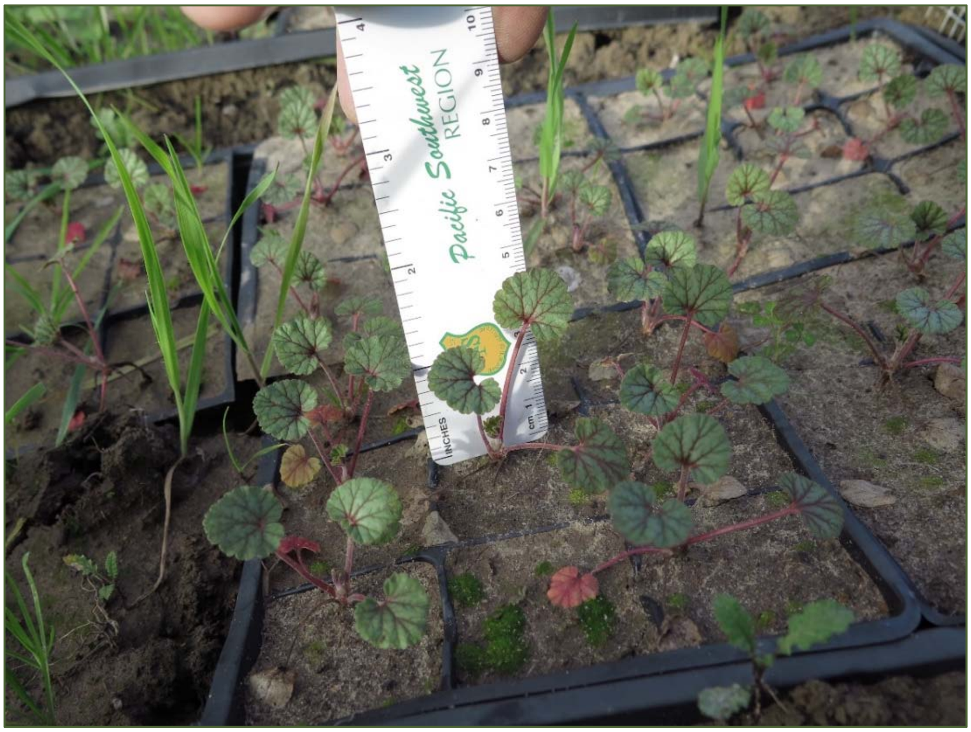
SPECIAL STATUS AND INVASIVE PLANT MANAGEMENT PILOT PROJECT

EAST CONTRA COSTA COUNTY HABITAT CONSERVATION PLAN / NATURAL COMMUNITY CONSERVATION PLAN



MARCH 2018

Prepared for

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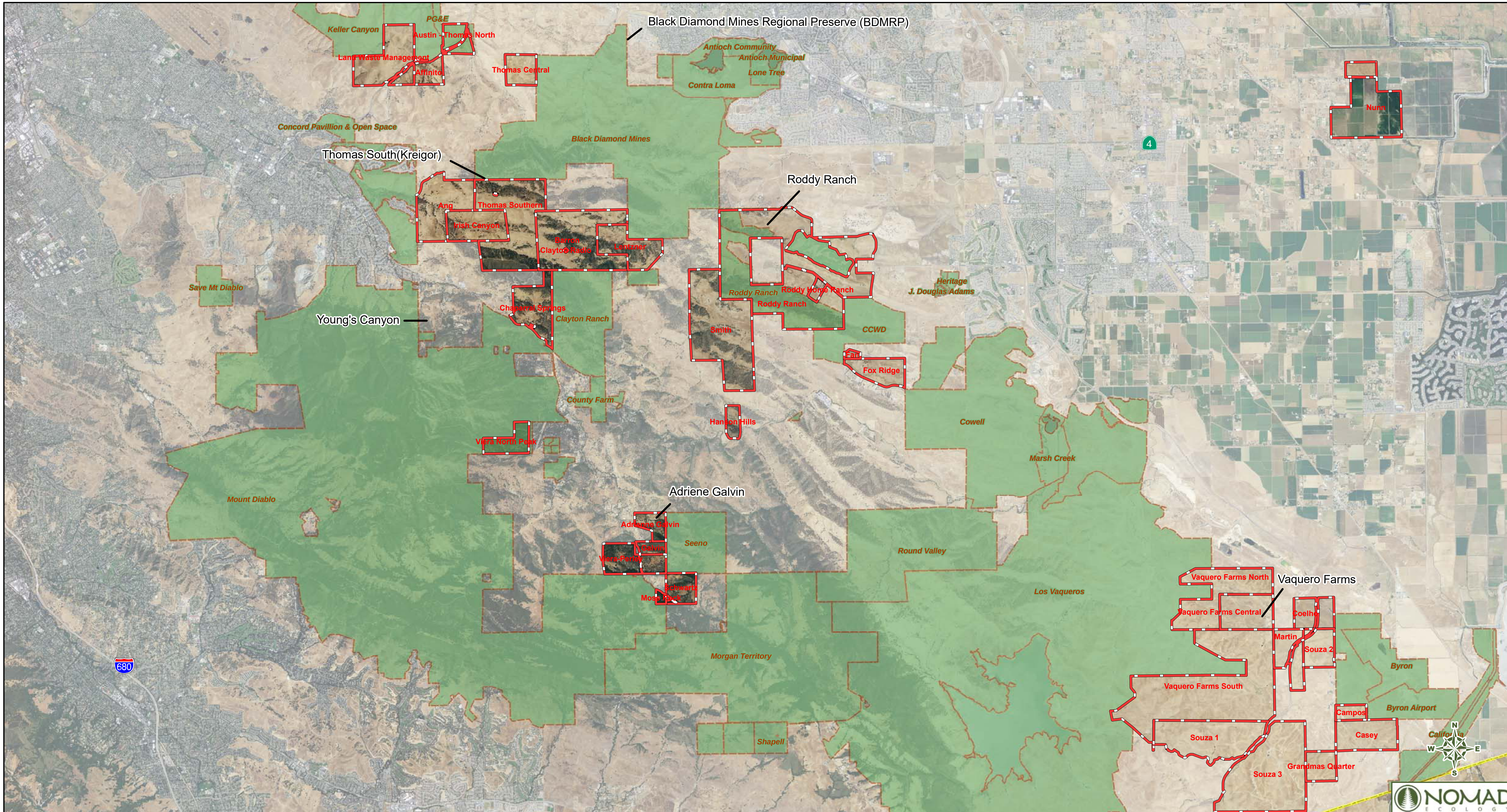
Section 1. INTRODUCTION

This project is a targeted study aimed at supporting adaptive management strategies for managing sensitive plant species that are listed in the East Contra Costa County HCP/NCCP ("HCP/NCCP" or "Plan"). Specifically, the goals of this project are to clarify the potential impacts of invasive weed management on select special status species covered by the HCP/NCCP and identify management tools and recommendations that increase efficacy of weed treatment while also protecting special status plant species. This project was the result of a collaboration between Nomad, East Contra Costa County Habitat Conservancy (Conservancy) and the East Bay Regional Parks Department (EBRPD). Nomad was responsible for designing and implementing the study as well as collecting, analyzing and reporting the results of the data, EBPRD assisted with herbicide application, and the Conservancy provided oversight and grant administration.

1.1. BACKGROUND

The East Contra Costa County Habitat Conservancy has biological goals and objectives for a number of plant species. Controlling invasive weeds is a key component to achieving biological goals of preserving and increasing rare plant populations in the HCP/NCCP Preserve System. Where invasive and special status species co-occur, management becomes complicated. Based on initial botanical resource surveys, two invasive grass species have been identified as threats for impacting sensitive plant species in the Preserve System. This study was designed to provide practical biological information to inform and design weed management strategies that will be effective, while having limited impact on special status species plant populations. Specifically, this inquiry focuses on the biology and relationship between three special status plant species targeted in the HCP/NCCP for conservation; round-leaved filaree (*California macrophylla*), shinning navarretia (*Navarretia nigelliformis* subsp. *radians*), and big tarplant (*Blepharizonia plumosa*); and two invasive grass species, medusa head (*Elymus caput-medusae*) and barbed goatgrass (*Aegilops triuncialis*). By comparing phenological patterns of these species as well as investigating the effects of different weed treatments on species composition, we hoped to identify key points of intervention and provide guidelines for effective management of both invasive weeds and special status plant species.

The study was comprised two different investigations: 1) a seed germination study and 2) an invasive weed management study. The seed germination study was set up and implemented at Black Diamond Mines Regional Preserve (BDMRP) and Vaquero Farms. These areas were selected because they both support the special status plants and invasive plants targeted in this study and they reflect the extreme range of climates within the geographic area of the HCP/NCCP. Seed collection of the target species was completed on Roddy Ranch, Thomas South (Kreigor), Adrienne Galvin, and Young's Canyon (owned by Save Mount Diablo). Invasive plant treatments and monitoring occurred at two locations within the preserve system: Kreigor and Roddy Ranch properties (Figure 1). Each of these locations support several rare plant taxa, including the three subjects of this study, and have significant populations of medusa head grass.



March 2018

Special Status and Invasive Plant Management Pilot Project

Legend

- Acquisition Parcels
- Public Land and Easements
- County Boundaries

Figure 1

Overview of Study Area

East Contra Costa County Habitat Conservancy

East Contra Costa County Habitat Conservancy

1:95,040

0 0.75 1.5 Miles

Sources: NAIP 2012; Contra Costa County. Projection: NAD 83 UTM Zone 10 North.

Contra Costa County, California

Goals and conservation measures identified in the Plan's conservation strategy that are addressed by this project include those for covered plants, exotic plant control, habitat enhancement and restoration, grassland management and monitoring and adaptive management needs. Specifically, the following conservation measures are addressed:

- **Conservation Measure 1.4** is intended to control the spread of noxious weeds (as defined by the California Department of Food and Agriculture) and invasive exotic plants listed by the California Exotic Pest Plant Council into new areas and to control infestations of noxious and serious weeds, where practicable

- **Conservation Measure 2.1** identifies the need to enhance, restore, and create land cover types and species habitat to improve the function of natural communities, maintain or increase populations of covered species, and promote native biological diversity within preserves.

- **Conservation Measure 2.4** requires that native grasslands will be enhanced in the preserves.

- **Conservation Measure 3.9** identifies the need to conduct experimental management to maintain or enhance covered plant populations.

- **Monitoring and Adaptive Management goals** relevant to this project by incorporating hypothesis testing and experimental management through projects and directed research; as well as collect the data necessary to refine and implement effective management within the Preserve System.

Statewide Applicability: In addition to addressing these conservation goals this study contributes to the general knowledge of controlling medusa head grass in rangelands across California. The lessons learned by this study are useful to land managers throughout California who are working to control invasive weeds and conserve special status plant populations.

1.2. SPECIES ECOLOGY AND DIFFICULTIES

In 2014, Nomad conducted a literature review, on behalf of the Conservancy, to better understand the biology and control of medusa head and barbed goatgrass. This literature review is included in Appendix A. In addition, a literature review that yielded no results, was also conducted to investigate biological and ecological information for the special status plants: round-leaved filaree, big tarplant, and shinning navarretia Through this effort, significant data gaps were identified and it was determined adequate information was not available to provide guidance to ensure preserve managers have the tools necessary to meet HCP/NCCP goals related to protecting and recovering rare plant populations. In particular, there were clear data gaps of biological information on target special status species; habitat requirements, germination timing, and germination rates.

Studies within the preserve system, have identified populations of the target sensitive plant species. Based on field observations these special status plant species have a strong affinity for heavy clay soils that Nomad refers to as clay barrens. Clay barrens generally act as refugia for many native species, harboring a greater cover and diversity of native plants species than in the surrounding non-native California grasslands. Mechanisms driving the relationship between target species and heavy clay soils is not well understood. However, one likely facet to this relationship is that clay barrens do not typically support high cover of non-native grasses, and thus are not vulnerable to the build-up of thatch or competition typical of non-native annual grassland species.

Most non-native annual grasses have a difficult time establishing and producing significant biomass in these clay barrens, though field observations of medusa head and barbed goatgrass have shown potential to occupy clay barrens and produce thatch, thus reducing habitat quality (Bartosh pers. observation). The ability of these species to invade unique habitats and soil types has been demonstrated in the literature (Rice et al. 2013, Young 1992), but clay barren invasion has not yet been thoroughly documented. Medusa head grass was first documented in Oregon in in 1887 and has since caused the wide spread degradation in varied habitats from serpentine soils (Meimberg et al. 2010) to vernal pools (Pollak and Kan 1998). Currently, medusa head grass is recognized as having an affinity for heavier clay soils that hold moisture later in the season, which supports this species' late season flowering. However, in the 1960s, medusa head grass was reported to favor courser soils (Young 1992). This apparent expansion in potential and utilized habitat indicates the species is either adapting to new conditions, or has been introduced multiple times from different genetic populations. This apparent expansion to utilize heavy clay soils is also of specific concern to these clay barren refugia habitats.

Barbed goatgrass, was first documented in California in 1907, though, in the last two decades it has become a wide spread problem (Davies et al. 2010). This species has also shown an ability to invade various habitats, from California non-native annual grasslands to serpentine soils. Barbed goatgrass invasion of serpentine soil appears to be a recent development. The ability to invade serpentine soils as well as high productivity grasslands is driven by a mix of phenotypic plasticity and genetic response (Meimberg et al. 2010; Rice et al. 2013). Barbed goatgrass may also reduce diversity by altering soil conditions. One study showed a significant change in microbiological communities in the soils as well as reduced vigor in native plants after barbed goatgrass establishment (Batten et al. 2006; Batten et al. 2008).

The ability of barbed goatgrass and medusa head to invade a wide range of habitats is of particular concern because both species have a negative effect on native diversity. This is in large part driven by the fact that both species have high silica content in the leaves, culms, and flowers/fruits. Plant matter containing high amounts of silica does not readily decompose, and creates a dense layer of litter that prevents other species from germinating and/or emerging. This drives grassland species composition towards a monoculture of invasive grasses and reduces native diversity (Maurer et al. 2014, Peters 1994). Control of both species is time consuming and expensive, and control of medusa head in particular, has been the subject of many studies.

Though there are ample studies investigating control methods for medusa head (Maurer et al. 2014) all are focused on controlling this species in degraded habitat, and not in higher quality habitats harboring special status and sensitive plant species such as those found in the HCP/HCCP Preserve System clay barren habitats. Land managers have used various methods of control on these invasive grasses, however, there is little understanding how these treatments impact other grassland species and species composition in general. While this is not a large concern in areas that are already severely degraded and dominated by non-native species typical of California non-native grassland, it is a serious concern when treating these invasive species in higher quality habitats and where they co-occur with special status plant species.

1.3. TARGET SPECIES

1.3.1 SPECIAL STATUS PLANTS

Round-Leaved Filaree (*California macrophylla*)

Round-leaved filaree [*California macrophylla* (Hook. & Arn. [1]) J.J. Aldasoro, C. Navarro, P. Vargas, L. Sâez, & C. Aedo] has a California Rare Plant Rank of 1B.1 indicating it is rare and seriously endangered

[1] In botanical literature binomial scientific names are followed immediately by the name of or the abbreviation for the publishing author(s) who validated the name. A scientific name is not strictly complete without the name(s) of the validating author(s) attached. Plant species that appear in this report that have regulatory significance are referred to by their binomial scientific name and author for nomenclatural relevance.

in California (CNPS 2018). This species is an annual herb of the geranium family (Geraniaceae). The type locality[2] for this species is from an 1833 David Douglas collection in the Berkeley Hills (Abrams 1955). The etymology of the genus name *California* is from the California floristic province (Baldwin et al. 2012).

Round-leaved filaree is a monotypic species in the *California* genus, which is differentiated from other members of the family by producing radial flowers, 5 fertile stamens, palmately lobed leaves, and no staminodes (Baldwin et al. 2012). This taxon is in flower from March to May (CNPS 2018).

Round-leaved filaree in seed

Round-leaved filaree occupies clay soils in cismontane woodland and valley and foothill grassland (CNPS 2018). It has been recorded as occurring in Alameda, Butte, Contra Costa, Colusa, Fresno, Glenn, Kings, Kern, Lake, Los Angeles, Merced, Monterey, Napa, Riverside, Santa Barbara, San Benito, Santa Clara, Santa Catalina Island, Santa Cruz Island, San Diego, San Joaquin, San Luis Obispo, San Mateo, Solano, Sonoma, Stanislaus, Tehama, Tulare, Ventura, and Yolo counties between 33 and 3,937 feet (15 to 1,200 meters) in elevation (CNPS 2018).

Big Tarplant (*Blepharizonia plumosa*)

Big tarplant [*Blepharizonia plumosa* (Kellogg) Greene] has a California Rare Plant Rank of 1B.1 indicating it is rare and seriously endangered in California (CNPS 2018). It is an annual species of the sunflower family (Asteraceae). The type locality for this species is from Stockton in San Joaquin County, California. The collector of this specimen is unknown. The etymology of the genus name *Blepharizonia* is a Greek word referring to the short plumose pappus (Baldwin et al. 2012).

Big tarplant is differentiated from other members of the genus by producing longer disk pappus (up to 3 mm), gray green leaves, heads in a spike to panicle-like clusters, and branches that are often arched-ascending (Baldwin in Baldwin et al. 2012). This late blooming taxon is in flower from July to November (CNPS 2018).

[2] A type locality is the geographical location where the type specimen, which is used to describe a species for the first time, was originally found.

Big tarplant in bloom.

Big tarplant occupies heavy clay sites in valley and foothill grassland (CNPS 2018). It occurs in Alameda, Contra Costa, San Joaquin, and Stanislaus counties between 98 and 1,657 feet (30 to 505 meters) in elevation (CNPS 2018).

Shining Navarretia (*Navarretia nigelliformis* subsp. *radians*)

Shining navarretia [*Navarretia nigelliformis* Green subsp. *radians* (J. T. Howell) A.G. Day] has a California Rare Plant Rank of 1B.2 indicating it is rare and moderately endangered in California (CNPS 2018). This species is an annual herb of the phlox family (Polemoniaceae). The type locality for this species is from a collection by John Thomas Howell in 1938, from Paicines in San Benito County (Abrams 1955). The etymology of the genus name *Navarretia* is from the 18th century Spanish physician, Francisco Fernandez de Navarrete (Baldwin et al. 2012).

Shining navarretia is differentiated from other members of the genus by being prickly, having strap-shaped calyx lobes, yellow corollas with spotted throats, and gray-green herbage (Baldwin et al. 2012). This taxon is in flower from March to July (CNPS 2018).

Shining navaretia in bloom.

Shining navarretia occupies heavy clay sites in cismontane woodland, valley and foothill grassland, and vernal pools (CNPS 2018; Baldwin et al. 2012). It occurs in Alameda, Contra Costa, Colusa, Fresno, Madera, Merced, Monterey, San Benito, San Joaquin, and San Luis Obispo counties between 249 and 3,281 feet (76 to 1000 meters) in elevation (CNPS 2018).

1.3.2 INVASIVE PLANTS

Medusa head grass (*Elymus caput-medusae*)

Medusa head grass [*Elymus caput-medusae* L.] has a Cal-IPC rank of High, indicating this species has severe ecological impacts on physical processes, plant and animal communities, and vegetation structure (Cal-IPC 2018). This species is an annual herb of the grass family (Poaceae). The type locality for this species is from an 18th century Linneaus collection from Portugal, Spain (Tropicos 2018). The etymology of *Elymus* is from a Greek word meaning covered, referencing the tightly cover grains (Baldwin et al. 2012).

Medusa head grass is differentiated from other members of the genus by being annual (Baldwin et al. 2012). This taxon flowers from April to July (Cal-IPC 2018). For more information on ecology and control of medusa head grass refer to Appendix A.

Medusa head in seed

Medusa head grass occupies disturbed areas and in various soils in scrub, chaparral, coastal regions, riparian area, and oak woodland (Cal-IPC 2018). In California it is found in Tehama, Siskiyou, Solano, Yuba, Ventura, Nevada, Calaveras, El Dorado, Sacramento, Placer, San Luis Obispo, Modoc, Butte, Shasta, Plumas, Merced, Glenn, Sutter, Lake, Lassen, San Benito, Mendocino, Humboldt, Trinity, Monterey, Santa Barbara, Sonoma and San Diego counties (CCH 2018) between 0 to 6,566 feet (0 to 2,000 meters) in elevation (Baldwin et al. 2012).

Barbed Goatgrass (*Aegilops triuncialis*)

Barbed goatgrass [*Aegilops triuncialis* L.] has a Cal-IPC rank of High, indicating this species has severe ecological impacts on physical processes, plant and animal communities, and vegetation structure (Cal-IPC 2018). This species is an annual herb of the grass family (Poaceae). The type locality for this species is also from an 18th century Linneaus collection only given as the Mediterranean (Tropicos). The etymology of *Aegilops* is from a Greek word meaning preferred by goats (Baldwin et al. 2012).

Barbed goatgrass is differentiated from other members of the genus by spikelets having more than one awn and distal spikelets being greater than 7mm (Baldwin et al. 2012). This taxon flowers from May to July (Cal-IPC 2018). For more information on ecology and control of barbed goatgrass refer to Appendix A.

Barbed goatgrass germinating in in spring

Barbed goatgrass occupies disturbed area and various soils in scrub, chaparral, coastal regions, riparian area, and oak woodland (Cal-IPC 2018). In addition, based on personal observation, barbed goatgrass is also found growing on serpentine soils Calaveras, Butte, El Dorado, Mendocino, Nevada, San Diego, Solano, San Luis Obispo, Sonoma, Tuolumne, Shasta, Los Angeles, Yolo, Yuba, Colusa, Placer, Amador, Marin, Sacramento, Napa, San Joaquin, Santa Clara, Contra Costa, Lake, Glenn, Trinity, Alameda, Tehama, Lassen, Stanislaus and Sutter counties (CCH 2018) between 0 to 3,281feet (0 to 1,000 meters) in elevation (Baldwin et al. 2012).

1.4. PROJECT GOALS

The goal of this study is to provide data that will help inform vegetation management practices. More specifically, to assess weed management techniques for control of medusa head grass and barbed goatgrass and their potential effects on special status plants and other native forbs. In an attempt to increase understanding of all target plant species in the context of management practices, there are two components to this project. First, a seed germination study, where seeds of all of the species described in the previous section, were planted and monitored to document germination rates, germination timing, and phenology. Increased knowledge of species life cycles, especially in relation to other species, helps managers use seasonal variance to maximize weed control outcomes while reducing harm to sensitive species that may co-occur with invasive species. Second, an experiment comparing multiple eradication treatments on medusa head and subsequent effects on species composition. Ultimately, we aim to close several of the species knowledge gaps and provide foundational information needed by preserve managers to meet the HCP/NCCP's biological goals and objectives related to protecting and recovering rare plant populations.

Experiments were conducted to:

a. Analyze the germination timing of three covered plant and two noxious weed species in a natural setting, at two locations that represent the range of these species within the preserve system. Seeds were collected from known populations in the preserve system and planted in outdoor plots so germination was driven by seasonal weather patterns to elicit natural germination events.

b. Compare germination timing of target special status plant species with noxious weed germination timing to determine the most effective window for treatment of each of the invasive species, since each may have different germination events.

c. Test and monitor efficacy of a variety of invasive species treatment/control methods that minimize harm to rare plant populations and maximize weed control. Invasive species treatment/control methods were employed at multiple plots. These plots were monitored to evaluate the response of weed species to abatement efforts, evaluate native species richness post-treatment, as well as any impacts to native species composition.

Section 2. STUDY METHODS

The seed germination study was designed as a quick and small pilot project to compare germination dynamics of the three special status species and two invasive grass species. The overarching goal is to determine if there is a viable phenology window for weeds treatments that would effectively reduce weed cover while not harming sensitive and native plant populations. As a pilot project it is also a goal to determine if the study methods are viable for bigger projects. Ideally, the seed germination study would yield results that describe germination rates, survival, germination timing, and phenology of all target species and clarify similarities and differences among various plants. The invasive plant treatment study was designed to compare three treatments and a control in effectiveness of reducing medusa head grass cover and impacts on native species composition. No study plots were installed in barbed goatgrass because there is currently no known population large enough within the preserve system that could contain all the necessary plots. Data from this experiment would inform best management practices that balances treatment effectiveness and reduces impact to special status and other native species.

2.1. SEED GERMINATION STUDY

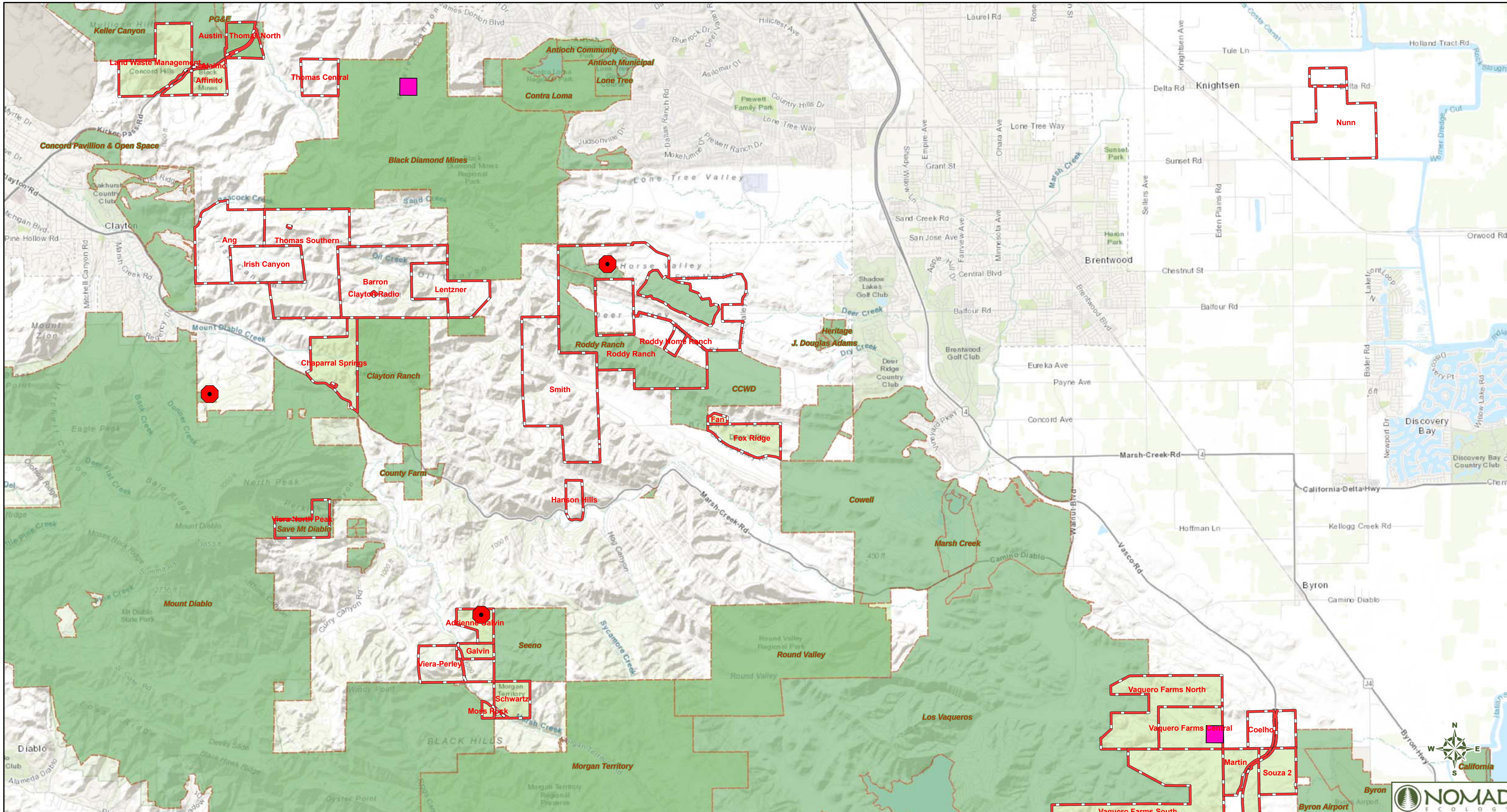
2.1.1 STUDY AREA LOCATIONS

The seed germination study was conducted at two locations: BDMRP, which is owned and managed by EBPRD (and is adjacent to Preserve System properties); and Vaquero Farms, which is part of the HCP/NCCP Preserve System that is co-managed by EBRPD. BDMRP is located south of the City of Antioch and represents the northwestern portion of the Preserve System. Vaquero Farms, located south of the community of Byron and represents the southeastern portion of the preserve system (Figure 2). Both locations are within the East Bay Regional Parks system and adjacent to offices and/or maintenance facilities, allowing for easy access and better protection from animal and human disturbance.

2.1.2 SEED COLLECTION

Seed collection of round-leaved filaree, big tarplant, and shinning navarretia was done under Heath Bartosh's CFDW collecting permit. Nomad followed protocols created by CDFW (CDFW 2015) and Rancho Santa Ana Botanic Garden (Wall et al. 2009) for collecting native seeds. When collecting seed in the wild, CDFW (CDFW 2018) recommends never collecting more than 10% of the seed present less than 20% of the individuals or fruits present in the populations. When collecting seed for rare species or small populations, Rancho Santa Ana Botanic Garden recommends the following three rules: (1) It is generally safe to harvest 10% of the seeds every 10 years or less; (2) It is generally unsafe to harvest 50% percent of seeds every other year; and (3) Less intense, more frequent harvests are safer than more intense, infrequent harvests. All seed collection of special status species for this project fell far below the recommended percentages. Seed collection for medusa head grass and barbed goatgrass did not require any permit and the above-mentioned seed collecting protocols did not apply to these invasive species.

Seed of target special status species was collected at three locations (Figure 2) and seed of target invasive grass species was collected at two locations (Figure 3). All collection sites were located in east Contra Costa County on preserve lands with the exception of barbed goatgrass which was collected on the Young Canyon property owned by the non-profit, Save Mount Diablo. Extensive rare plant surveys and mapping have been done on these lands providing the necessary information to target the most robust populations for seed collection (Nomad 2011-2017).



March 2018

Special Status and Invasive Plant Management Pilot Project

Legend

- Acquisition Parcels
- Public Land and Easements
- Seed Germiation Study
- Seed Collection

Figure 2

Seed Germination Study

East Contra Costa County Habitat Conservancy

East Contra Costa County Habitat Conservancy

1:79,200

0 0.625 1.25 Miles

Sources: NAIP 2012; Contra Costa County. Projection: NAD 83 UTM Zone 10 North.

Contra Costa County, California

A census of the rare plant populations, including an estimation of seeds per individual, was conducted to estimate the amount of seed of special status plants that could be harvested responsibly within the bounds of accepted protocols. For each of the special status plant species, the number of seeds per individual was counted from a representative sample of plants in each population. The size of each population was then either censused by direct count or estimation. Round-leaved filaree and big tar plant populations were documented by direct count of individuals. Shinning navarretia populations consisted of many small plants, often with a hundred or more individuals in a small clump, making it difficult to count individuals efficiently. These populations were estimated by walking five foot transects to make an ocular estimate of each population. To estimate the amount of seed available at each population, the average number of seeds per individual was multiplied by the estimated or censused number of individuals in that population. There were four locations where the special status plant seed was collected: Roddy Ranch, Kreigor, Adrienne Galvin and Young Canyon (Figure 2). Table 1 summarizes the location, datem of seed collection, and amount of seed collected.

Table 1. Seed Collection Dates and Locations

Species	Location	Date	Number of Seeds Collected (Collector's Initials)
California macrophylla round-leaved filaree	Roddy Ranch	4/15/15	140 (BP, GW)
Navarretia nigelliformis subsp. *radians* shinning navarretia	Roddy Ranch	4/27/15	200 (BP, GW)
Elymus caput-medusae medusa head	Adrienne Galvin	6/19/15	120 (BP)
Aegilops triuncialis barbed goatgrass	Adrienne Galvin	6/19/15	120 (BP, GW)
Blepharizonia plumosa big tarplantg	Roddy Ranch/ Kreigor Pass	9/09/15	140 (HB, BP)
California macrophylla round-leaved filaree	Roddy Ranch	4/21/16	0 (BP, GW)
Navarretia nigelliformis subsp. *radians* shinning navarretia	Roddy Ranch	4/21/16	160 (BP, GW)
Blepharizonia plumosa big tarplant	Kreigor Pass	9/5/16	140 (BP, GW)
Elymus caput-medusae medusa head	Adrienne Galvin	10/19/2016	120 (BP, GW)
Aegilops triuncialis barbed goatgrass	Young's Canyon (Save Mount Diablo Property)	10/21/16	108 (BP, GW)

Gregg Weber collecting big tarplant seeds at Kreigor

Closeup of big tarplant seeds.

2.1.3 SEED GERMINATION STUDY DESIGN

The goal of the seed germination study was to document and compare germination rates, germination timing, and phenology of the target species. The trials took place at two locations: BDMRP and Vaquero Farms (Figure 2). To best mimic natural conditions, seeds were planted in locally collected heavy clay soils and seed germination trays were buried three to four inches deep into the soil. Burying trays helped prevent the exposure of the sides of the seed trays to sun that could excessively dry soil in the trays. To protect the trays from small rodents, quarter inch wire fencing was installed on the ground below the trays. A wood frame with the same type of fencing covering it was placed over the top of the trays and secured to the ground with landscaping staples. In addition, soil cores were collected from the seed collection areas and installed in the trays adjacent to the seed germination trays. This was done in the event special status species had special germination cues or requirements that would prevent them from germinating in the first year. The study was done at both locations for two seasons. Season 1 took place fall 2015-spring of 2016. Season 2 took place fall 2016-fall 2017.

All special status plant species were planted in plastic seed starting packs that were three cells by three cells (nine cells total) and placed within the larger seed germination tray. In the first season trials, the special status species were planted in five starter packs (45 cells total) at the rate of three seeds per cell for a total of 135 planted seeds. The remainder of the space in the tray was filled will the soil from the soil seed bank core.

Round-leaved filaree germination tray. On the right is the soil sore and on the left are seed germination trays

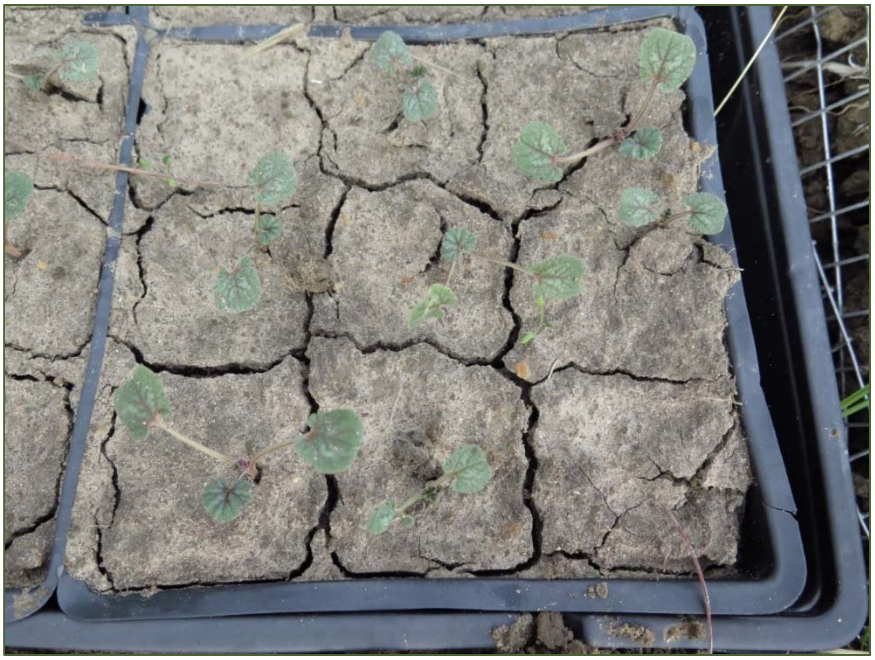
The invasive grass germination trials were only installed at Vaquero Farms due to concerns about introducing the invasive grasses at BDMRP. The invasive grass seed was planted at the rate of three seeds per cell (nine cells per pack), in four packs, for a total of 108 seeds. No soil seed bank core was collected for the invasive grasses because the literature is well established that these species do not have special germination requirements.

Germination trays installed in the ground with wire mesh

Germination tray with wood frame at BDMRP

Seed Planting Season 1: Fall 2015-Spring 2016

In Season 1, seeds for round-leaved filaree and shinning navarretia were planted on May 5, 2015. Seeds for medusa head grass and barbed goatgrass were planted on June 19, 2015, and big tarplant was planted on September 9, 2015. All soil cores were installed on the same date as the seeds were planted. Each of the special status species had a total of 135 seeds planted at each location and each of the invasive grasses had 108 seeds planted at one location.



Round-leaved filaree seedlings in germination trays.

Seed Planting Season 2: Fall 2016-Spring 2017

In Season 2 seeds of round-leaved filaree and shinning navarretia were planted on June 2, 2016. Seeds of medusa head grass and barbed goatgrass were planted on October 25, 2016 and seeds of big tarplant were planted on September 5, 2016. Seeds were planted using the same method as the previous season. Due to low seed production of round leaved filaree, the same amount seed from the previous year could not be collected. Enough seed was collected from the previous year's experiment to plant two seed starting packs with one seed for at both locations (36 seeds total). Shinning navarretia and big tarplant were planted in the same way as the previous year. During the Season 2 the invasive seed tray was moved from Vaquero Farms to a private residence in Martinez, to ensure there was no weed establishment from the trials.

Seed Germination Data Collection

Data on seed germination was collected every other week from the time of the first rains (November) to when the plants died (typically May). This was not the case with the invasive grasses as they were not allowed to go to seed. This was a precaution to prevent establishing new weed populations. Big tarplant flowered much later than all other species. So few of the Big tarplant seeds germinated that we reduced our data collection visits during the summer and early fall. During every visit, the number of seeds germinated, average height, and phenology data were collected. Photos were taken of each germination tray and once seedlings emerged detailed photos of seedling cotyledon leaves as well as secondary leaves were taken to help facilitate identification of young plants in the wild. A total of 26 visits were made over the course of two seasons. Appendix B includes the seed germination datasheet that was used for this data collection effort.

2.2. INVASIVE PLANT STUDY

2.2.1 LOCATION OF STUDY AREAS

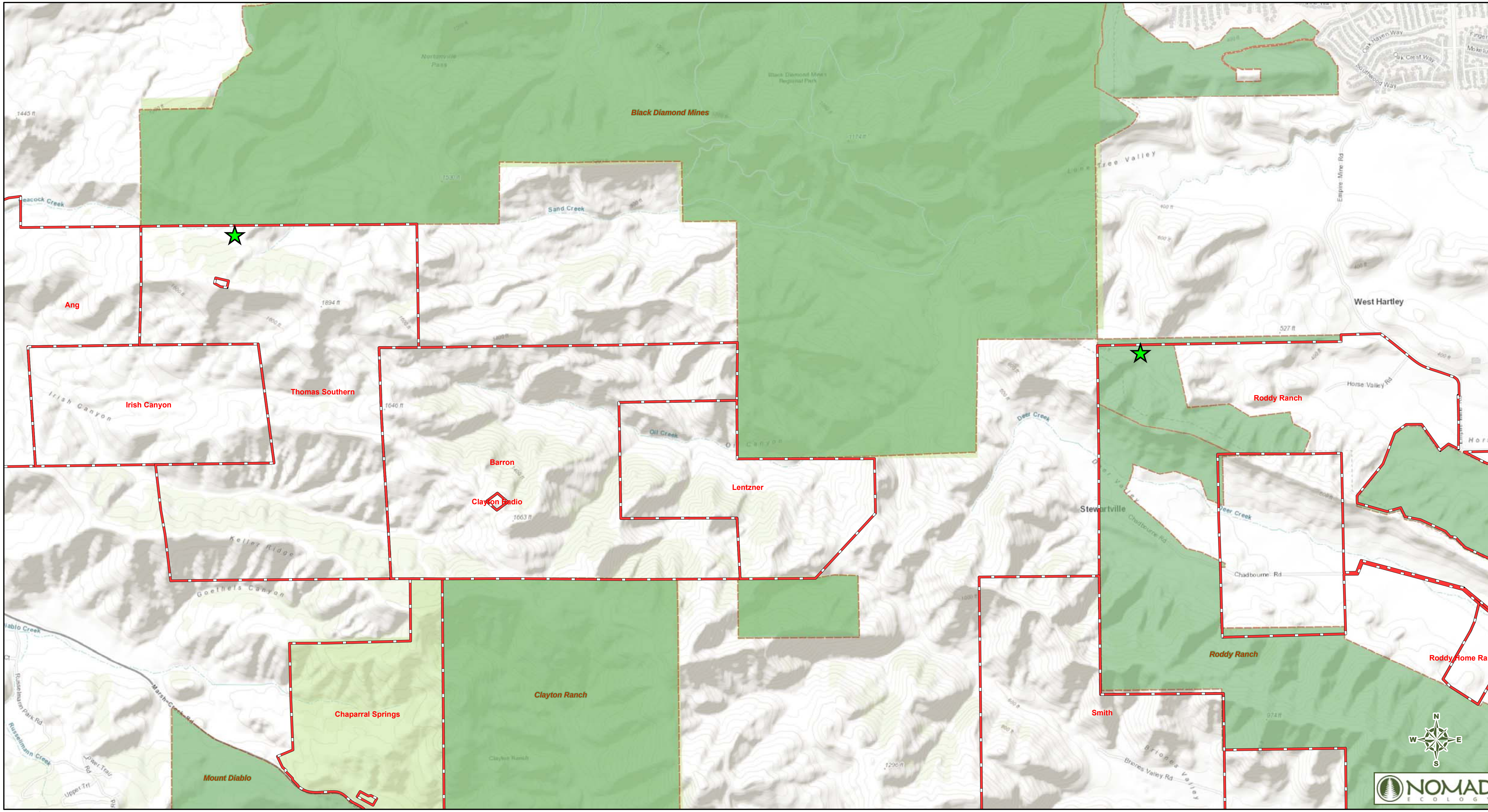
The invasive plant treatment study, which focused on medusa head grass was conducted at two locations within the preserve system; Kreigor and Roddy Ranch (Figure 3). These locations were chosen due to the high cover medusa head grass, presence of big tarplant and the different microclimates they represent. Differing precipitation and temperatures regimes were observed to a have a large impact on phenology at these sites providing a dataset that is realistic and representative of the condition found across the Preserve System.

2.2.2 TREATMENTS

Invasive plant treatments were aimed at reducing medusa head grass cover. Tree treatments were tested. The treatments were (1) hand pulling, (2) line trimming, and (3) line trimming and follow-up herbicide spray, with a control that did not include any treatment. The follow-up herbicide treatment was performed approximately one month after the line trimming treatment was applied by spraying any noticeable resprouting medusa head plants. This was done by EBRPD Resource Analyst Pamela Beitz. Nomad staff preformed all other treatments immediately after vegetation data was collected. These treatments were designed to mimic treatments used by EBRPD staff. A treatment that consisted of just spraying was not included because EBPRD does not broadcast spray for invasive grasses. It should also be noted that hand pulling is not a viable option for control at a large scale, but may provide as a useful tool in small areas where sensitive rare plant populations exist.

2.2.3 INVASIVE PLANT TREATMENT SAMPLING DESIGN AND DATA COLLECTION

This study consisted of 10, 3-meter x 12-meter plots at each location. Each plot had four sub-plots (3-meters x 4-meters) for a total of 40 sub-plots. Each subplot had one treatment applied (Figure 4). This study uses a block design to compare the effects of each treatment. Vegetative cover data was collected using the same methods for all treatments: point-intercept transects. Two, three-meter transects were random placed in each treatment subplot and cover data was collected at every five centimeters (60 data points per transect, and 120 data points per sub-plot). For every point taken there were three possible canopy hits and one soil surface hit. The transects were placed randomly using a random number table to determine line placement at the downhill edge of each treatment. Two transects could not be placed within 10 centimeters of one another. Timing of data collection and treatment implementation was based on phenology of medusa head. The goal was to allow medusa head to develop almost to the seed stage to exhaust underground storage enough that the plants would not have enough resources develop new florets, while also applying the treatments early enough to prevent the seed from fully developing on the plant after it was hand-pulled or line trimmed. The cover data was analyzed to compare the effects of the treatments on medusa head grass cover, species composition, and amount of litter and bare ground cover.



March 2018

Special Status and Invasive Plant Management Pilot Project

Legend
- Acquisition Parcels
- Public Land and Easements
- ★ Invasive Plant Study

Figure 3

Invasive Plant Study

East Contra Costa County
Habitat Conservancy

1:24,000

0 1,000 2,000

Feet

East Contra Costa County Habitat Conservancy

Sources: NAIP 2012; Contra Costa County. Projection: NAD 83 UTM Zone 10 North.

Contra Costa County, California

Figure 4. Plot and Treatments at the Kreigor and Roddy Ranch Sites

Roddy Ranch

90 Line Trim and Spray	Line Trim	Control	Hand Pull
91 Hand Pull	Control	Line Trim	Line Trim and Spray
92 Line Trim	Control	Hand Pull	Line Trim and Spray
93 Control	Hand Pull	Line Trim	Line Trim and Spray
94 Line Trim and Spray	Control	Line Trim	Hand Pull

Kreigor

105 Line Trim	Control	Line Trim and Spray	Hand Pull
106 Line Trim	Line Trim and Spray	Hand Pull	Control
107 Hand Pull	Control	Line Trim	Line Trim and Spray
108 Hand Pull	Line Trim and Spray	Control	Line Trim
109 Line Trim and Spray	Hand Pull	Control	Line Trim

Invasive plant treatment plots, post-treatment, at the Kreigor location.

2.3. Data Analysis

Data analysis was performed using statistical package R. The seed germination study did not have sufficient samples to perform any formal statistical analysis so all data were presented in a summary form in tables and graphs. The invasive plant treatment study was a randomized block design using ANOVA to test difference among treatments and Tukey test to assess differences among every combinations of treatments.

2.4. Personnel and Field Investigation

The following personnel conducted the field investigations. Report preparation was completed by Nomad:

Heath Bartosh
Senior Botanist
Nomad Ecology, LLC
822 Main Street
Martinez, CA 94553
(925) 228-1027

Brian Peterson
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Jaclyn Inkster
Botanist and Restoration Ecologist
Nomad Ecology, LLC

Adam Chasey
Botanist
Nomad Ecology, LLC

Greg Weber
Botanist
Nomad Ecology, LLC

Elyse DeFranco
Biologist
Nomad Ecology, LLC

Erick Mahood
Biologist
Nomad Ecology, LLC

Scott Cashen
Senior Biologist
Nomad Ecology, LLC

Pamela Beitz
Resource Analyst
East Bay Regional Parks District

2.4.1 Seed Germination Field Visits

Installation of plots was conducted by Nomad Senior Botanist Heath Bartosh (HB) and Botanist Brian Peterson (BP). Seed Collection and planting was conducted by Mr. Bartosh, Mr. Peterson and Nomad botanist Gregg Weber (GW). Collection of seed germination data was conducted by Mr. Bartosh, Mr. Peterson and Nomad Botanists Jaclyn Inkster (JI), Adam Chasey (AC) and Nomad biologist Erick W. Mahood (EWM). This work was conducted over the course of two seasons: April 4, 2015-April 20, 2016 (Season 1) and April 21, 2016-May 23, 2017 (Season 2). Table 2 details the sampling season, dates, tasks preformed and personnel for this study.

Table 2. Seed Germination Study Work Dates

Sampling Season	task	Date	Personnel
Season 1 (04/4/15-04/20/16)	Wild Population Estimate round-leaved filaree/shinning navarretia	04/13/15	BP, GW
	Seed Collection round leaved filree/shinning navarretia	4/15/15	HB, BP
	Plot Install/Planting round leaved filree/shinning navarretia	05/05/15	HB, BP
	Seed Collection/Planting medusa head/barbed goatgrass	6/19/15	BP
	Seed Collection/Planting big tarplant	09/09/15	BP
	Plot Data Collection	11/20/15	HB, BP
	Reference Check round leaved filree	11/30/15	HB
	Plot data Collection/ Reference Check medusa head	12/3/15	BP
	Plot Data Collection	12/9/15	HB
		12/31/15	BP
		1/5/16	BP
		1/21/16	HB
		2/4/16	HB, BP
	Plot Data Collection/ Reference Check round leaved filree	3/4/16	BP
	Plot data Collection	4/20/16	BP, EM
Season 2 (04/21/16-5/23/17)	Reference Check/ Wild Population Estimation/ Seed collection round leaved filree and shinning navarretia	4/21/16	BP, GW
	Planting round leaved filree and shinning navarretia	6/2/16	BP
	Seed Collection/Planting big tarplant	9/5/16	BP, GW

Sampling Season	task	Date	Personnel
	Seed Collection medusa head	10/19/16	HB, BP, EWM
	Plot Data Collection	10/20/16	BP
	Seed Collection barbed goatgrass	10/21/16	BP, GW
	Planting medusa head and barbed goatgrass	10/25/16	HB, BP, EWM
	Plot Data Collection	10/28/16	BP, AC
		11/11/16	AC
		11/21/16	BP
		12/9/16	HB, BP, EWM
		12/22/16	AC, JI
		1/18/17	BP
		2/2/17	AC
		2/22/17	BP
		3/6/17	AC
		3/23/17	AC
		4/5/17	BP
		4/21/17	AC
		5/8/17	BP
		5/23/17	BP

In Season 1, on March 17, 2015, Mr. Peterson and Mr. Weber estimated the number of individuals and seed production of round-leaved filaree and shinning navarretia at a single population on Roddy Ranch in support of the seed collecting effort. On April 4, 2015 Mr. Bartosh and Mr. Peterson collected seed of round-leaved filree and shinning navarretia from the Roddy Ranch populations. On May 5, 2015, Mr. Bartosh and Mr. Peterson installed seed germination plots and planted round-leaved filree and shinning navarretia seeds. On September 9, 2015, Mr. Bartosh and Mr. Peterson collected and planted big tarplant seed. Reference checks of a wild round-leaved filree population were conducted November 30, 2015, by Mr. Bartosh and Mr. Peterson and on May 4, 2016, by Mr. Peterson. Seed germination plot data was collected by Mr. Bartosh and/or Mr. Peterson on the following dates; November 20, 2015, December 3, 9, & 31, 2015, and January 5 & 21, 2016, February 4, 2016, May 4, 2016, and April 20, 2016.

In Season 2 on April 21, 2016, Mr. Peterson and Mr. Weber estimated the number of individuals and seed production of round-leaved filree and shinning navarretia at the same populations on Roddy Ranch. Seed of shinning navarretia was also collected on this date. On June 2, 2016, round-leaved filree and shinning navarretia were planted by Mr. Peterson. On September 5, 2016, Mr. Peterson and Mr. Weber collected and planted big tarplant seed. On October 19, 2016, medusa head seed was collected by Mr. Bartosh, Mr. Peterson and Mr. Mahood. On October 21, 2016, barbed goatgrass seed was collected by Mr. Peterson and Mr. Weber. On October 25, 2016, medusa head grass and barbed goatgrass seed was planted by Mr. Bartosh, Mr. Peterson and Mr. Mahood. Seed germination plot data was collected by Mr. Bartosh, Mr. Peterson, Mr. Mahood, Mr. Chasey and Ms. Inkster on the following dates; October 28, 2016, November 11 & 21, 2016, December 9 & 22, 2016, January 18, 2017, February 2 & 22, 2017 May 6 & 23, 2017, April 5 & 21, 2017 and March 8 & 23, 2017.

2.4.2 Medusa Head Field Visits

Mr. Bartosh and Mr. Peterson installed the medusa head grass study plots. Data collection was conducted Mr. Peterson, Ms. Inkster, Mr. Chasey, Nomad biologist Elyse DeFranco (ED) and Senior Biologist Scott Cashen (SC). Implementation of treatments was performed by Mr. Peterson, and Ms. Inkster. Follow-up herbicide spraying was performed by EBRPD Resource Analyst Pamela Beitz (PB). This work was conducted over the course of two years. In 2016 dates ranged from 03/10/16-6/24/16. In 2017 dates ranged from 5/8/17-6/30/17. Table 3 details the year, dates, tasks preformed, and personnel for this study.

Table 3. Medusa head Study Work Dates

Sampling Season	task	Date	Personnel
2016	Plots Installation	3/10/16	HB, BP
	Data Collection	5/16/16	BP, JI
	Data Collection	5/17/16	BP, JI
	Data Collection	5/26/16	BP, ED
	Data Collection	5/27/16	BP, JI
	Data Collection & Treatments	5/31/16	BP, JI
	Herbicide Spraying	6/24/16	PB
2017	Data Collection	5/8/17	BP, AC
	Data Collection	5/9/17	BP, JI
	Data Collection Treatments	5/10/17	BP, JI
	Medusa head Phenology Check at Kreigor pass	5/11/2017	BP, SC
	Spraying	5/30/17	PB
	Data Collection	6/8/17	BP, AC
	Data Collection & Treatments	6/9/17	BP, JI
	Herbicide Spraying	6/30/2017	PB

In 2016, Mr. Bartosh and Mr. Peterson installed treatment plots at both study locations on May 10. Data collection was conducted by Mr. Peterson and Ms. Inkster or Ms. DeFranco on May 16, 17, 26, 27, & 31. Implementing treatments was done on May 31 by Mr. Peterson and Ms. Inkster. On June 24, follow-up herbicide spraying was conducted by Ms. Beitz.

In 2017, Mr. Peterson and Ms. Inkster or Mr. Chasey collected vegetation data on May 8-11, and June 8 & 9. Treatments were implemented on May 10 and June 9 by Mr. Peterson and Ms. Inkster. Follow-up herbicide spraying was conducted on May 30 and June 30 by Ms. Beitz.

2.5. Limitations

Limitations for both studies were identified. The seed germination study limitations included seed availability, appropriate germination locations for invasive weed species, low germination rates of big tarplant, and small sample size. For the medusa head grass study limitations include low cover of big tarplant and logistics associated with varied medusa head grass phenology between locations.

In 2015, the round-leaved filaree population at Roddy Ranch had many individuals that produced abundant viable seed. In 2016, however, seed production at the Roddy Ranch population was too low to collect seed from. Some seed was collected from the previous years (Season 1) seed germination plots allowing some round-leaved filaree to be planted for the second season, though in smaller numbers. Due to the lack of round-leaved filaree seed, the second season planting only consisted of 18 cells with one seed in each cell repeated at each location (36 total seeds). This represents a difference of 234 seed from Season 1 to Season 2. A further limitation included only receiving permission to plant the invasive grass component of the study at Vaquero Farms in the first season. In Season 2 the invasive grass trails had to be moved to Nomad's outdoor garden in Martinez, CA.

Big tarplant germination trials had low germination rates in both years at both sites. Though there was some germination to indicate timing, the sample size was too low to determine with any confidence. It should be noted that growth in seed germination trays prevents roots access the soil below. These growing conditions may not have been ideal for the plant's need for late season moisture accessed by longer root systems This would have impacted late season phenology and ultimately survival, thus, survival rates may be artificially low. The last limitation of this the seed germination study was its small sample size, known from the beginning of this project which is intended to be a pilot study, to direct potential future, larger studies. The small sample size was exasperated by the fact that there was low germination at Vaquero Farms in Season 1 and almost no germination by any species at Vaquero Farms in Season 2.

The Study was designed to compare different eradication treatments, both in effectiveness and impact on native forb populations. A major reason for this study was to better understand potential effects of weed treatment on big tarplant. Directly addressing and studying this management concern was difficult for two reasons. First, big tarplant has low absolute cover in grasslands making it difficult to obtain a large enough sample size to determine treatment effectiveness with confidence. Second, due to the sensitive nature of this species, knowingly causing potential harm by treatment practices (ie. spraying and line trimming) is not advisable. For these reasons, the general effect on species composition is considered as a proxy for big tarplant.

Section 3. ENVIRONMENTAL SETTING

3.1. SETTING

The locations associated with the seed germination and invasive plant portions of this study are located within BDMRP and Kriegor, Roddy Ranch, and Vaquero Farms preserves. A brief setting discussion is provided for regional context (Figure 1).

The site within BDMRP associated with this study is one of the outdoor seed germination plots. It is located east of the main entrance kiosk on Somersville Road at Sidney Flat. The plot location is situated east of the visitor parking lot and west of a maintenance yard in an area of non-native grassland habitat on a west facing slope. This ungrazed site is in full sun and at 500 feet in elevation and on the boundary of the San Joaquin Valley and San Francisco Bay subregions of the California Floristic Province (Baldwin et al. 2012).

The Kriegor site is where one of the invasive plant treatment study sites is located. This grazed parcel is part of the HCP/NCCP Preserve System. This treatment plot is located in non-native grassland on a north facing slope below Kriegor Peak, that lacks sun in the early morning, and is west of a paved intersection. This location is at 1,665 feet in elevation and lies within the San Francisco Bay Subregion of the California Floristic Province (Baldwin et al. 2012).

Roddy Ranch, which is also a part of the HCP/NCCP Preserve System. The second invasive plant treatment study was installed on the Roddy Ranch, located west of Deer Valley Road. The treatment site itself is near the northern boundary of Roddy Ranch along Empire Mine Road. The plot is on a north facing slope in grazed non-native grassland that is bordered to the north and south by blue oak woodland. This site is at 650 feet in elevation and lies within the San Joaquin Valley Subregion of the California Floristic Province (Baldwin et al. 2012).

Vaquero Farms, which is located west of Vasco Road, was the location for the second seed germination site. The germination plot is located just outside of the Vaquero Farms ranger office in non-native annual grassland near a stock pond. It is in full sun, on flat ground, and at 100 feet in elevation in an area that is ungrazed. This plot is also located within the San Joaquin Valley Subregion of the California Floristic Province (Baldwin et al. 2012).

3.2. PRECIPITATION

The average annual precipitation among the four study areas ranges between 12 and 24 inches. Vaquero Farms has the lowest average annual precipitation with 12-14 inches, and Kriegor Pass has the highest average annual precipitation with 22-24 inches. BDMRP expects an average of 20-22 inches of precipitation annually, and Roddy Ranch expects an average of 18-20 inches of precipitation annually (PRISM 2007).

Three local weather stations were used to report the annual precipitation for 2016[3] and 2017 water years[4]. The BDMRP weather station was located roughly between the Kriegor Pass and BDMRP study areas. Table 4 below shows the cumulative precipitation for the 2016 and 2017 water years (DWR 2018).

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[3] 2016 Water Year: October 1, 2015-September 30, 2016.
[4] 2017 Water Year: October 1, 2016-September 30, 2017.

Table 4. Cumulative Precipitation for 2016 and 2017 Water Years

STUDY AREA	NEAREST PRECIPITATION STATION	2016 WATER YEAR PRECIPITATION (INCHES)	2017 WATER YEAR PRECIPITATION (INCHES)
Kriegor	BDMRP	13.94	18.25
BDMRP			
Roddy Ranch	Roddy Ranch Golf Club	11.81	18.54
Vaquero Farms	Byron Airport	10.92	18.45

Section 4. RESULTS

4.1. SEED GERMINATION STUDY

Results of the seed germination study include germination rates, plant survival, germination timing, and phenology. Germination Rates and Survival

Germination rates are based on the number of seeds planted in each cell compared to the number of germinated seeds. Table 5 below shows lower germination rates in special status plant species than the invasive grasses. Round-leaved filaree had the highest germination rates of the special status species in both years; 23% in season 1 and 24% in Season 2. Shinning navarretia had the second highest germination rates; 16% in season 1 and 21% in Season 2. Big tarplant had low germination rates both years at both locations. Generally, all special status species had higher germination rates at BDMRP than Vaquero Farms, with the exception of big tarplant in Season 2. However, none of the big tarplant seedlings at Vaquero Farms in Season 2 survived.

Medusa head grass had the highest germination rate (43%) and barded goatgrass had the second highest (32%) in season 1. Both medusa head grass and barbed goatgrass had less cover, approximately by half, in season 2 compared to season 1. This could be due to the fact that in the second season, the location of the invasive grass trial was moved to an area that had much more shade (Table 5).

Table 5. Germination Rates

SPECIES	LOCATION	SEASON 1	SEASON 2
SPECIAL STATUS PLANTS			
California macrophylla round-leaved filaree	BDMRP	23%	24%
	Vaquero Farms	10%	0%
Navarretia nigelliformis subsp. *radians* shinning navarretia	BDMRP	16%	21%
	Vaquero Farms	7%	7%
Blepharizonia plumosa big tarplant	BDMRP	1%	5%
	Vaquero Farms	1%	0%
INVASIVE PLANTS			
Aegilops triuncialis barbed goatgrass	Vaquero Farms/Martinez	32%	15%
Elymus caput-medusae medusa head	Vaquero Farms/Martinez	43%	17%

Survival rates are based on the number of germinated seed and the number of individuals that produced seed. Neither medusa head grass nor barbed goatgrass were allowed to progress to the seed dispersal stage, which made this measure obsolete. Table 6 below shows that big tarplant had the highest survival; this is misleading since only two plants germinated and one of these plants survived. This may indicate big tarplant has low germination rates but relatively high survival rates. Without a larger sample size, it is impossible to determine this with any confidence. Shining navarretia had relatively consistent survival rates across seasons at BDMRP with 31% in season one and 22% in season 2. In both seasons, shinning navarretia had 0% survival at Vaquero Farms. Round-leaved filaree had varied survival between seasons at BDMRP with 12% in Season 1 and 100% in Season 2. This is interesting since there were three seeds planted per cell and most cells only had one seed germinate in season one, while only one seed was planted in each cell in season two with a similar result. This may indicate strong intra-species competition at the germination phase of the life cycle of round-leaved filaree. Generally speaking, all special status plant species had higher survival rates at BDMRP than at Vaquero Farms, potentially indicating the climatic limits of the species range.

Table 6. Special Status Plants Survival Rates

Species	Location	Season 1			Season 2		
		Total Germinated	Plants Survived to Seed Set	Survival Rate	Total Germinated	Plants Survived to Seed Set	Survival Rate
California macrophylla round-leaved filaree	BDMRP	32	4	12%	13	13	100%
	Vaquero Farms	13	0	0%	0	0	NA
Navarretia nigelliformis subsp. *radians* shinning navarretia	BDMRP	22	7	31%	27	6	22%
	Vaquero Farms	9	0	0%	9	0	0%
Blepharizonia plumosa big tarplant	BDMRP	2	1	50%	7	0	0%
	Vaquero Farms	1	0	0%	1	0	0%

4.1.1 Germination Timing

Germination timing as shown in Table 7 and 8 as counts of new germination events represented as a positive number, no new germination events represented as a zero, and newly dead seedlings represented as a negative number. Figure 4 shows germination timing in Season 1 and shows that germination for all target species begins in mid- to late-November, peaks around mid-winter and begin to see mortality in early spring as the rainy season tapers off. Though this is the general trend, the different species appear to have varied germination timing and distribution of germination events (Figure 5). Round-leaved filaree and barbed goatgrass appear to have a short period where most of the seeds germinate in December. In contrast, shinning navarretia and medusa head grass appear to have staggered germination with individuals starting to germinate in January, peaking in mid-February and declining through March and April.

Table 7. Germination Timing Season 1

Species	November		December		January		February		March		April	
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30
Special Status Plants												
California macrophylla round-leaved filaree	NA	+20	+22	+2	NA	12	0	NA	-3	NA	NA	-25
Navarretia nigelliformis subsp. *radians* shinning navarretia	NA	5	0	+8	NA	+15	+2	NA	-17	NA	NA	-6
Blepharizonia plumosa big tarplantg	NA	+2	+1	0	0	0	0	0	0	0	0	-1
Invasive Plants												
Elymus caput-medusae medusa head	NA	+9	+15	+5	+17	NA	NA	NA	NA	NA	NA	-46

Species	November		December		January		February		March		April	
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30
Aegilops triuncialis barbed goatgrass	NA	+17	+18	-14	NA	+1	NA	NA	-21	NA	NA	-1

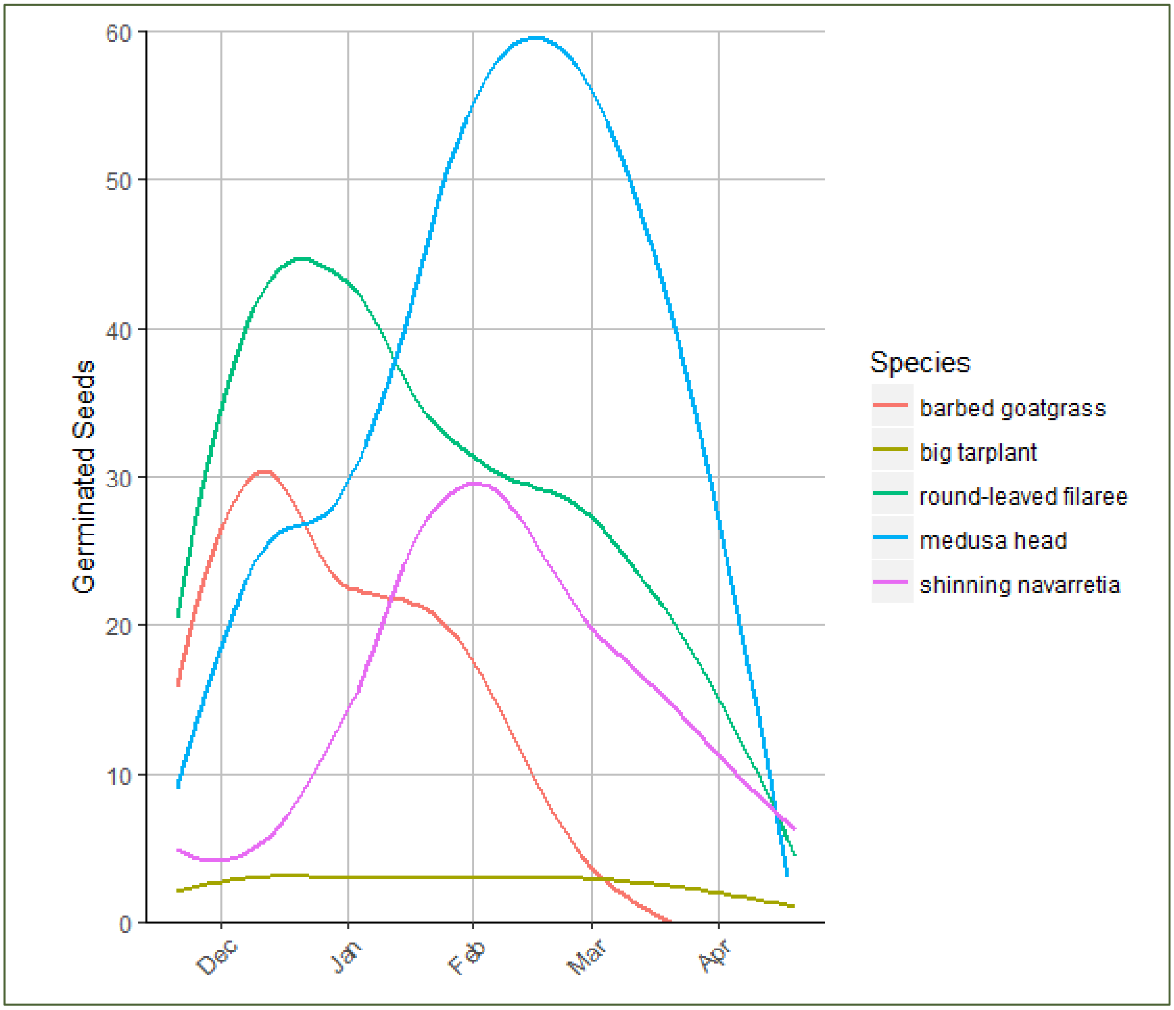

Figure 5. Germination Timing in Season 1

Season 2 germination trends tell a slightly different story than Season 1. This is possibly driven by the decreased precipitation regimes in both seasons (Table 4). Figure 6 and Table 8 shows the phenology of germination in Season 2. Germination in season two was lower than season one overall. This is likely due to including the very low germination rates at Vaquero Farms when averaging the germination rate overall. All peak numbers of germinated seeds are later in the year than in season one. One striking difference is how the round-leaved fillaree, medusa head, and shining navarettia have very similar germination rates throughout season two, and very different rates from one another in season one. Shinning naverretia also had many more individuals germinate in the second season compared to the other species. This does not account for the fact that in Season t2, significantly fewer round-leaved filaree seeds were planted and the invasive grass trays where moved to a more shady location. Despite this confounding factor, later germination peaks and the similar timing of germination events of all species when compared to the previous season indicates species response is variable under different climate conditions.

Table 8. Germination Timing in Season 2

Species	Oct	November		Dececember		January		February		March		April		May	
	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31
Special Status Plants															
California macrophylla round-leaved filaree	+9	+4	0	0	0	0	0	0	0	0	0	0	0	-12	-1
Navarretia nigelliformis subsp. *radians* shinning navarretia	0	0	+10	+8	0	-7	+1	+1	+13	0	+7	-5	-6	-11	+1
Blepharizonia plumosa big tarplantg	+5	+1	+1	-6	0	0	0	0	0	-1	0	0	0	0	0
Invasive Plants															
Elymus caput-medusae medusa head	0	+18	NA	-2	-1	-1	-2	+1	+2	NA	0	0	0	-3	-12
Aegilops triuncialis barbed goatgrass	NA	+5	NA	+6	+3	-2	-1	+2	0	NA	+3	NA	-2	-1	-10

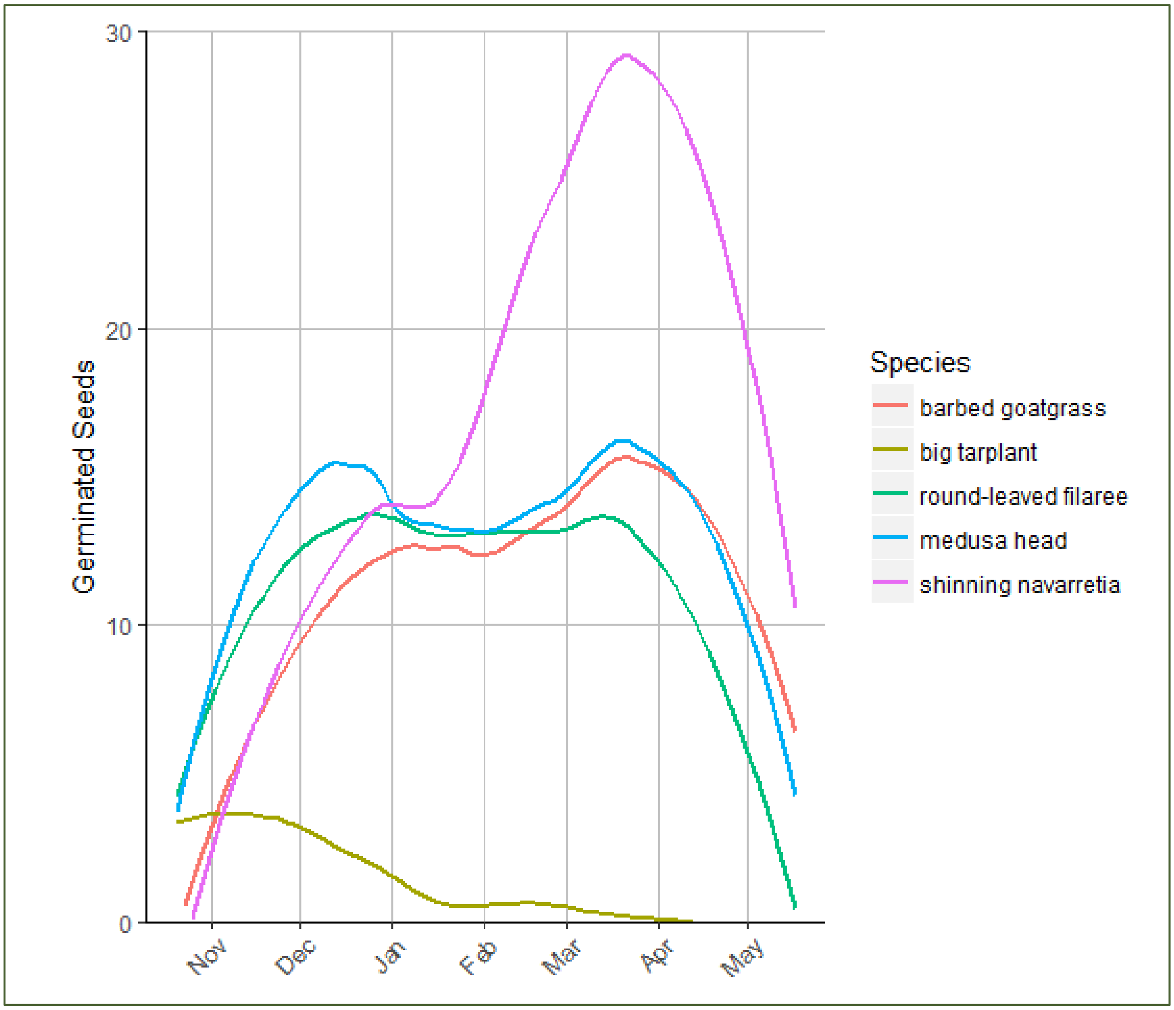

Figure 6. Germination Timing in Season 2

In both seasons there was low germination of big tarplant in November and mortality in early December (Figure 4-5). It is difficult to know if this was due to low viability or poor habitat. The winter die off could potentially be due to lack of drainage and excessively wet soils, or some other artifact from being planted in pots. It could also indicate a potential temporal bottle neck in big tarplant survival due to precipitation. Low sample sizes make it impossible to determine with any confidence.

4.1.2 PHENOLOGY

Phenology of the special status plants was described using four simple categories: cotyledon leaves (Cot), secondary Leaves (Sec), flowers (Fls), and seeds (Seed). Phenology of grasses was described using two simple categories: primary leaves (Prim), secondary leaves (Sec). NA stands for no data and a 0 indicates no zero individuals germinated. No grasses were allowed to flower or seed during the study to prevent introduction of an invasive species. Table 9 shows the phenology of the target species over season one. Interestingly, shinning navarretia has cotyledon leaves as well as secondary leaves from December to April. This indicates seeds were germinating throughout the season. In contrast, the round-leaved filaree population only has cotyledon leaves in late November, illustrating seedlings all germinated in a relatively early part of the rainy season.

Table 9. Phenology Season 1

Species	Nov	December		January		February		March		April	
	16-30	1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30
Special Status Plants											
California macrophylla round-leaved filaree	Cot	Sec	Sec	Sec	Sec	Cot/ Sec	Sec	Sec/ Fls	NA	Seed	NA
Navarretia nigelliformis subsp. *radians* shinning navarretia	Cot	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Seed
Blepharizonia plumosa big tarplantg	Cot	Cot/ Sec	Cot/ Sec	Cot/ Sec	NA	Sec	NA	Sec	NA	NA	Sec
Invasive Plants											
Elymus caput-medusae medusa head	Prim	Prim	Sec	Sec	NA	NA	NA	NA	NA	NA	Dead
Aegilops triuncialis barbed goatgrass	Prim	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec

Season 2 phenology data in Table 10 illustrates a similar dynamic as in Season 1 especially with shinning navarretia germinating throughout the season while other species germinated during a short window in late-fall early-winter.

Table 10. Phenology Season 2

Species	October	November		December		January		February		March		April		May	
	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-28	1-15	16-31	1-15	16-30	1-15	16-31
Special Status Plants															
California macrophylla round-leaved filaree	Cot	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Fls	Fls	Seed	Seed	Seed	Dead
Navarretia nigelliformis subsp. *radians* shinning navarretia	0	0	0	Cot	Cot	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Cot/ Sec	Sec/ Fls/ Seed	Sec/ Fls/ Seed	Sec/ Fls/ Seed	Sec/ Fls/ Seed
Blepharizonia plumosa big tarplantg	0	Cot	Cot	Cot	Sec	Sec	Sec	Sec	Dead	Dead	Dead	Dead	Dead	Dead	Dead
Invasive Plants															
Elymus caput-medusae medusa head	0	Prim	MS	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec
Aegilops triuncialis barbed goatgrass	NA	Prim	MA	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec	Sec

Medusa head grass and barbed goatgrass were not allowed to flower or seed in this project. However, it has been well documented that these are late season grasses with flowering typically happening in late-May early-June and seeding throughout June (Baldwin et al. 2012). Big tarplant did not bare robust phenological data in this study due to low germination rates but it is well known that this species is a late season flower and seeder. Table 11 below shows an approximation of flowering phenology for medusa head barbed goat grass and big tarplant using herbarium record numbers as an approximation for flowering phenology. This is based on the assumption that most herbarium vouchers are taken when a species are flowering.

Table 11. Herbarium Record Phenology Table

Species	Herbaria Specimen Collections Averaged By Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aegilops triuncialis barbed goatgrass	0%	0%	0%	1%	58%	29%	10%	0%	0%	0%	0%	0%
Blepharizonia plumosa big tarplant	0%	0%	0%	0%	0%	3%	3%	26%	38%	29%	0%	0%
Elymus caput-medusae medusahead	1%	0%	1%	8%	34%	40%	12%	1%	2%	1%	1%	0%

4.1.3 Seedling Photos

Round-leaved Filaree


3/24/2016


3/23/17


4/21/16

Big Tarplant


11/11/16


2/4/16


06/09/17

Shinning Navarretia


01/22/16


2/4/16


03/04/16


04/05/17


04/21/17


05/08/17

Barbed Goatgrass


10/21/16


12/3/15


12/9/15

Medusa Head Grass


12/3/15


05/31/16


06/08/17

4.2. Invasive Plant Treatment Study

The results of the invasive plant treatment study, focused on medusa head grass, compares vegetation cover in the four medusa head treatment types. Absolute cover of medusa head, native species, non-native species, forbs, litter, and bare ground were compared by treatment type by year. The four treatments include a control, hand pulled, line trimmed, and line trimmed with follow-up herbicide spray. The following figures are graphs that show absolute vegetation cover across all treatments in the 2016 and 2017 seasons. The 2016 season represents baseline data that was collected before any treatments were implemented. The 2017 season represents one year after the initial treatments. A third season of data collection is still needed.

Figure 7 shows medusa head cover among treatments and years over both locations. This illustrates no significant difference of baseline medusa head cover across treatments in season 1. However, in season 2, there was a significant difference between treatments (p-value 0.000494, Table 12). Using the Tukey HSD test for multiple comparisons shows that hand pulling, line trimming, and line trimming with follow-up herbicide spray all had cover that was significantly lower than the control (Table 13). There was no significant difference of cover between the medusa head removal three treatments.

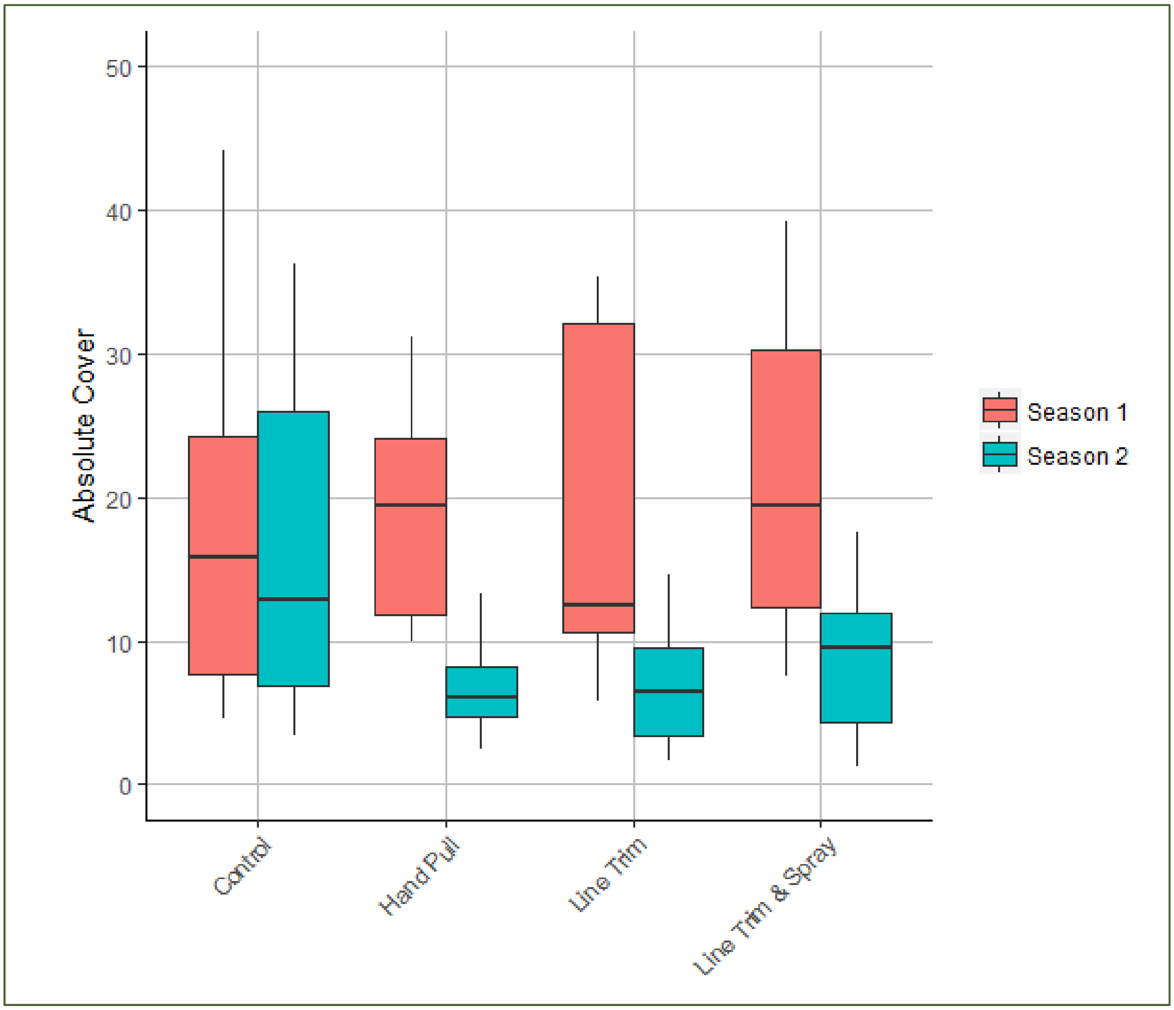

Figure 7. Medusa head Cover Among Treatments Over Two Years

Table 12. Comparison of Treatments and Year Using ANOVA

	DF	SUM SQ	MEAN	F-VALUE	P-VALUE
Treatment	3	0.1301	0.04336	7.579	0.000494 *
Plot	1	0.2666	0.26658	46.595	6.41e-08 *
Residuals	35	0.2002	0.00572		

*significant at Alpha 0.05

Table 13. Tukey HSD for Multiple Comparisons

TREATMENT	ADJUSTED P-VAULE
Hand Pull-Control	0.001064*
Line Trim-Control	0.001533*
Line Trim Spray-Control	0.015576*
Line Trim-Hand Pull	0.999235
Line Trim Spray-Hand Pull	0.758551
Line Trim Spray-Line Trim	0.826483

*significant at Alpha 0.05

Figure 8 shows forb cover across treatments over two years illustrating no significant difference between treaments. There does appear to be lower forb cover overall in season two. Lower forb cover may have been driven by climate conditions , and not treatment type. Lack of response to treatments may be a result of forb populations requiring more than one season to increase cover in response to treatments. This might be explained by the lack of a decrease in litter cover shown in later sections, which is a major driver of forb supression.

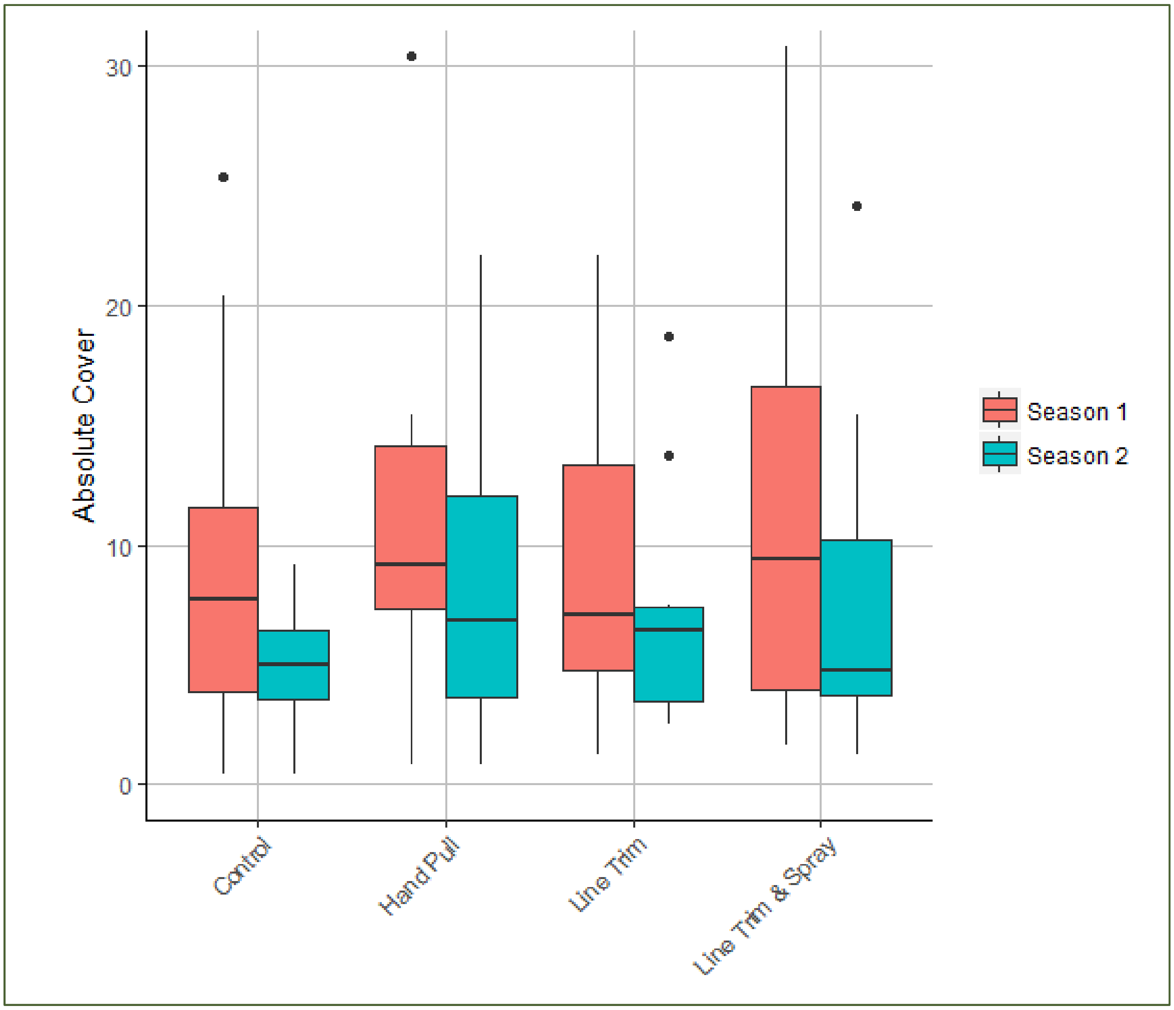

Figure 8. Forb Cover Among Treatments Over Two Years

Figures 9 and 10 show native and non-native cover across treatments over two years respectively. Neither native nor non-native cover showed significant differences over treatment in either year. Though not statistically significant, there does appear to be a slight increase in native cover when comparing the three treatments to the control (Figure 7).

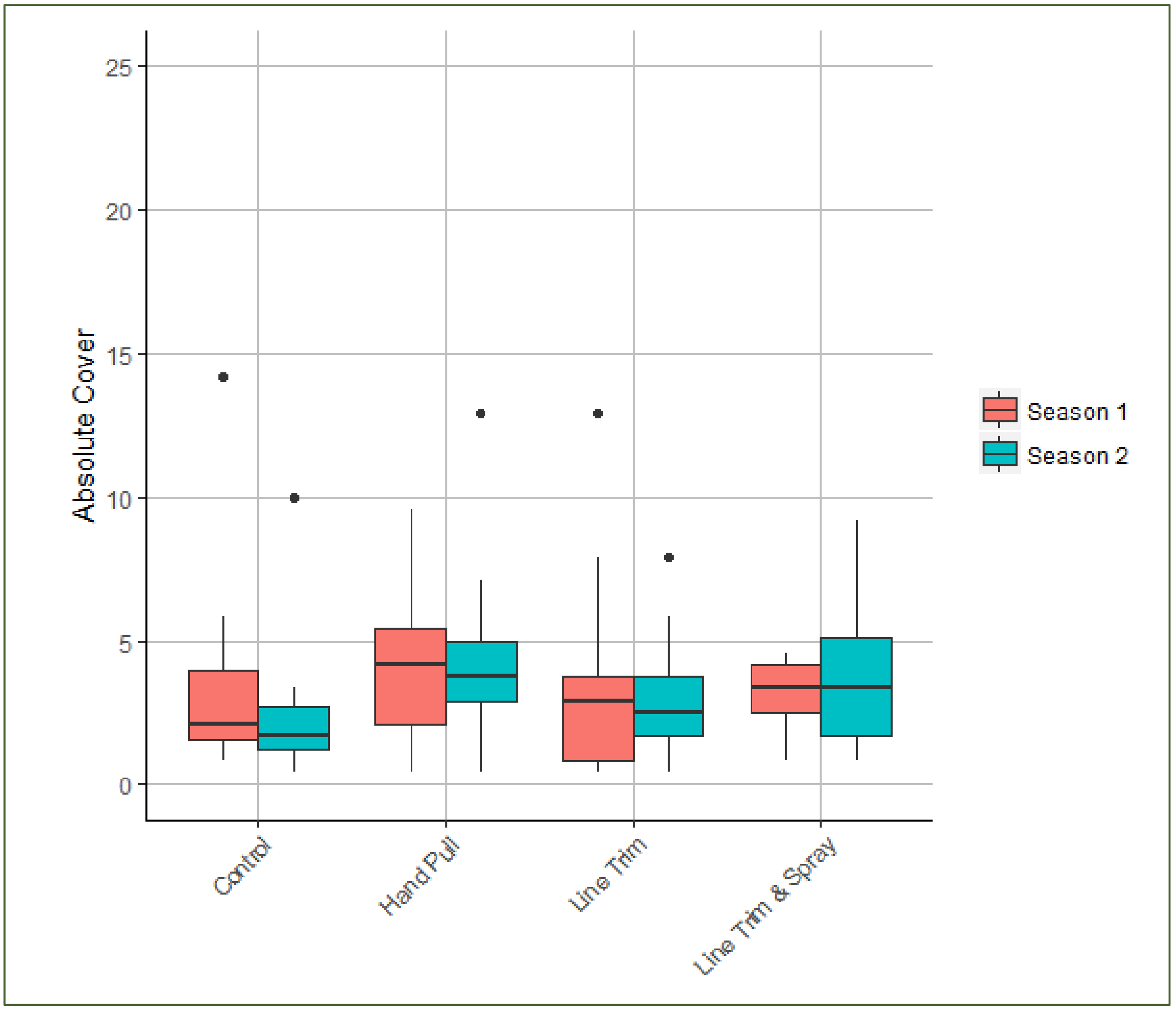

Figure 9. Native Cover Among Treatments Over Two Years

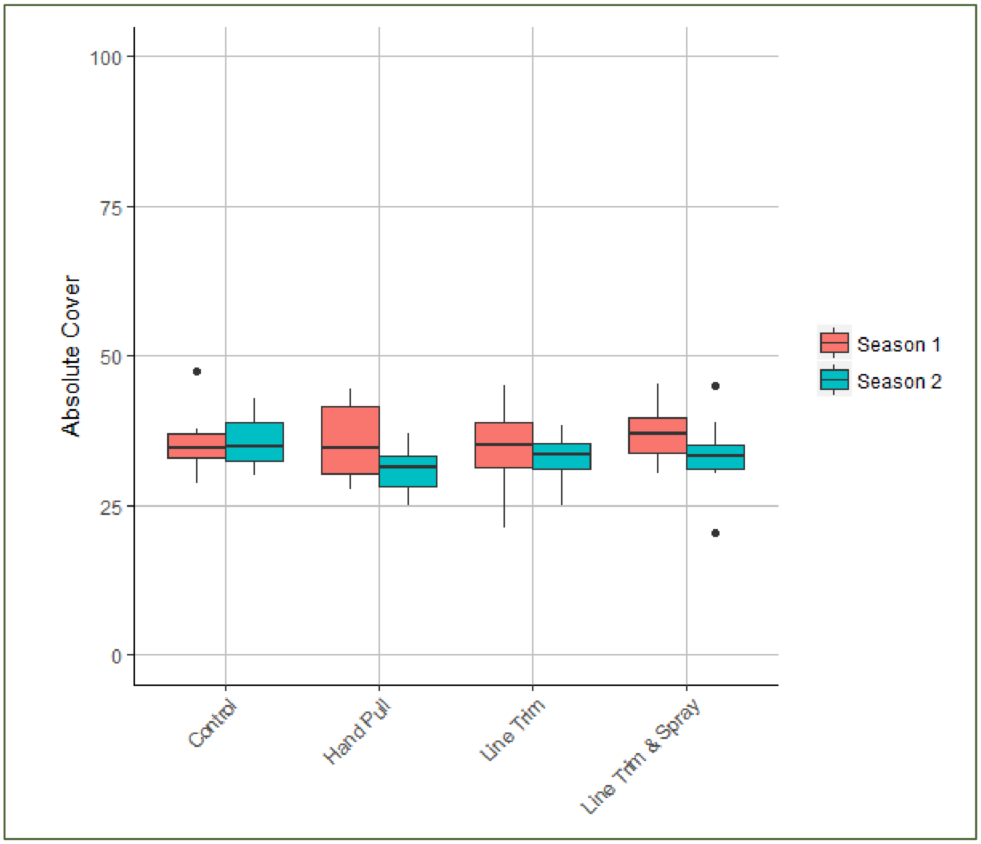

Figure 10. Non-Native Cover Among Treatments Over Two Years

Figures 11 and 12 show cover of litter and bare ground respectively among treatments and year. Litter cover is consistent across treatments and years. This is what would be expected in the first year after implimentation of weed treatments. Treaments were focused on the removal of living biomass and inflorescences of medusa head, not the removal of litter. Though reduction of medusa head may reduce litter input in the future, litter that is already present will require time to break down, and thus continue to supress growth of other plants. Bare ground does not show any differences between treatments. There is slight evidence, however, that bare ground cover may have increased between season one and season two, though the difference is not significant (Figue 11).

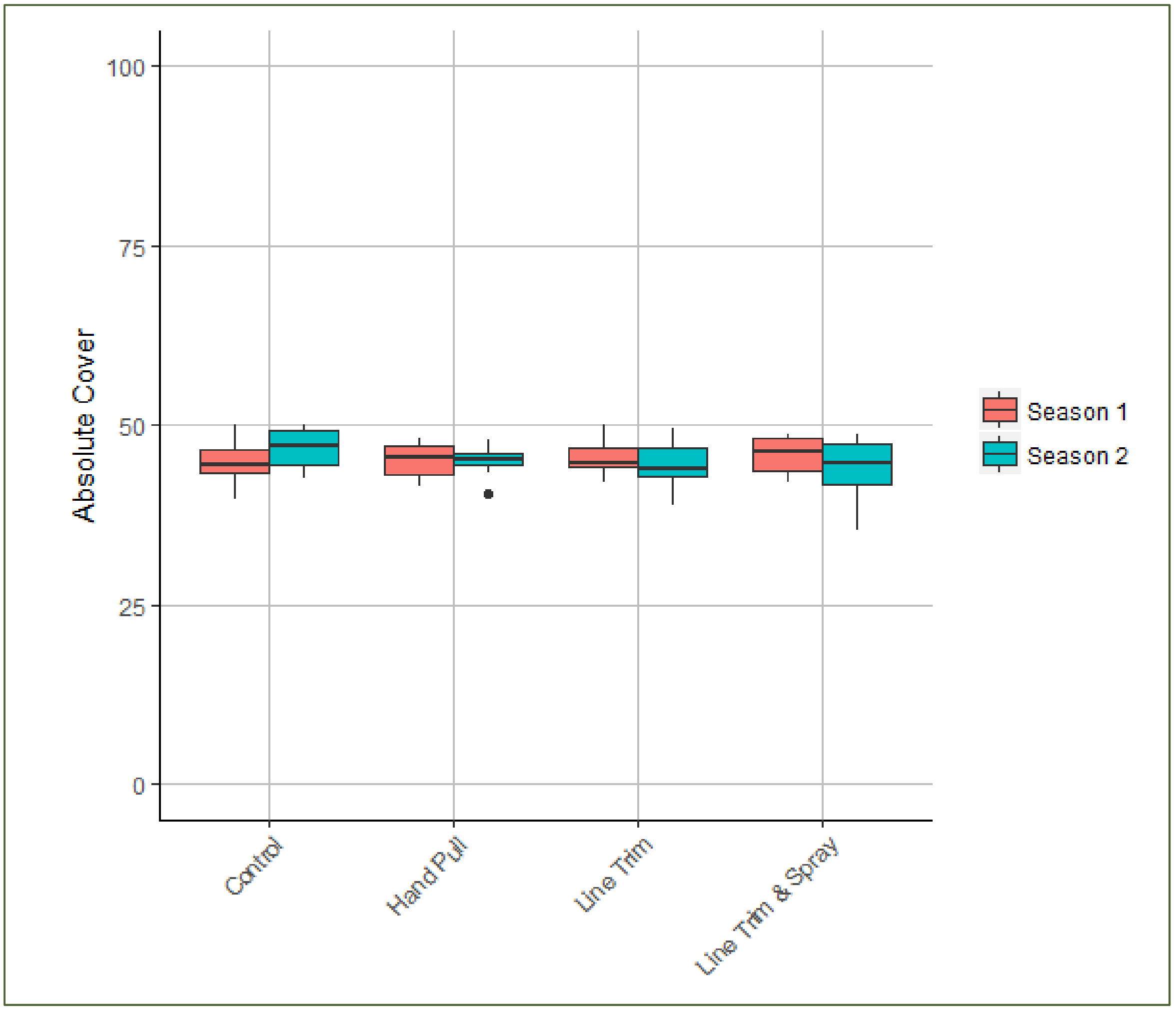

Figure 11. Litter Cover Among Treatments Over Two Years

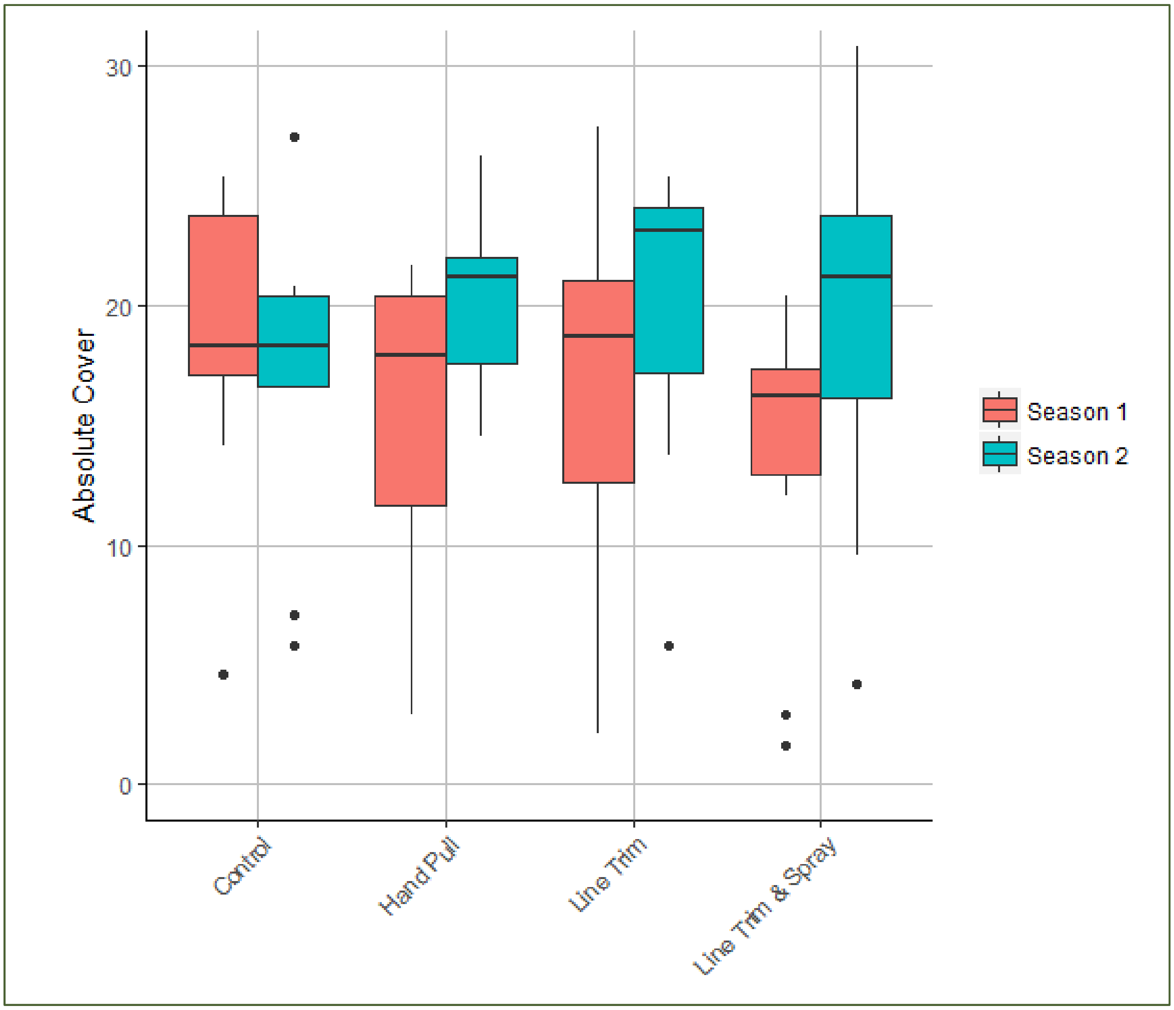

Figure 12. Bare Ground Cover Among Treatments Over Two Years

Section 5. DISCUSSION AND RECOMMENDATIONS

5.1. DISCUSSION

5.1.1 SEED GERMINATION STUDY

The seed germination study was a pilot project with a small number of samples, making it difficult to identify trends with confidence. Despite this limitation, some interesting potential trends were identified. Differences between BDMRP and Vaquero Farms were particularly stark. Germination rates were lower at Vaquero Farms and seeds that did germinate had a low survival. This may indicate that Vaquero Farms represents the edge of the environmental conditions that support the targeted special status species. This hypothesis is corroborated by previous survey results at Vaquero Farms that documented populations of round-leaved filaree and shinning navarretia, but with small populations indicating sub-optimal habitat or a range edge.

A goal of this study was to determine if there was an early season germination difference between special status plant species and the target invasive grasses to identify a potential point of intervention where weed management would not harm special status plant species. Though the results show species germinating and developing at different times, there is not a clear and clean distinction between the two groups and no specific early season time was identified where target invasive grasses are vulnerable and special status species are not. In addition, the comparison of germination timing between years illustrated complex dynamics where germination timing may be more different in one season than in the next, likely in response to climate conditions. This variation between seasons of germination dynamics would make it exceedingly difficult to predict the relationship of germination time among species. Current practices focus on medusa head grass and barbed goatgrass late season flowering and seeding for a point of intervention. At this point, most if not all special status species, and other grassland other species for that matter, have already gone to seed and are not as vulnerable to damage from weed management practices. This conventional wisdom, for the time, remains the best management practice.

5.1.2 INVASIVE PLANT TREATMENTS STUDY

The ideal treatment for medusa head grass would be cost effective and reduce medusa head grass cover while not harming native forbs. Additionally, medusa head grass control would hopefully, reduce litter cover and increase cover of bare ground over time. Relatively low vegetative cover and a high amount of bare ground is an important habitat characteristic of clay barrens.

All medusa head grass treatments reduced medusa head grass cover in the first year following the treatments. Medusa head grass cover was not significantly different among treatments. The lack of difference between treatments could be due to the fact that data collection occurred only once the first year after treatments were implemented.

There were no other significant differences between any of the species composition measures among treatments. The reduction in medusa head grass cover overall without significant increase in other measures of cover is in part explained by how the data were collected. There were three potential canopy layers and a soil surface measure for every point-intercept. The reduction in medusa head overall is shown as a reduction of medusa head at all canopy levels. Further, the effect on species composition of medusa head treatments may not be noticeable after one application as the system has not had time to shift from reduced litter and increased bare ground and forb cover. Despite the lack of significance, some potential trends were identified. Forb cover appears lower in the second season. Likewise native cover did not have any significant difference among treatments, but there may have been an increase in native cover within treatments compared to the control. Litter did not have any significant difference between treatments and control and show strong consistence across years. This is a potential explanation for a lack of response in species composition measure because heavy litter generally suppresses grassland species from germinating. It should also be noted that big tarplant was found in two of the plots at Kreigor (plots 93 and 94) at very low covers of less than 0.001%. Cover was too low to make any determination of treatment effects.

Through implementing this study, it was discovered that medusa head grass phenology was vastly different with the different climates in the Preserve System (between Roddy Ranch and Kriegor). This illustrates a major challenge managers have when creating and implementing weed management plans. In particular, medusa head grass treatments rely heavily on specific phenological timing. The Preserve System is very topographically diverse and has properties across strong temperature and moisture gradients that can drive phenology.

5.2. RECOMMENDATIONS

5.2.1 ADDITIONAL STUDIES

As a pilot project the one of the main goals of this work was to inform potential future studies. Ideally, additional studies on this subject would clarify germination timing dynamics, determine the impact of invasive grasses on clay barrens, and determine whether special status species grow in clay barrens because of a physical or chemical mechanisms in the soil or a lack of competition. Potential future studies in the clay barren ecosystems that would increase biological and ecological knowledge of target plants and inform land management practices might include:

- Increased samples size of the seed germination study to better detect trends.
- A formal seed viability test for special status species to better understand baseline biology.
- Planting multiple species together in plots to identify competition dynamics.
- Planting special status species in soils with different levels of clay to help determine if attributes in clay soils are directly driving niches or indirectly through competition dynamics.
- Documentation and mapping of invasive grasses growing on clay barrens in the preserve system.

Based on the data collected for the medusa head grass study, at least one more year of data should be collected to better determine the effects of treatment types. Though treatments had an impact on medusa head grass cover overall, it may take more than one season for differences among treatments to manifest. Further, trends in species composition were identified but were not significant. One more year of data would help determine what are true effects, and what are artifacts of sample size and seasonal variation. For these reason we recommend collecting another round of data in spring 2018.

5.2.2 MANAGEMENT RECOMMENDATIONS

Management recommendations yielded from the seed germination study include the following:

- Avoid weed management practice in late fall and early winter as this is when most species germinate and are most vulnerable. In addition, during this time, plants are typically small and potentially hard to identify and or detect.
- Line trimming before late April could severely impact sensitive species' ability to produce seed, thus impacting the following year's population.

- Clearly identify and map areas where special status plant species populations are co-occurring with medusa head grass and barbed goatgrass and create weed management plan specific to these conditions.

Management recommendations generated from the medusa head grass treatment study would be more robust and informative if another season of data were collected. However, management recommendation based on the current dataset are as follows:

- Medusa head grass treatments should be timed late in the season after a majority of the population has flowered and before seeds begin to mature. Based on plot locations in this study, phenology of medusa head grass varies widely across the preserve system. Kriegor, in the western portion of the preserve system, is at 1,640 feet elevation and was treated on June 30, 2017. Where Roddy Ranch, further east and at 600 feet elevation, was treated a month earlier on May 30, 2017. Generally speaking, areas in the western portion of the preserve and/or at higher elevations should be treated mid to late June. Whereas areas in the east and/or at lower elevations should be treated mid to late March. Though, due to the complicated mix of environmental gradients throughout the preserve system and variation of precipitation and temperature from year to year, generalizations are hard to make, therefore checking on annual plant phenology should be part of the pre-treatment process.
- Medusa head grass treatments should be applied at least two, preferably 3-4 years in a row..
- If part of the goal of reducing medusa head grass at a site includes promoting health of other species populations, and especially if it is a struggling sensitive plant population, litter should also be reduced manually in conjunction with other medusa head treatments.
- If there are known populations of special status plant species co-occurring with invasive weeds, it is recommended weed treatment be done by hand pulling, where feasible, and avoid line trimming. Line trimming should be avoided from late October to late May if target area includes round-leaved fillaree and/or shinning navarretia; and from July to mid-November if big tarplant is present. It is recommended that hand pulling be done by staff whom are familiar with identification of the target species. Further, to reduce risk of harming special status plant populations hand pulling should be done when plants are easy to identify and avoid, or after they have gone to seed. Based on the variation in phenology of special status plant species, exact timing of hand pulling would have to be determined on a case by case basis.
- Map medusa head grass and barbed goatgrass populations throughout the preserve system to track movement and identify where invasive grass populations threaten clay barren habitat.

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APPENDIX A 2014 WEED MEMO

December 31, 2014

East Contra Costa County
Habitat Conservancy
30 Muir Road
Martinez, Ca 94553

Technical Memorandum – Literature Review on Control Strategies for Two Invasive Grass Species on East Contra Costa County Habitat Conservancy Preserves, California

Dear Ms. Fateman:

This technical memorandum details the biology and control of two invasive plant species of concern; barb goatgrass (*Aegilops triuncialis*) and medusahead (*Elymus caput-medusae*). These species are present in Contra Costa County and are showing a generalized increase in distribution and population density state wide (Cherr 2009; Meimberg et al. 2010). These species reduce the quality of habitat and degrade the rangeland they occupy. Furthermore, both species have shown the ability to adapt to harsh edaphic substrates that many of California's endemic plant species grow on.

Below is information on the biology and potential control methods for each of these species. The information below represents a summary of information gathered from scientific literature, land management reference books, and government agency publications. Control techniques are separated into mechanical, cultural, and chemical. Recommendations for herbicide use and timing are in general terms, for more detailed information on application methods, specific herbicides, and safety please refer to the appropriate sources.

BARB GOATGRASS (*AEGILOPS TRIUNCIALIS*)

General Information

Barb goatgrass is a winter annual in the grass family (Poaceae) with spikes that resemble those of winter wheat. It flowers from May to August and stays green in the summer after other annual grasses have turned yellow. The spikelet and its associated node and rachis is called a joint and can persist on dried grass or disarticulated joints may fall to the ground. The spikelets have long barbed awns that can attached to clothes and animal fur serving as its main mode of dispersal.

This species is native to Mediterranean Europe and western Asia and is now found as a noxious weed in California and north to southern Oregon. Introduced to California in 1907 its distribution and abundance was relatively limited until the last two decades where its distribution expanded rapidly showing an ability to establish in a variety of environmental conditions (Davies, Nafus, and Sheley 2010; Rice et al. 2013). Barb goatgrass is one of the few non-native annual grasses to effectively invade communities on serpentine soils. Typically goatgrass establishes well in dry, disturbed sites, fields, pastures, and roadsides. However, goatgrass is also known to establish in undisturbed grasslands and oak woodlands (DiTomaso and Healy 2007). This is a concern as it is still unclear how many different habitats goatgrass is or will be able to establish in.

Relevant Life History Traits

Barb goatgrass is an annual that reproduces by seeds, which can stay dormant and viable in the soil for up to 5 years. Seeds are produced in pairs, sibling seeds, within the spikelet. One sibling seed is larger and does not experience any dormancy whereas the other smaller seed is dormant for at least a year before it is able to germinate. From the perspective of the parent, the strategy of having half of the seeds produced dormant for a year or more ensures some recruitment in an environment that is unpredictable from year to year. From the perspective of the sibling seed, this reduces potential competition between close relatives (Dyer 2004). Seeds mature later into the season than most other grasses. Spikes and joints fall in summer near parent plants or disperse to greater distances with water, human activities, vehicle tires, wind, and by ingestion or clinging to livestock (DiTomaso and Healy 2007). One study shows roads as a major pathway for dispersal with goatgrass reducing drastically greater than 1,000 meters from a road (Gelbard and Harrison 2003).

Ecological harm

Goatgrass forms dense monocultures that produces a thick layers of thatch and competes for resources. Goatgrass reduces diversity where it invades and degrades rangeland, reducing forage where it grows from 50 to 75% (Peters 1994). It also has a competitive advantage over native forbs and grasses in two ways; first it has a rapidly establishing root system and germinates early ensuring competitive advantage. Second, it generates a thick layer of thatch with its own detritus that significantly reduces the ability of other species to germinate (Davy 2008). Though it is not well understood, it is suspected that goatgrass alters soil dynamics to its favor. One study showed a significant change in microbiological communities in the soil after goatgrass establishment and that natives grown in the soil showed reduced vigor (Batten et al. 2006; Batten, Scow, and Espeland 2008).

One aspect of particular concern is that goatgrass has shown the ability to invade and create monocultures in serpentine grassland as well as productive grassland. Serpentine grassland is usually relatively resistant to annual grass invasion due to the unique and poor quality of soil, and harbors many important endemic species. This ability to invade serpentine soils as well as high productivity grasslands is driven by a mix of phenotypic plasticity and genetic response (Meimberg et al. 2010; Rice et al. 2013). This causes particular concern for other unique soil types that act as refugia for native species. For example, the heavy clay lenses and rich native grasslands that support the HCP/NCCP Covered species Diablo helianthella (*Helianthella castanea*) within HCP preserves. The most abundant barb goatgrass infestations in the HCP preserves are in the Morgan Territory Road corridor where it threatens Diablo helianthella occupied habitat.

Control Strategies

A variety of measures have been taken to control goatgrass in California. First and foremost early detection and removal is the most effective tactic. Goatgrass is limited by dispersal with a majority of the seed falling close to the mother plant. Consequently new infestations are limited to small areas, at least initially, that can be detected and removed. Techniques discussed below are separated into mechanical, cultural, and chemical. Table 1 shows each control method and the appropriate timing.

Table 1. Timing of Control for Barb Goatgrass

Abatement Method	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Hand Pulling	X	X	X	X	X	X						
Prescribed Fire					X	X	X					
Mowing				X	X	X						
Tilling			X	X	X							
Pre-emergent Herbicide										X	X	X
Foliage Herbicide	X	X	X	X								
Seed Formation Herbicides					X	X						
Intensive Grazing	X	X	X		X	X						

Note: Shaded areas indicate emerging/growth stage (light gray), flowering (green), seed formation (dark gray), and seed set (pink).

Mechanical

Hand pulling and hoeing is effective, but labor intensive. From an operational perspective this makes hand pulling and hoeing only practical for small infestations. The roots must be pulled out and removed or disposed of in a way that ensures the roots will dried out (DiTomaso et al. 2013). In contrast to eradication studies where using fire for two years greatly reduced goatgrass (DiTomaso et al. 2001), multiple studies have shown that hand pulling requires more than two years to achieve eradication (Aigner and Woerly 2011; Merenlender and Heaton 2014). This is likely because dormant seeds, once thought to remain dormant for only a year or two, have the capability to last for three to five years in the soil and are not stimulated wholesale by hand pulling like they are by fire. Stimulating dormant seed helps speed up the eradication process as it draws out all of the seed that is dormant in the soil. Manual removal of thatch in combination with hand pulling may increase seed bank stimulation for the next year while also increasing habitat for native forbs.

Mowing does not kill the plant but can reduce seed production. However, timing is critical and if done after seed has matured, mowing may spread seed or increase the abundance and density of the infestation. Mowing should be done when seed is developing, but not after it has matured. If mowing is done too early, the plants will recover and produce another crop of seed. Even if done at the correct time mowing is limited in its effectiveness because it has been observed that a certain percentage of plants take on a semi-prostrate form that is low enough to the ground to escape injury from mower blades (DiTomaso et al. 2013). Mowing in combination with hand pulling over three to four years is a promising method for obtaining significant population reductions.

Tilling using sweep tillage V-blades will effectively bury seed below emergence depth, however seed is viable for up to 5 years and seed may be brought back to the surface during subsequent tilling. This technique may be best applied in an agricultural context due to the generalized destructive nature of tilling. In rangeland environments erosion soil moisture loss, and damage to desirable species caused by tilling may outweigh the benefits of the weed control (DiTomaso et al. 2013).

Cultural

Heavy grazing during the early growing period followed by removal of cattle has been shown to increase density of goatgrass. This is likely due to heavier grazing on other more desirable species in combination with goatgrass's ability to vigorously regrow after injury. Furthermore the long awns produced by goatgrass ensure its protection from grazers while seed is forming. Though livestock typically avoid goatgrass, intensive grazing early in the season will reduce densities and may be a viable option in areas where it is desired to remove all the vegetation and replant. Additionally intensive grazing right before seed formation will reduce seed set and depending on the season may cause limited damage to native grasses and forbs that have already gone to seed. Burning has been used successfully to control goatgrass, but like mowing, timing is critical. Burning needs to happen while seeds are on the plant and still forming. Seed that have fallen to the ground and are on the soil surface, will not be killed by a fire (DiTomaso et al. 2001). An experiment resulted in successful control of goatgrass at Hopland UC Berkeley using fire in 1997 and 1998 where cover was reduced by 92% after two years of consecutive burning. They saw a general increase in native species and decrease in other non-native species in the burn plots (DiTomaso et al. 2001). One issue with using fire is that there is a short time when the plants are dried out enough to ignite effectively while still having seed attached to the plant, this is typically in late spring, but varies from year to year. If the intent is to eradicate goatgrass it is necessary to have a multi-year management plan when using fire. The open ground in combination with the flush of nitrogen caused by the fire will stimulated dormant seed to germinate in the next season requiring a second treatment the following year.

Chemical

Using chemical means to control goatgrass is limited by the fact that there are no grass-specific registered herbicides for rangeland management. There has been little research and development of pre-emergent herbicides for goat grass. Glyphosate (Roundup, Accord XRT II) is used to kill the whole plant and is an effective treatment for small patches in winter or spring. However glyphosate is non-selective and can damage or kill all plants it comes in contact with and would not be recommended for use if valued native plants are mixed in the population. In addition, because mortality of vegetation in sprayed areas is total, spraying should be followed by seeding with desirable species to avoid establishment of weeds (Peters 1994). If glyphosate is used it should be done in late June before goatgrass seed is mature but after most other species have already gone to seed.

Clethodim (Envoy Plus) and fluazifop (Fusilade II) are grass specific herbicides that are typically used in an agricultural context, but have been gaining attention by natural area managers. One study showed that both herbicides were effective in controlling goatgrass while leaving native perennial grasses and forbs unscathed. These herbicides should be used with caution as they will also favor non-native forbs and non-native *Festuca* spp. (Aigner and Woerly 2011). Furthermore investigation of these herbicides' effect on all taxonomic groups is not well understood. One study showed that they effectively controlled *Erodium cicutarium* as well as other species in that genus. This could be a problem for native plants related to *Erodium* sp. like the HCP/NCCP Covered species round-leaved filaree (*California macraphylla*). These herbicides have many unknown environmental effects in the rangeland context and require caution when using. Suggestions made here are in general terms, for more detailed information on application times, methods, and specific products reference Weed Control in Natural Areas in the Western United States (DiTomaso et al. 2013).

Recommendations

Treatment of areas infested with barb goatgrass has the potential to improve habitat and increase native plant cover. However, weed treatments also have the potential to harm native plant populations growing within or around barb goatgrass stands. This is of particular concern for sensitive and rare plants species. During rare plant surveys in 2014 Diablo helianthella was observed growing with barb goatgrass. The most effective treatment and the least likely to harm Diablo helianthella is early detection in combination with hand pulling of barb goatgrass before it goes to seed. However, hand pulling is labor intensive and may not be a viable option if populations are too large and well established. Diablo helianthella is a broadleaved perennial that typically goes dormant by July allowing managers to take advantage of barb goatgrasss' late season flowering and seeding.

Mowing when seed is starting to form but before it is mature, towards the end of June or beginning of July, would significantly reduce seed production while limiting damage to Diablo helianthella. However, it should be noted though damage may be limited by spraying or mowing during the summer, there still may be impacts on Diablo helianthella. Though plants have already gone to seed, and most energy is in the underground caudex at this time, damage to any surviving above ground leaves may reduce the amount of energy transferred to caudex for the next season. This may not be a significant problem for a one-time treatment, but may have a significant impact on plant vigor if practiced for many years in a row.

Properly timed grazing using goats or sheep may provide an effective tool for reducing populations of barb goatgrass. However, a detailed grazing plan that included a combination of weed treatments including follow up spraying, hand pulling, or mowing, would be key to successful use of grazing. If done improperly grazing could increase size and abundance of barb goatgrass populations. Livestock are often vectors of weed seed either by seed attaching to the body or through the digestive track. Caution should be taken to not use livestock while any noxious weeds are seeding and sites that are graved should be monitored the previous year for new weed introductions.

MEDUSAHEAD GRASS (*ELYMUS CAPUT-MEDUSAE*)

General Information

Medusahead is an ascending to erect winter annual in the grass family (Poaceae). It flowers in early summer and matures at least 2-4 weeks later in the season than most other annual grasses making it highly visible from a distance after other annual grasses turn brown. Medusahead is a noxious rangeland weed that forms dense stands that displace desirable vegetation and wildlife and lower livestock carrying capacity (Young 1992). Senesced plants form a dense layer of thatch that takes 2 or more years to decompose. The thatch layer greatly reduces seed germination of other species and creates fuel for wildfires.

Medusahead contains high levels of silica, which makes it unpalatable to livestock except during the early growth stages (Young 1992). The stiff awns and hard florets can injure the eyes, nostrils, and mouths of grazing animals.

This species is native to Europe and the Middle East and is now found as a noxious weed throughout the Western United States. Specimens were first collected in Oregon in 1887 and later in 1908 near Los Gatos California (Young 1992). It inhabits disturbed sites, grassland, rangeland, openings in chaparral, oak woodlands, and can rarely be found in agronomic fields. It grows best on clay soils or where deep soil moisture is available late in the growing season (DiTomaso and Healy 2007). However, it is important to note that beginning in the 1960s it was observed occupying more course soils indicating it is adapting to new conditions or has had multiple introductions providing wider genetic variability (Young 1992).

Relevant Life History Traits

Medusahead is an annual grass that reproduces by seed. Seed is initially dormant until it is broken by temperature cues, namely an appropriate cooling period (Barton 1962). Seed production is usually prolific and disperses locally with wind and water and to greater distances with human activities, soil movement, and by clinging to machinery, tires, shoes, clothing, and to animals. Germination is typically rapid with most seeds germinating in fall after the first rain. However, some seeds remain dormant and germinate in the winter or spring. It has been observed that seedling can maintain very high densities under low moisture conditions (DiTomaso and Healy 2007).

Ecological Harm

Medusahead forms monocultures and a dense layer of litter that prevents other species from germinating and/or emerging. It reduces diversity where it invades and decreases valuable forage quantity, primarily through competition. Medusahead has been shown to be a strong competitor at the seedling phase and inhibits competitor recruitment by litter build up. Litter decomposes very slowly due to its high silica content (Maurer, Russo, and Godell 2014).

Medusahead does well in areas that have late season soil moisture to support the species' late seed maturation. This has caused a widespread invasion and degradation of many vernal pool habitats in California (Pollak and Kan 1998). Another, less documented, unique habitat that medusahead threatens is heavy clay lens soils which are abundant in the eastern part of the HCP/NCCP inventory area. These are small protrusions of heavy clay that appear to support high native diversity and abundance and have relatively high resistance to other invasive annual grasses. Medusahead has been observed growing in these conditions and is clearly reducing the quality of the heavy clay lens habitat where several of the HCP/NCCP Covered plant species are known to occur, especially on Roddy Ranch where big tarplant (*Blepharizonia plumose*), shining navarretia (*Navarretia nigelliformis* subsp. *Radians*), and round-leaved filaree (*California macrophylla*) have been recorded. Protecting this heavy clay lens habitat, particularly in Horse Valley should be a high priority for abatement as medusahead has been recorded growing with these covered plant species.

Control Strategies

A variety of measures have been taken to control medusahead in California. The most effective is early detection and removal. In general, most methods attempt to take advantage of medusahead's late maturation. This allows for burning or spraying to be selective to medusahead and makes timing of treatment one of the most important issues when controlling the species. The most effective treatment plans will include a multiyear process. Medusahead forms a seed bank that will persist under most treatments. Consequently the seed bank needs to be allowed to germinate while not allowed to replenish for multiple years before the population will disappear. Techniques discussed below are separated into mechanical, cultural, and chemical. Table 2 shows each control method and the appropriate timing.

Table 2. Timing of Control for Medusahead Grass

Abatement Method	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Hand Pulling	X	X	X	X	X	X						
Prescribed Fire					X	X	X					
Mowing				X	X	X						
Tilling			X	X	X							
Pre-emergent Herbicide										X	X	X
Foliage Herbicide	X	X	X	X								
Seed Formation Herbicides					X	X						
Intensive Grazing	X	X	X		X	X						

Note: Shaded areas indicate emerging/growth stage (light gray), flowering (green), seed formation (dark gray), and seed set (pink).

Mechanical

Hand pulling and hoeing is effective, but labor intensive. From an operational perspective this makes hand pulling and hoeing only practical for small infestations. The roots must be pulled out and removed or disposed of in a way that ensures they roots will dried out (DiTomaso et al. 2013).

Mowing has produced mixed results. In the early spring it is ineffective as a control measure and may harm desirable plants. If mowing is too late in the early summer after seed has begun to mature mowing will only facilitate the spread of seed. Mowing in the beginning of flowering helps reduce seed formation and can significantly reduce population density if done multiple years in a row, but is not seen as an effective treatment for completely eradicating populations (DiTomaso and Healy 2007). In general, mowing is most effective when coupled with a follow up of hand pulling and done for multiple years. One study showed that mowing combined with hand follow up was very successful, reducing cover to 1.5%, as long as mowing was conducted at the correct time, specifically at early kernel development when anthers and stigmas are no longer present and seeds are still very soft (Niederer 2014).

Tilling has shown some benefit if done before seed set. This technique may be best applied in an agricultural context due to the generalized destructive nature of tilling. In rangeland environments erosion soil moisture loss, and damage to desirable species caused by tilling may outweigh the benefits of the weed control (DiTomaso et al. 2013).

Cultural

Grazing has been shown to reduce density of medusahead, but does not eliminate it. Reduction in density is not due to heavy grazing but mostly caused by trampling effects. The high silica content of medusahead renders it unpalatable to livestock except for in very early stages (Torell, Erickson, and Haas 1961). Though there may be a reduction of density due to grazing in the short term. However in the long term grazing may actually select for medusahead. As grazing reduces cover of species that are preferred forage, species that are avoided, like medusahead, will likely benefit from the reduced competition (Pollak and Kan 1998; DiTomaso and Healy 2007). However, East Bay Parks has been using sheep to control medusahead with some success (pers.comm. Denise Defreese 2014).

Burning has been used successfully to control medusahead. However, results have been mixed and it appears that successful treatment is contingent on burning conditions. Fire at any time of the year will help reduce litter accumulation which has been shown to increase germination of other desirable species in medusahead infested areas (Pollak and Kan 1998). However, if the objective is to kill seeds and reduce population densities, burns must be executed at the correct time when the seed is developing, in its seed formation stage while the seed is still maturing on the plant (McKell, Wilson, and Kay 1962). If fire is used too early in the season, fires may burn poorly and plants will have time to recover and create a seed crop. If done too late after the seed has fallen from the mother plant, seeds will not be killed by the fire (Murphy and Lusk 1961). It is necessary to have a multi-year management plan when using fire to reduce population levels because seed that is dormant on the soil surface or soil seed bank will remain unscathed by the fire and germinated readily the following season. It may even appear that fire increases density the following year due to the removal of thatch and an increase of available nitrogen (Pollak and Kan 1998; McKell, Wilson, and Kay 1962). This germination flush is the result of dormant seeds germinating from the seed bank, and if allowed to reseed will ensure persistence. For this reason it is essential that there is a multi-year eradication plan in place before fire can be used effectively.

Chemical

Using chemical means to control medusahead is limited by the fact that there are no grass-specific registered herbicides for rangeland management. This limits use of herbicides to small patches so other desirable plant species are not affected. Pre-emergence herbicides used on medusahead include sulfometuron (Oust), rimsulfuron (Matrix), and aminopyralid (Milestone). These are applied in the fall as seeds are just starting to germinate. Many of these are non-discriminate herbicides that control both broad leaf forbs and grasses so caution should be used if there are valuable native species growing within the target area (Kay and McKell 1963). Herbicides used during active growing and flower formation include those based on glyphosate (Roundup and Accord XRT II). These herbicides can effectively reduce medusahead populations, however they are non-discriminate damaging unintended forbs and grass targets. Applied in fall and spring the likelihood of harming other species is high (DiTomaso and Healy 2007). Using herbicides at this time of year is still risky however, and the unintended effects on native species are unknown. If valued native species are present, using these herbicides to inhibit seed production is not recommended. Suggestions made here are in general terms, for more detailed information on application times, methods, and specific products reference Weed Control in Natural Areas in the Western United States (DiTomaso et al. 2013).

Recommendations

Treatment of areas infested with medusahead has the potential to improve habitat and promote native plant cover. However, weed treatments may also harm native plants, of particular concern are rare and sensitive native species. Three rare and sensitive plants were observed growing with or in the vicinity of medusahead during 2014 rare plant surveys; round-leaved filaree, big tarplant, and adobe navarretia. The different life histories of these species makes it difficult to recommend one single treatment. The most effective treatment and least likely to harm sensitive species is early detection in combination with hand pulling of medusahead before it goes to seed. However, hand pulling is labor intensive and may not be a viable option if populations that are too large and well established.

Round leaf filaree germinates in late winter/early spring and drops its see by the end of May making it safe to spray when medusahead is forming seed in June. However, big tarplant and adobe navarretia share habitat with round-leafed filaree and are late flowering species that would be harmed by any spraying during summer months. Even if grass-specific herbicide is used unintended effects on covered species are still not well understood and therefore is not worth the risk. Early stages of medusahead growth, October-January, may provide a safe window for spraying in areas where big tarplant or adobe navarretia grows. However, fall and winter month is when round leaf filaree begins to germinate (Gillespie 2005). A clear understanding of location, extend and density of rare and sensitive plant populations is key to type and timing of treatment. Sensitive and rare plants populations were recorded in 2014, however these annual plant populations vary significantly in size and abundance from year to year depending on conditions.

Properly timed grazing may provide an effective tool for reducing populations of medusahead. However, a detailed grazing plan that included a combination of weed treatments like follow up spraying or hand pulling would be key to successful use of grazing. If done improperly grazing could increase size and abundance of medusahead populations. Mowing, if combined with hand pulling, is a viable option for medusahead control. In areas where rare plants are located or suspected to be located a line trimmer could be used so that desired species could be avoided. In areas where it is determined sensitive or rare species are absent, a riding mowing could be used to increase efficiency of treatment and would be helpful for large patches. The proper time to mow is during early kernel or seed development. Timing will vary from year to year depending on conditions so it is important that timing is based on biology and not calendar dates. It is recommended to monitor the population by opening multiple florets scattered throughout the treatment area. Ideally all sexual parts of the flower (stigmas and anthers) should be absent but seed should not yet be formed and should be soft. Mowing should be done when a majority of individuals are in this stage for maximum effect (Niederer 2014).

To gain a clear understanding of population size and spatial distribution it is recommended that rare plant monitoring occur for two to three years, ideally in dry and wet years, to understand the extent of these populations prior to any weed treatment other than hand pulling or mowing with a line-trimmer.

Sincerely,

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APPENDIX B SEED GERMINATION STUDY DATA FORM

Seed Germination Study Data Form

Location:

Date:

Observer:

Species:

Phenology:

Heights:

Total germinated:

Photos:

Notes: