honeybees are rarer to find and are known to travel far distances to gather food, likely nesting far from the dunes (Van der Meer, 2020). Bumblebees, on the other hand, create annual nests close to the dunes in nearby forests or pastures (Van der Meer, 2020). Solitary bees are of the utmost importance to the health of the ecosystem, as they contribute to most pollination of the flowering plants (Van der Meer, 2020). These bees have no central hive and, instead, nest in

the ground throughout the dunes (Van der Meer, 2020). The seven most common solitary bees that inhabit this specific dune system are the Silver Bee (*Habropoda miserabilis*), Sweat Bee (*Lasioglossum pavonotum*), Mason Bee (*Osmia integra*), Carpenter Bee (*Ceratina acantha*), Wool-carder Bee (*Anthidium palliventre*), Mining Bee (*Colletes hyalinus oregonensis*), and Leaf-cutter Bee (*Megachile wheeleri*), with some of them preferring very specific plants in the area (Van der Meer, 2020).

Figure 9: Silver Bee - Habropoda miserabilis (left). Figure 10: Wool-carder Bee - Anthidium palliventre (right). Photos courtesy of friendsofthedunes.org.

Field Methods

We surveyed the Barr parcel on March 1 and March 8, 2020 for the three rare plants (*L. carnosa*, *E. menziesii*, and *G. millefoliata*) in our site. *The Jepson Manual: Vascular Plants of California, Second Edition* was our source for identification (Baldwin, 2012). We started on the very southern end of the Barr parcel and walked in a zig-zag formation to look for the three rare plant species. All three plant species have a rosette growth habit, so we counted each live rosette as an individual plant. *Erysimum menziesii* often occurs as individuals, *L. carnosa* occurs in clusters (five or more plants) or individuals, and *G. millefoliata* tends to occur in clusters. We

took a GPS waypoint directly above individual plants or in the center of clusters. We used flags to mark the central point of each cluster, as we estimated the number of individuals in a continuous area around that point.

A Garmin GSPMAP 64s GPS unit was used to record the longitude and latitude of all three species (Appendix A). For *E. menziesii* and *G. millefoliata*, we used a point-count method for individuals and groups of plants, recording how many were in each group. For *L. carnosa*, we did point counts in a scarcer region and a line-intercept method along a trail in a more abundant region. The line-intercept method was done by walking a trail and counting every single plant that occurred on the trail. The .gpx file from the GPS unit was then converted to .csv and imported into ArcGIS Pro as shapefiles. The map for *L. carnosa* was constructed by digitizing a polygon around the abundant line-intercept and graduated symbols for the scarce region (Figure 11). Graduated symbols were used for the other two species (Figure 10 and Figure 12).

RESULTS

We found all three rare species (*L. carnosa*, *E. menziesii* and *G. millefoliata)* in the Barr parcel during our surveys. We recorded approximately 909 individuals of *L. carnosa* total, primarily along paths. *Erysimum menziesii* was abundant throughout the site, regularly dispersed, with 180 individuals recorded. *Gilia millefoliata* was also abundant, with a more clustered distribution and a total of approximately 1,323 individuals recorded in our survey.

The three rare species of interest were not observed on the southern end of the Barr parcel, or under trees (Figures 10, 11, and 12). The three rare species were only observed in open sandy sections of the parcel. *Erysimum menziesii* was found in all areas of the open sandy sections of the parcel included on the tops of ridges and the bottoms of canyons (Figure 10).

Layia carnosa was found near a social trail that is just outside of the Barr Parcel and scarcely along the designated trail in the parcel (Figure 11). *Gilia millefoliata* was found mostly at the bottom of canyons in the open sandy sections of the parcel (Figure 12).

We observed multiple invasive species in the site, including ice plant (*C. edulis*), European beach grass (*A. arenaria*), yellow bush lupine (*L. arboreus*), and Himilayan blackberry (*Rubus armeniacus*). *Carpobrotus edulis* and *A. arenaria* occurred in open sections of the Barr parcel that would be suitable habitat for *L. carnosa, E. menziesii* and *G. millefoliata* if they were not inhabited by invasive species. *Lupinus arboreus* and *R. armeniacus* occurred more frequently among the groves of *P. contorta ssp. contorta* and on the southern end of the parcel, which are not suitable habitat for *L. carnosa, E. menziesii* and *G. millefoliata*.

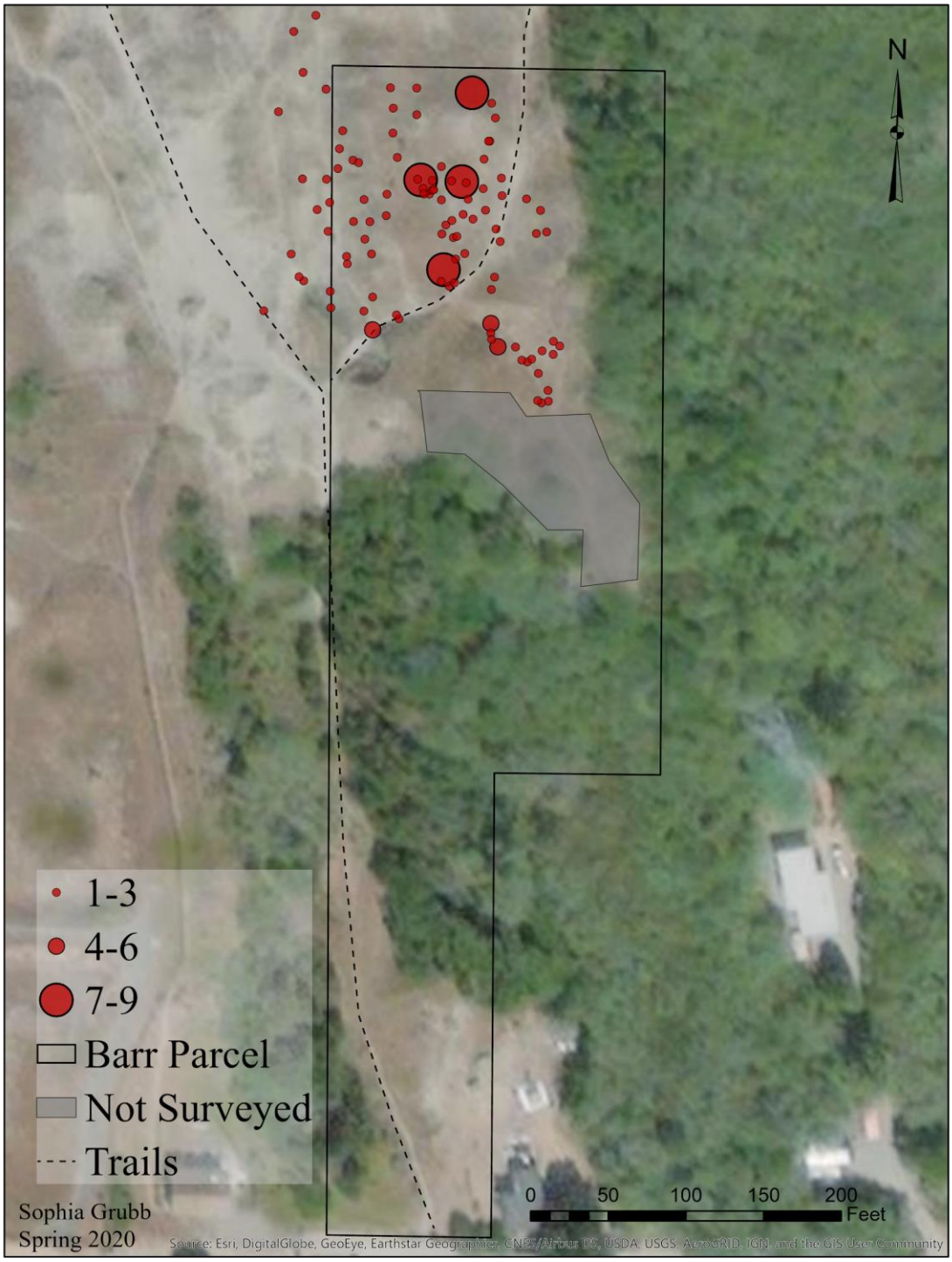


Figure 10: Erysimum menziesii distribution in a section of the Barr Parcel showing individual point counts ranging from 1-3, 4-6, 7-9 individuals.

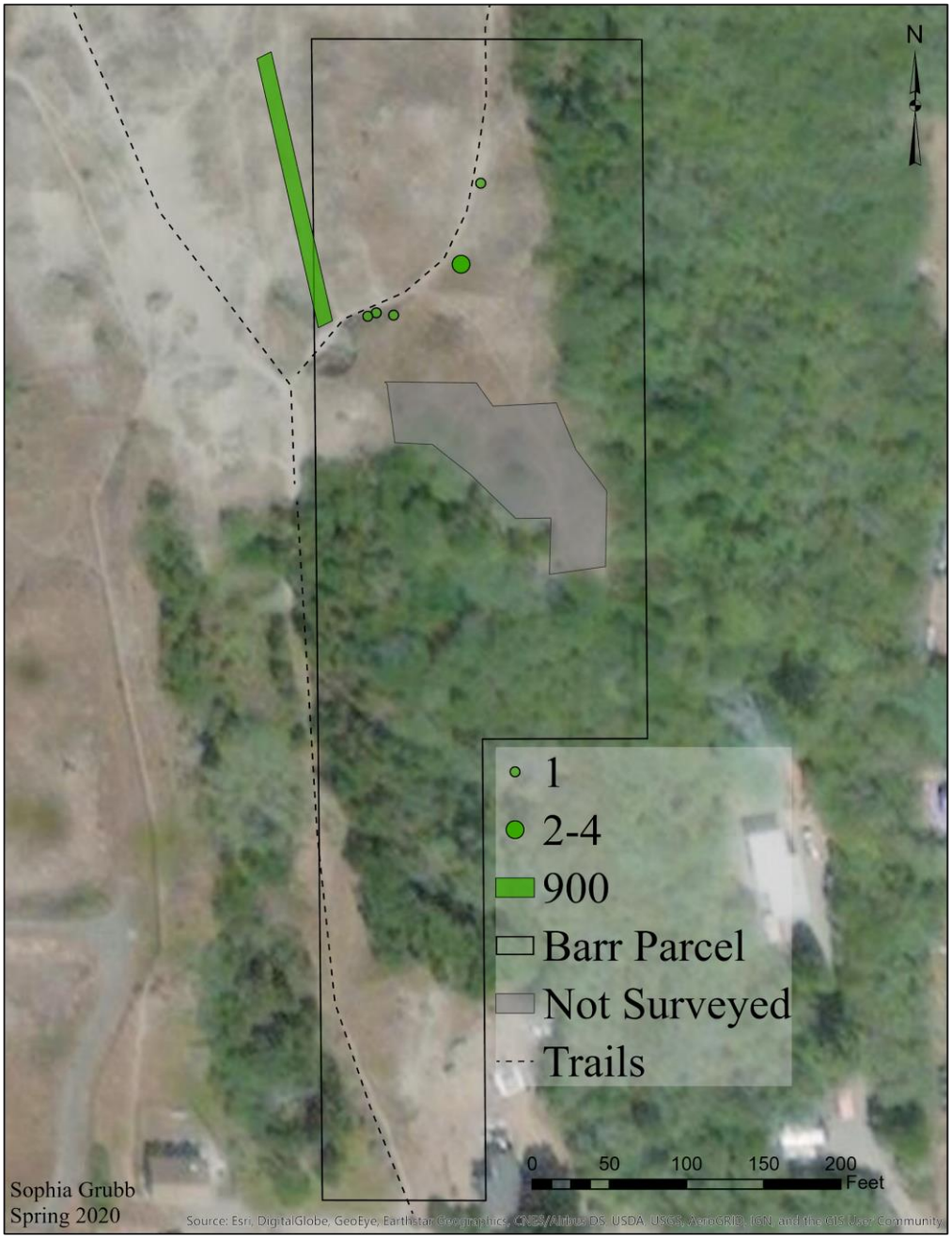


Figure 11: Layia carnosa distribution in a section of the Barr Parcel with individual point counts ranging from 1 and 2-4 individuals. One section located in the northwestern section of the parcel contained 900 individual species.

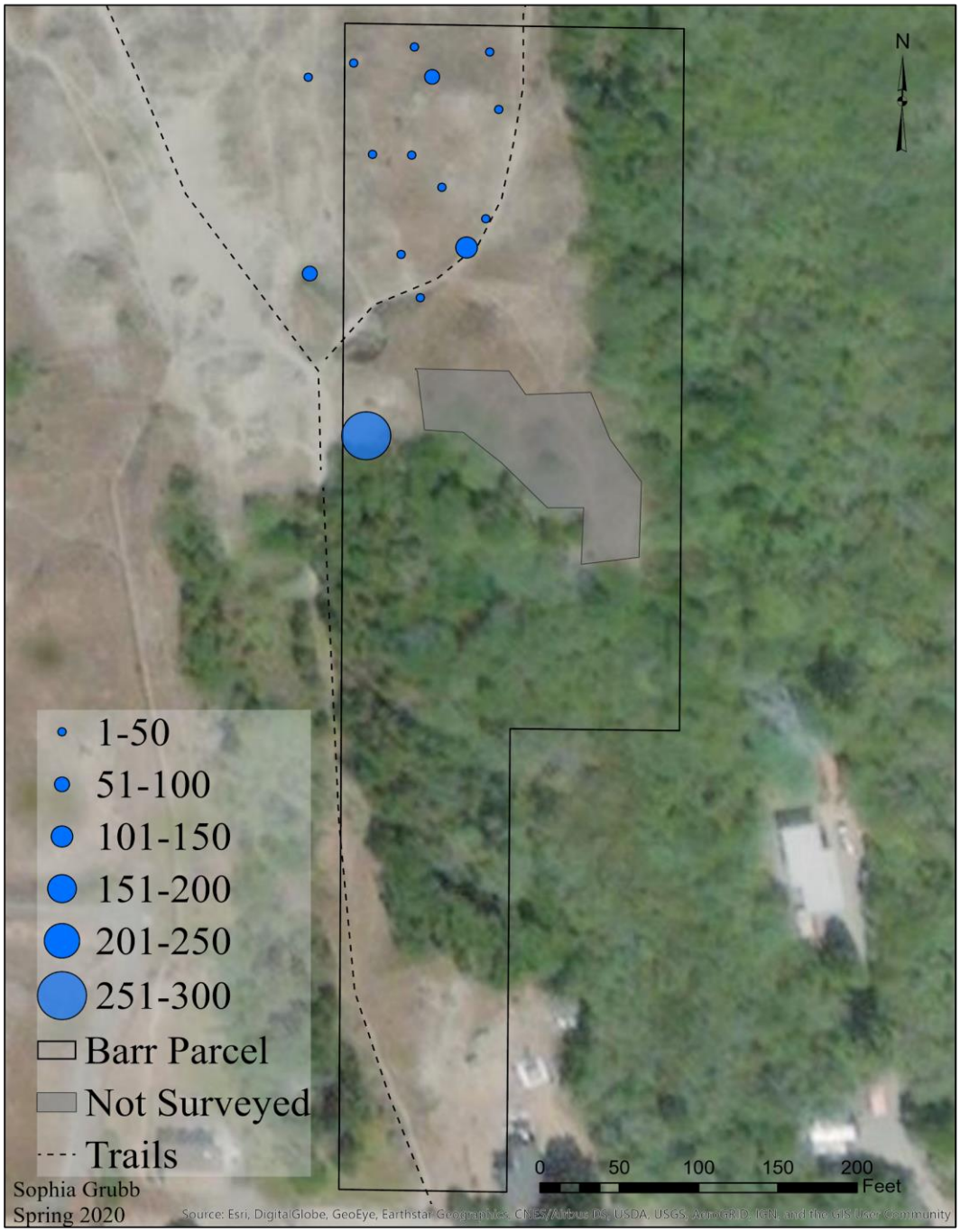


Figure 12: Gilia millefoliata distribution in a section of the Barr Parcel with individual point counts ranging from 1-50, 51-100, 101-150, 151-200, 201-250, 250-300.

MANAGEMENT RECOMMENDATIONS

Based on our observations at the Barr parcel we assembled a series of management recommendations to assist in the conservation and restoration of *L. carnosa*, *E. menziesii*, and *G. millefoliata* (Figure 13). First and foremost, we recommend invasive plant removal in the Barr parcel. We found a variety of invasive plants present on the site during our surveying, including *C. chilensis, L. arboreus, R, armeniacus,* and *A. arenaria*. To prevent these invasive plant species from outcompeting the rare native plant species described at this site, they should be removed. The southern end of the parcel is unsuitable habitat for any of the three rare species of concern because it is mostly forested. Invasive removal is still recommended to reduce reseeding in the nearby suitable habitat.

Invasive Species Removal Recommendations

Carpobrotus chilensis Removal

Carpobrotus chilensis was only observed in sparse patches throughout the site and should pose no issue for our three species' success if Friends of the Dunes continues their restoration efforts. This plant is fairly easy to remove using bare hands, but shovels and rakes can also be helpful (Andreu et al., 2010). Due to the dense mats that the plant forms, it is possible to remove large patches by rolling them up like a carpet or rug (Ditomaso, 2013). This can be more efficient than ripping up small pieces by hand, saving time and energy for staff and volunteers. Lastly, it is recommended that all plant material be removed to prevent resprouting (Andreu et al., 2010). If this is not an option, mulching with the plant material will prevent most resprouting (Ditomaso, 2013).

Lupinus arboreus Removal

Lupinus arboreus was found in small clusters in the northwestern portion of the Barr Parcel (*Figure 13*). Since *L. arboreus* is a shrub, it is recommended that it be removed using a weed wrench to ensure that roots are dislodged. This can be fairly difficult due to the slopes and loose soil, especially if mature. A second option for mature shrubs is to cut the base of the trunk with a saw or clippers and split the trunk to avoid resprouting (Ditomaso, 2013). This can be done with a shovel, axe, pulaski, or mattock. If young enough, *L. arboreus* can be removed by hand-pulling or dug up with a shovel. It is recommended that the area be rechecked for small plants during flowering so they are easily visible.

Rubus armeniacus Removal

R. armeniacus occurs in the southwestern portion of the parcel (*Figure 13*). It is an extremely robust invasive that demands a lot of time and effort to remove manually. Its dense, connected, and multi-stem brambles make it impossible to remove large portions at one time without machinery. It also has large thorns that necessitate careful extraction. In regard to manual removal, it is recommended that the aboveground biomass be removed (with gloves and long sleeves) using a pulaski, mattock, or clippers and as much of the roots be dug up as possible. It is unlikely that all of the below-ground biomass will be removed, and it is imperative that root sprouts be managed regularly to exhaust the root stores (Ditomaso, 2013).

Ammophila arenaria Removal

Ammophila arenaria was mainly seen on the edges of our site and in areas adjacent to our site (Figure 13). This could pose an issue to our three species due to its successful spread and

competition against natives (California State Parks, n.d.). The areas in and around the Barr parcel that are covered by *A. arenaria* pose a problem, but also an opportunity. The problem is that *A. arenaria* can colonize both disturbed and undisturbed soil throughout the dunes. So, even though restoration may be done on the Barr parcel, the existence of *A. arenaria* nearby means the possibility of recolonization unless the grass is routinely monitored and managed (Ammophila arenaria Profile, 2018). The areas that have been taken over by *A. arenaria* offer the opportunity of a blank canvas for native vegetation. Once eliminated, prime habitat for our three focal species will open up and become available (Maslach, 2002). There are only so many square miles of coastal dunes where these species can thrive, so it is important to open up any area of suitable habitat where they can thrive. The removal of these invasive species should be done manually without the use of herbicides, as the effects of herbicides on the sensitive native species in the dune ecosystem is not known. This is in line with Friends of the Dunes' strong belief in manual invasive removal (Friends of the Dunes, 2020). According to the California Invasive Plant Council (2013), *A. arenaria* can be completely removed through a two-year process. It is recommended to start the process in March, when the grass is emerging from dormancy, and that the rhizomes be dug out to a depth of eight inches. Resprouts should then be removed approximately every one to two months for two seasons.

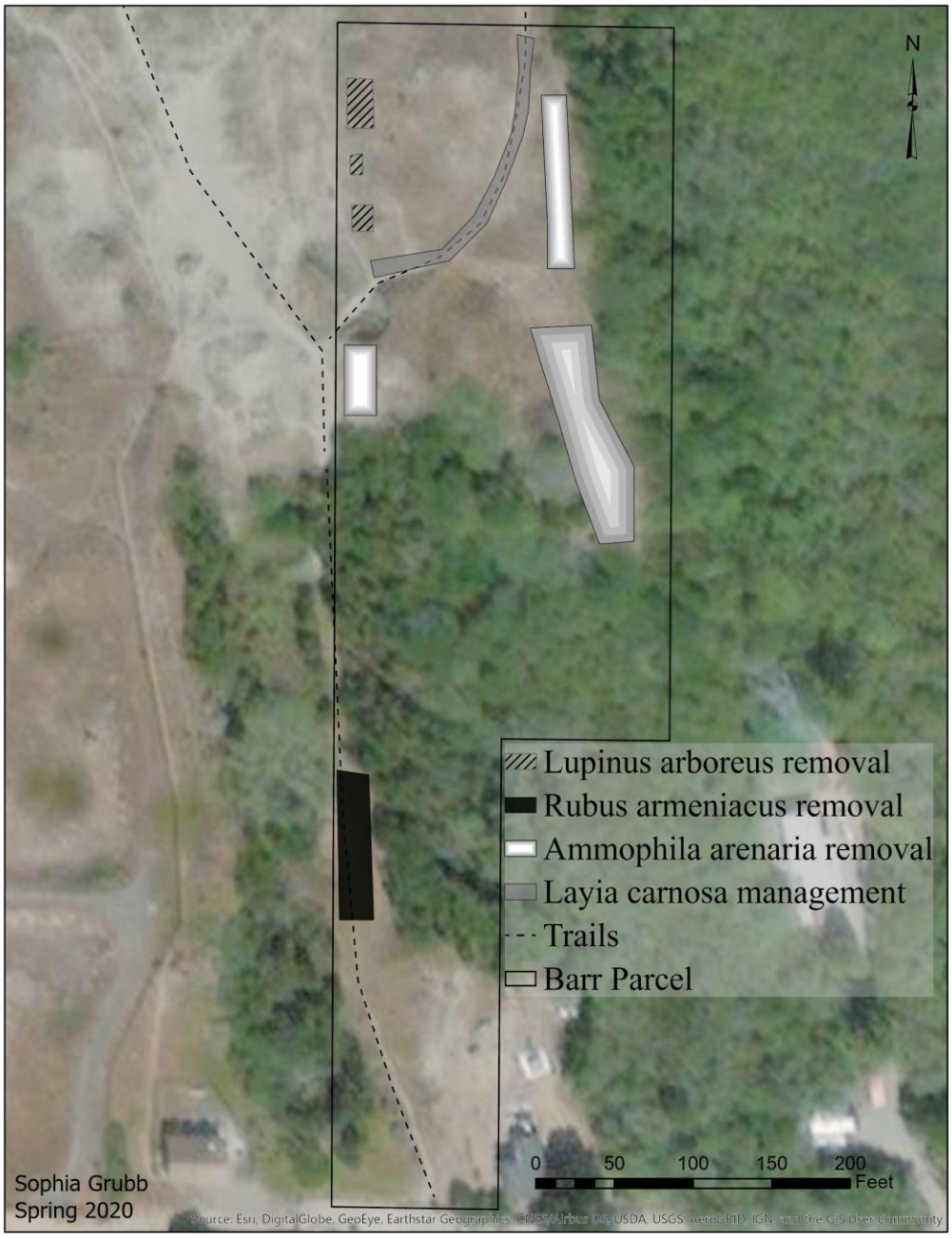


Figure 13: Map showing recommended management actions to remove invasive species Rubus armeniacus, Ammophila arenaria, and Lupinus arboreus and to maintain trails for L. carnosa. The trail indicated under L. carnosa management should be used for increasing abundance of the species. Various regions of the Barr parcel will have invasive species removal.

Management of Rare Species

Beach Layia (*Layia carnosa*)

Layia carnosa populations do better when exposed to regular disturbance (Abrego et al., 2017). We found *L. carnosa* solely along, and next to, the walking paths within our site. This is consistent with findings that *L. carnosa* responds well to disturbance (Abrego et al., 2017). It is important that the paths in the Barr parcel are open to the public and exposed to foot traffic to maintain disturbance needed by the *L. carnosa* population. Restoration crews can remove competing plants within a 1ft radius of *L. carnosa* plants to replicate disturbance and encourage *L. carnosa* germination and growth (Abrego et al., 2017). To create suitable habitat for *L. carnosa* that is away from roads and trails, it was recommended by Abrego et al. (2017) that at least a one meter area around the plant be completely cleared of vegetation, mimicking disturbance and giving the individual plant the room that it needs to reproduce and spread (Abrego et al., 2017). The National Park Service has also witnessed a significant increase and return of *L. carnosa* in restored dune areas, making its success highly probable with the removal of invasive plant species (Endangered Beach Layia, 2020).

Menzies' Wallflower (*Erysimum menziesii*) and Dark-eyed Gilia (*Gilia millefoliata*)

In contrast to *L. carnosa*, *E. menziesii* and *G. millefoliata* do not respond positively to disturbance. Thus, it is important that trails are clearly marked, and visitors understand the importance of staying on the path. This can be encouraged with signage at the entrance from Lupine Ave and throughout the trail system. This information could also become part of the Friends of the Dunes education curriculum during their programs. *Erysimum menziesii* responds

well to seeding and transplanting, and is thus a candidate for this method regarding new areas cleared of *A. arenaria* and *C. edulis* (Maslach, B. 2002)

While surveying we unknowingly collected some data points outside of the Barr parcel but decided to include them on our maps because they would benefit from restoration in the area as well, and could help to recolonize parts of the Barr parcel through seeding. These findings are crucial evidence showing that *E. menziesii, L. carnosa,* and *G. millefoliata* grow around and within the Barr Parcel (Figure 3, Figure 4, and Figure 5).

The main source of human error in this project was counting individual plants in large groups. We estimated the number of individuals in large groups and our estimations are probably either over or under the true number of individuals. Also, on the first day of data collection we did not have flags to section off parts of the parcel that were already surveyed. This could have resulted in underestimating or overestimating the counts. There were three surveyors, so there is likely to be some inconsistency in data collection. GPS units are not entirely accurate, so the location of our points on the map may be slightly off.

CONCLUSION

Dune ecosystems are unique and sensitive. The Friends of the Dunes property is one of few restored native dune ecosystems on the west coast. We surveyed the Barr parcel for Friends of the Dunes in order to map the distribution of three rare plants on the property and make management recommendations. All three rare species were present in the parcel, as were many invasive species. These invasive species at the site represent a threat to rare dune plants. Incorporating the Barr parcel into Friends of the Dunes' restoration plan is critical to protecting

the rare plants *L. carnosa*, *E. menziesii* and *G. millefoliata* in the site. Removing invasive plant species will eliminate competition that is threatening the rare plant populations. *Layia carnosa* populations thrive when exposed to small-scale disturbance, but *E. menziesii* and *G. millefoliata* are more sensitive to disturbances. These rare plants in the Barr parcel will depend on conservation and restoration actions to survive in their native habitat.

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APPENDIX A

Appendix A. Raw GPS data of all the point counts collected.

ID	Latitude	Longitude	Elevation	Species	Count
1	40.85353302	-124.167422	14.698177	*Erysimum*	4
2	40.85356596	-124.167443	12.635967	*Erysimum*	1
3	40.85353302	-124.167413	13.102966	*Layia*	450
4	40.85401196	-124.167532	10.660266	*Layia*	450
5	40.85362002	-124.167264	10.557167	*Erysimum*	1
6	40.85364098	-124.167259	10.976089	*Erysimum*	7
7	40.85361198	-124.167245	9.26673	*Erysimum*	1
8	40.85361801	-124.167233	8.919079	*Erysimum*	1
9	40.85366	-124.167231	9.672012	*Erysimum*	1
10	40.85366998	-124.16721	7.583762	*Erysimum*	1
11	40.85369797	-124.167237	9.019809	*Erysimum*	1
12	40.85370401	-124.167264	10.168541	*Erysimum*	2
13	40.85372002	-124.167255	9.532665	*Erysimum*	1
14	40.85369999	-124.167229	8.510089	*Erysimum*	1
15	40.85372798	-124.167241	8.391086	*Erysimum*	1
16	40.853731	-124.167192	7.620071	*Erysimum*	1
17	40.85373896	-124.167215	8.174356	*Erysimum*	1
18	40.85376604	-124.167204	8.629979	*Erysimum*	1
19	40.85371398	-124.167138	8.240669	*Erysimum*	1
20	40.85369202	-124.167128	8.447942	*Erysimum*	1
21	40.85374701	-124.167163	8.490762	*Erysimum*	2

ID	Latitude	Longitude	Elevation	Species	Count
22	40.85377299	-124.167125	9.548319	*Erysimum*	2
23	40.85380401	-124.167127	9.339313	*Erysimum*	1
24	40.85378498	-124.167169	8.430602	*Erysimum*	1
25	40.85379504	-124.167209	8.583036	*Erysimum*	2
26	40.85379696	-124.167219	8.581714	*Erysimum*	9
27	40.85376402	-124.167266	7.997485	*Erysimum*	1
28	40.85362899	-124.16735	12.497231	*Gilia*	20
29	40.85355297	-124.167305	10.800236	*Gilia*	20
30	40.85373502	-124.167394	12.057093	*Erysimum*	3
31	40.85377299	-124.167393	12.203886	*Erysimum*	1
32	40.85379998	-124.167322	7.856062	*Erysimum*	1
33	40.853774	-124.167307	7.398282	*Erysimum*	1
34	40.853774	-124.167294	7.864299	*Erysimum*	2
35	40.85378104	-124.167287	7.212119	*Erysimum*	1
36	40.85378196	-124.167284	7.213779	*Erysimum*	1
37	40.85379797	-124.167243	7.75097	*Erysimum*	1
38	40.85380501	-124.167329	9.076871	*Gilia*	15
39	40.85383703	-124.167168	9.179106	*Erysimum*	1
40	40.85386897	-124.167155	9.804765	*Erysimum*	3
41	40.85379797	-124.167288	7.066071	*Erysimum*	1
42	40.85374902	-124.167259	6.554696	*Gilia*	5
43	40.85378397	-124.167309	7.194967	*Erysimum*	2
44	40.85379898	-124.167315	7.444319	*Erysimum*	7
45	40.85382303	-124.167267	6.513769	*Erysimum*	3
46	40.85386897	-124.167158	9.172244	*Erysimum*	3

ID	Latitude	Longitude	Elevation	Species	Count
47	40.85388799	-124.167132	8.639771	*Gilia*	3
48	40.85391004	-124.167143	8.873036	*Erysimum*	2
49	40.85393602	-124.167152	8.637398	*Erysimum*	1
50	40.85395404	-124.167198	8.041403	*Erysimum*	9
51	40.85383804	-124.16737	7.588637	*Erysimum*	1
52	40.85388104	-124.167381	7.961024	*Erysimum*	1
53	40.85364299	-124.167201	4.542882	*Gilia*	150
54	40.85378003	-124.16709	7.952044	*Layia*	1
55	40.85363603	-124.167136	5.284426	*Layia*	5
56	40.85354601	-124.167294	7.417632	*Layia*	1
57	40.85355003	-124.167335	8.902482	*Layia*	1
58	40.853544	-124.167355	9.573705	*Layia*	1
59	40.85369403	-124.167158	5.034986	*Gilia*	50
60	40.85376796	-124.167068	6.923934	*Erysimum*	3
61	40.85374801	-124.167035	8.000948	*Erysimum*	2
62	40.85370996	-124.16702	8.830126	*Erysimum*	1
63	40.85370703	-124.167044	8.290777	*Erysimum*	2
64	40.85362899	-124.16714	4.983542	*Erysimum*	1
65	40.85360703	-124.167147	5.526885	*Erysimum*	1
66	40.85380602	-124.167419	10.315115	*Gilia*	30
67	40.85396703	-124.167464	8.091232	*Gilia*	10
68	40.85399704	-124.167326	4.147268	*Gilia*	30
69	40.853961	-124.167327	4.027053	*Erysimum*	1
70	40.853961	-124.167388	4.183598	*Erysimum*	1

ID	Latitude	Longitude	Elevation	Species	Count
71	40.85392504	-124.167381	5.499916	*Erysimum*	3
72	40.85391398	-124.167326	4.806157	*Erysimum*	1
73	40.85354702	-124.167147	5.263216	*Erysimum*	4
74	40.85353	-124.167147	5.566691	*Erysimum*	2
75	40.85351902	-124.167145	5.261193	*Erysimum*	1
76	40.85350603	-124.16713	4.475232	*Erysimum*	4
77	40.85350603	-124.167089	4.429687	*Erysimum*	2
78	40.85348298	-124.167074	4.550093	*Erysimum*	1
79	40.85347996	-124.167061	4.02887	*Erysimum*	2
80	40.85348499	-124.167051	4.417411	*Erysimum*	2
81	40.85349999	-124.167027	6.001307	*Erysimum*	2
82	40.85351701	-124.167001	8.043053	*Erysimum*	1
83	40.85349396	-124.167001	6.558198	*Erysimum*	1
84	40.85350896	-124.166986	7.116557	*Erysimum*	1
85	40.85346001	-124.167035	4.98527	*Erysimum*	3
86	40.85343	-124.167012	2.825103	*Erysimum*	3
87	40.85341098	-124.167011	2.82884	*Erysimum*	3
88	40.85341198	-124.167036	3.375834	*Erysimum*	1
89	40.85340796	-124.167027	3.37024	*Erysimum*	2
90	40.85399	-124.167154	5.798775	*Gilia*	20
91	40.85394398	-124.167285	5.037364	*Gilia*	75
92	40.85553998	-124.166064	1.12428	*Gilia*	150
93	40.85571298	-124.166041	1.305286	*Gilia*	150
94	40.85575598	-124.166123	5.559652	*Gilia*	150

ID	Latitude	Longitude	Elevation	Species	Count
95	40.855975	-124.166342	13.258457	*Gilia*	60
96	40.854508	-124.166946	18.609095	*Erysimum*	1
97	40.85330696	-124.167424	15.000576	*Gilia*	280
98	40.85359303	-124.167558	9.796482	*Gilia*	75
99	40.85355297	-124.167361	12.152748	*Erysimum*	1
100	40.85356001	-124.167367	12.100803	*Erysimum*	1
101	40.85359102	-124.167423	11.767519	*Erysimum*	1
102	40.85364902	-124.167483	10.711441	*Erysimum*	1
103	40.85366696	-124.167427	11.913091	*Erysimum*	1
104	40.85369303	-124.167443	10.397594	*Erysimum*	2
105	40.85366202	-124.167485	11.112541	*Erysimum*	1
106	40.85372396	-124.167432	13.042759	*Erysimum*	1
107	40.85372396	-124.16747	10.585049	*Erysimum*	1
108	40.85376302	-124.167446	12.233002	*Erysimum*	3
109	40.853817	-124.167508	10.568634	*Erysimum*	2
110	40.853832	-124.167473	11.970062	*Erysimum*	1
111	40.85382798	-124.16746	12.98098	*Erysimum*	1
112	40.85385203	-124.167505	10.635782	*Erysimum*	1
113	40.85388397	-124.167498	11.591263	*Erysimum*	1
114	40.85395698	-124.167538	9.122707	*Erysimum*	1
115	40.85398598	-124.167592	10.852718	*Erysimum*	1
116	40.85408698	-124.167564	9.319942	*Erysimum*	1
117	40.85405798	-124.167615	12.325386	*Erysimum*	2
118	40.85391599	-124.167648	9.811687	*Erysimum*	1
119	40.85394097	-124.167568	8.346341	*Gilia*	30

ID	Latitude	Longitude	Elevation	Species	Count
120	40.85379797	-124.16759	9.274536	*Erysimum*	1
121	40.85379797	-124.167534	10.906728	*Erysimum*	1
122	40.85375698	-124.167526	10.942528	*Erysimum*	1
123	40.85374399	-124.167555	9.256289	*Erysimum*	1
124	40.85370602	-124.167529	8.633331	*Erysimum*	1
125	40.85361801	-124.167584	7.751465	*Erysimum*	1
126	40.85362497	-124.167595	8.112161	*Erysimum*	1
127	40.85366503	-124.167614	10.100775	*Erysimum*	1
128	40.85356403	-124.167676	12.047352	*Erysimum*	1
129	40.85359999	-124.167522	7.397844	*Erysimum*	2
130	40.85357099	-124.16752	10.297081	*Erysimum*	1