U.S. Fish and Wildlife Service
Humboldt Bay National Wildlife Refuge
Humboldt County, California

MANAGEMENT AND MONITORING PLAN, and
PROGRESS REPORT for Invasive Annual Grasses
at the Lanphere and Ma-le'l Dunes Units,
Humboldt Bay National Wildlife Refuge

CONTROL TARGET: Invasive annual grasses (primarily *Bromus diandrus, Vulpia bromoides, Aira praecox, Briza maxima*)

SITE NAME: Lanphere and Ma-le'l Dunes Units, Humboldt Bay NWR

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INVASION ECOLOGY:

Distribution and Spread on the North Spit Dunes

The invasive annual grasses *Bromus diandrus, Vulpia bromoides, Briza maxima and Aira praecox,* have proliferated over the semi-stable dunes of Humboldt Bay during the past 25 years. *Polypogon monspeliensis* has also invaded, but is limited to wet swales and is not treated in this management document. Early detections of *Bromus hordeaceous* and *Hordeum murinum* have also been mapped and treated. In addition, several invasive perennial grasses have also begun to make inroads, notably *Anthoxanthum odoratum* and *Holcus lanatus*. For convenience, this suite of species will be referred to as invasive annual grasses, to differentiate them from the more prevalent invasive perennial grass *Ammophila arenaria*. Although *Aira caryophyllea* has also been included on past inventories of invasive annual grasses, this species has not proved to be invasive at the Lanphere Dunes.

The first regional inventory of invasive annual grasses on the North Spit of Humboldt Bay was undertaken in1998, when USFWS and its partners mapped cover by species of dominant grasses over the entire North Spit. At that time, a total of 547 acres were covered with a mix of grass species (Fig. 1). Many of these occurrences were coincident with *Lupinus arboreus* (*i.e.* occurring under and around lupine shrubs). *Lupinus arboreus* is known to facilitate secondary grass invasions (Pickart et al. 1998). In some places where *Lupinus arboreus*

had been removed as a management action, but no management of grasses followed, annual grasses were the dominant cover. In 1998, over the entire spit, the most abundant genus was *Aira*. This species was already well established on the Lanphere Dunes when The Nature Conservancy began managing it in the 1970s. However, other species, especially *Bromus diandrus* and *Briza maxima*, were observed to colonize and spread beginning in the 1990s. *Bromus diandrus* was the second most extensive species in 1998. Together with *Briza maxima* this species poses the greatest threat of the invasive grass species, in part due to its abundance but also due to its robust size. In 1998 *Briza* was much more prevalent at the south end of the Spit, but it has since become a major invader in the north

Field mapping over most of the original area was repeated using consistent methods in 2009. By 2009 total annual grass covered 2,286 acres, an increase of 550% (Fig. 1). Not all species increased equally. *Briza* showed the greatest increase in cover (1,000%), followed by *Bromus* (320%) *and Vulpia/Aira* (246%).

Between 1998 and 2009 management of annual grasses occurred in some areas, especially at the Lanphere and Ma-le'l Dunes Units of HBNWR. During this same period there was a dramatic increase in annual grass cover, especially *Bromus diandrus*, on the Bair and Woll parcels; private property adjoining the North boundary of the refuge. All annual grasses reproduce by seed, and seeds are generally wind dispersed. For this reason, control within political boundaries is extremely expensive and difficult. Given the orders of magnitude increase in seed dispersal from the increasing population of *Bromus* to the north, it is likely that in the absence of management much of the Lanphere Dunes would now be covered with annual grasses. Without a major initiative to control this species to the north, management at Lanphere Dunes will need to continue indefinitely. The refuge purchased the Bair parcel in 2011. The addition of the Woll parcel to the refuge, and the restoration of both parcels, is a high priority for the refuge.

Invasion impacts

On the North spit, invasive annual grasses overstabilize dunes, and outcompete native dune mat species. Areas that were dominated by *Bromus diandrus* saw a dramatic increase in native cover and species diversity, including increased numbers of the endangered Humboldt Bay wallflower, after annual grass removal at the Lanphere Dunes Unit (this report). However, restoration of annual-grass-invaded dunes is complicated by the fact that *Aira praecox* is strongly correlated with biotic soil crusts (Gordon 2000). These crusts are themselves an important source of biodiversity with likely ecosystem services, and they also provide nesting substrate for shallow-nesting native solitary bees, especially *Megachile wheeleri* (Gordon 2000). *Megachile* is an important pollinator of the dune mat flora (Nyoka 2004).

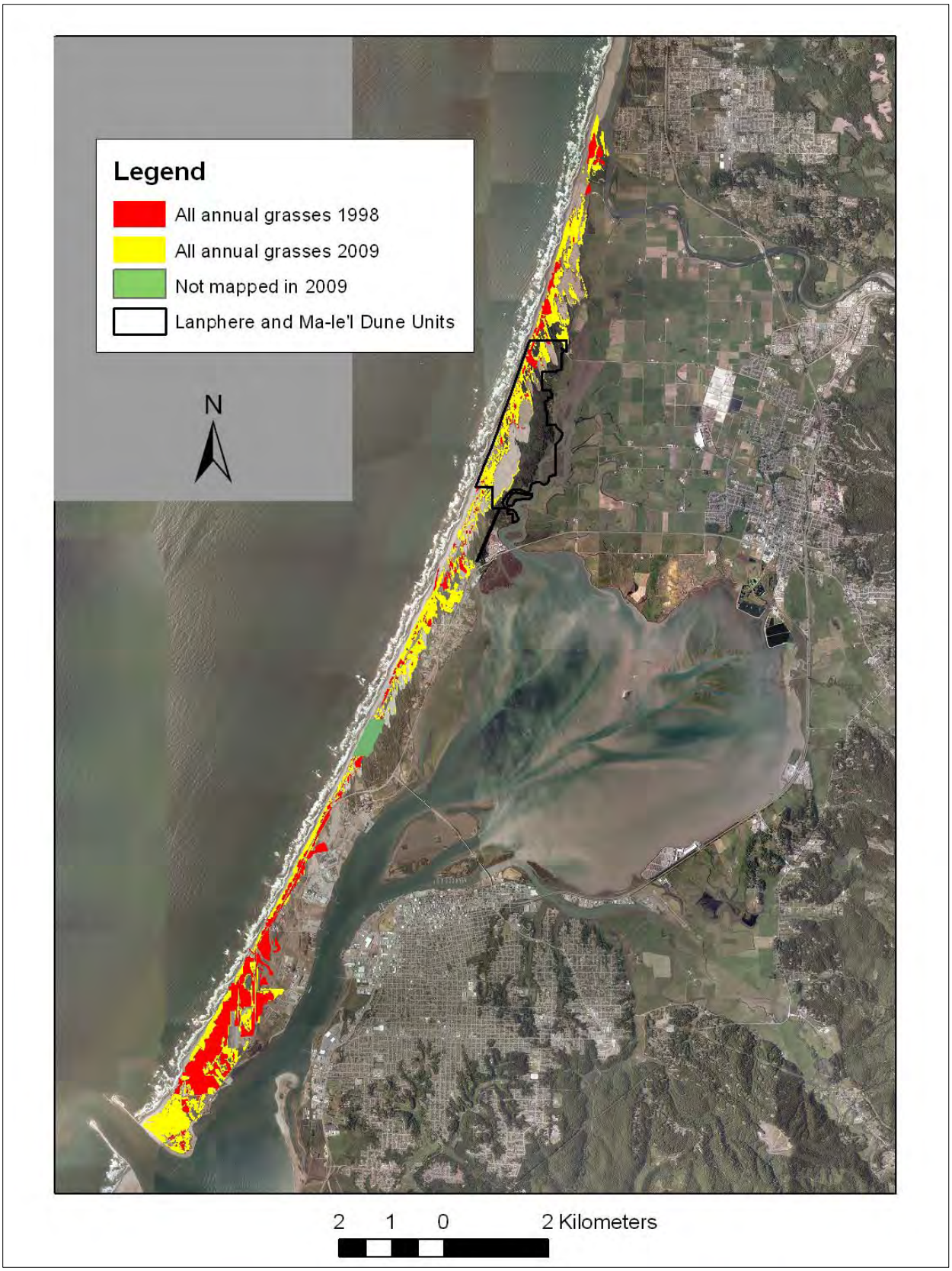

Figure 1. Extent of all invasive annual greases in 1998 compared with 2009 over the entire North Spit.

In other ecosystems, notably coastal prairie, annual grasses are known to bring about ecosystem-level changes, by altering fire regimes and nutrient cycling. Studies on the North Spit have shown that increases in annual invasive grass cover are correlated with increased nitrogen, although this was tested only in a system where nitrogen-fixing *Lupinus arboreus* was present (Pickart et al. 1998). Additional research is needed to document changes in nutrient cycling in early successional dune mat and biotic soil crusts that may occur directly as the result of annual grass invasion. It appears that these invasions increase dune stability and possibly accelerate succession to later successional vegetation. Finally, there is very little information on the effect of these invasions on terrestrial invertebrates, which are a very important part of the dune ecosystem. The thatch ant *Formica obscuripes* is one of the most conspicuous insects on the dunes, and has been characterized as a keystone species capable of community level consequences in our dune system (Crutsinger and Sanders 2005). *Formica* colonies are characterized by systems of large thatch nests. Many, but not all of these nests sport a lush growth of *Bromus diandrus* in the spring (Fig. 2) It isn't known whether the ants bury the seeds or the nitrogen patches merely act as nurseries (or both). Nests can also act as nurseries for native species, and certainly play an important role in succession by creating nutrient-rich patches. The role of invasive as opposed to native species in this complex interaction needs to be teased out in future studies.

In addition to thatch ants, there are many terrestrial insect and invertebrate communities that could potentially be restructured through the invasion of annual grasses. These grasses produce a thick, continuous layer of shallow, fibrous roots and duff that is very different from the patchy and more diverse rooting architecture of native dune grasses, which are usually rhizomatous and/or stoloniferous. In addition, annual grasses may provide a food source for a completely different set of invertebrate herbivores than native species. Finally, it is conceivable that the rooting architecture and species changes associated with annual grass invasions could alter vertebrate use of the dunes. More study is needed in this area.

Figure 2. A thatch ant nest acting as a nursery for *Bromus diandrus*.

KNOWN RESPONSE TO MANAGEMENT

There have been a number of experimental projects conducted on annual grass control on the North Spit, and large scale management at the Lanphere Dunes Unit has been ongoing since 1997. The first experiment was motivated by observed increases in *Briza maxima* at the Manila Dunes, and extended over three years. This study concluded that hand pulling was more effective than weedeating or burning for this species (Miller 1997, 1998; Pickart 1999). A subsequent, two-year experiment by The Nature Conservancy compared flaming, pulling, mowing, and duff removal, and found that duff removal was most effective for a combination of species (Wear 2000 and USFWS unpublished data). Burning worked well on some but not all species, and handpulling was not effective for the smaller *Vulpia* and *Aira* species. The success of duff removal was attributed in part to the collateral removal of buried seeds. However the method was labor intensive and generated large amounts of debris. As part of a study evaluating the effect of flaming and radiant heat on survival of the solitary bee *Megachile wheeleri*, Tatum (2010) compared flaming and radiant heat to test their effectiveness on the smaller annual grass species *Vulpia* and *Aira*, as well as any impacts on biotic soil crusts. Both treatments resulted in a significant decrease in *Vulpia* and *Aira* after two years of treatment. Subsoil temperatures didn't differ between the two treatments and an observed reduction in biotic crust was not statistically significant. The radiant heater allowed greater precision of application, allowing for more avoidance of biotic crusts. The study concluded that heat did not penetrate sufficiently to affect larval success and adult emergence. Although Gordon (2000) found a positive association between Aira spp. And *Megachile wheeleri* nests, Tatum (2010) found no significant correlation between the percent cover of annual grasses or biotic soil crusts and the density of *M. wheeleri* nests, although both were present in all nesting areas.

The Bureau of Land Management successfully used heavy equipment to restore annual grass-invaded dunes in a relatively small area at the Samoa Dunes Endangered Plant Protection Area (Wheeler 2000). This method consists of turning over the soil, exposing the deeper mineral soil at the surface and burying the surface layers of duff, grasses, and seed bank. This technique can be used only once, since subsurface sand is then contaminated. It presents a very efficient method to remove grasses, requiring very little follow up work, provided there are no nearby seed sources. The method is limited to areas that have been heavily invaded, because any native species will also be buried. The method is not appropriate where endangered plants are present.

A management protocol has evolved at the Lanphere Dunes that is useful for multiple species management of annual grasses that are growing interspersed with native (including endangered) plants. Beginning around April (the season may vary with weather), *Bromus diandrus* and *Briza maxima* are pulled by hand. Their florets are too large and heavy to burn, and flaming just wilts the stems and causes surviving intact seeds to fall. In appropriate areas, *Vulpia* and *Aira* are both treated with propane torches (in areas with biotic soil crusts a radiant heater may be used). In this method, the flame or heater is held close to or even in contact with grasses, and while they sometimes catch the flame doesn't carry. It is possible to be quite selective with the radiant heater (and to a lesser extent with the propane torch), avoiding most native plants. However, when natives are interspersed densely with grasses, the native species are burned. Monitoring has shown that the vascular plants are able to recover (see below). Flaming is initially applied for one-three seasons, and reduces but does not eliminate *Aira* and *Vulpia* and/or their seed bank, and the species over time can recover, requiring retreatment. Only hand removal is used for the smaller grasses around endangered and rare plants, and near trees or shrubs where the fire might carry. Hand pulling must be repeated over a number of years until the seed bank is depleted. Repeated removal has resulted in a continued decline in grasses with an accompanying increase in natives (see below). It appears that the seed bank may be depleted within approximately 6 years, with subsequent plants likely dispersed form offsite. Several *Briza* populations on the Lanphere Dunes have been extirpated, but new patches continue to be detected and treated.

MANAGEMENT HISTORY

Prior to 2002, annual grass control was restricted to several scattered populations of *Briza maxima* and *Bromus diandrus*. Beginning in 2002 a more comprehensive management strategy was developed, tracking progress over mapped occurrences. Areas flamed between 2003-2006 are shown in Fig. 3. Labor expended by year over this period is shown in Fig. 4. Years of lower labor between 2005 and 2009 reflect a lack of resources rather than decreased labor needs (see Appendix A).The maximum invasion extent is mapped in Figs. 5a-c. Prior to 2009, Ma-le'l annual grass management was documented in the Ma-le'l restoration reports. A detailed history of management actions by location is included in Appendix A. Maps of areas receiving particular treatments in different years are maintained in a GIS at the Lanphere Dunes office.

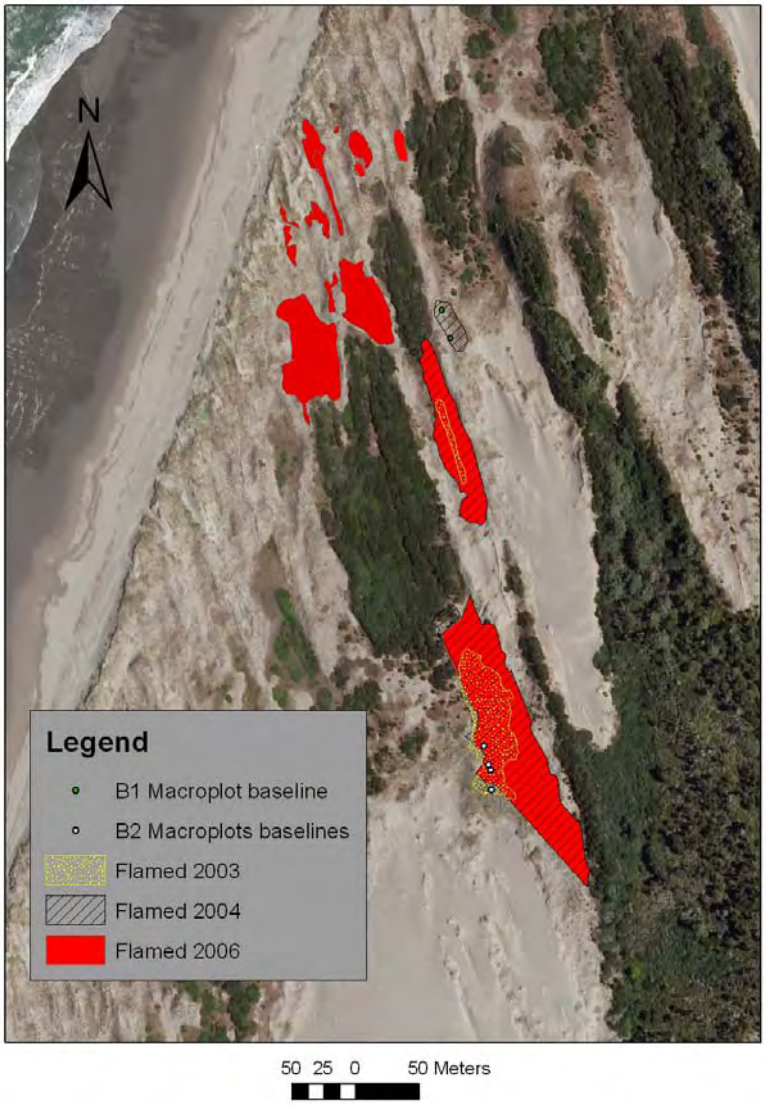

Figure 3. Map showing history of flaming activities from 2003-2006.

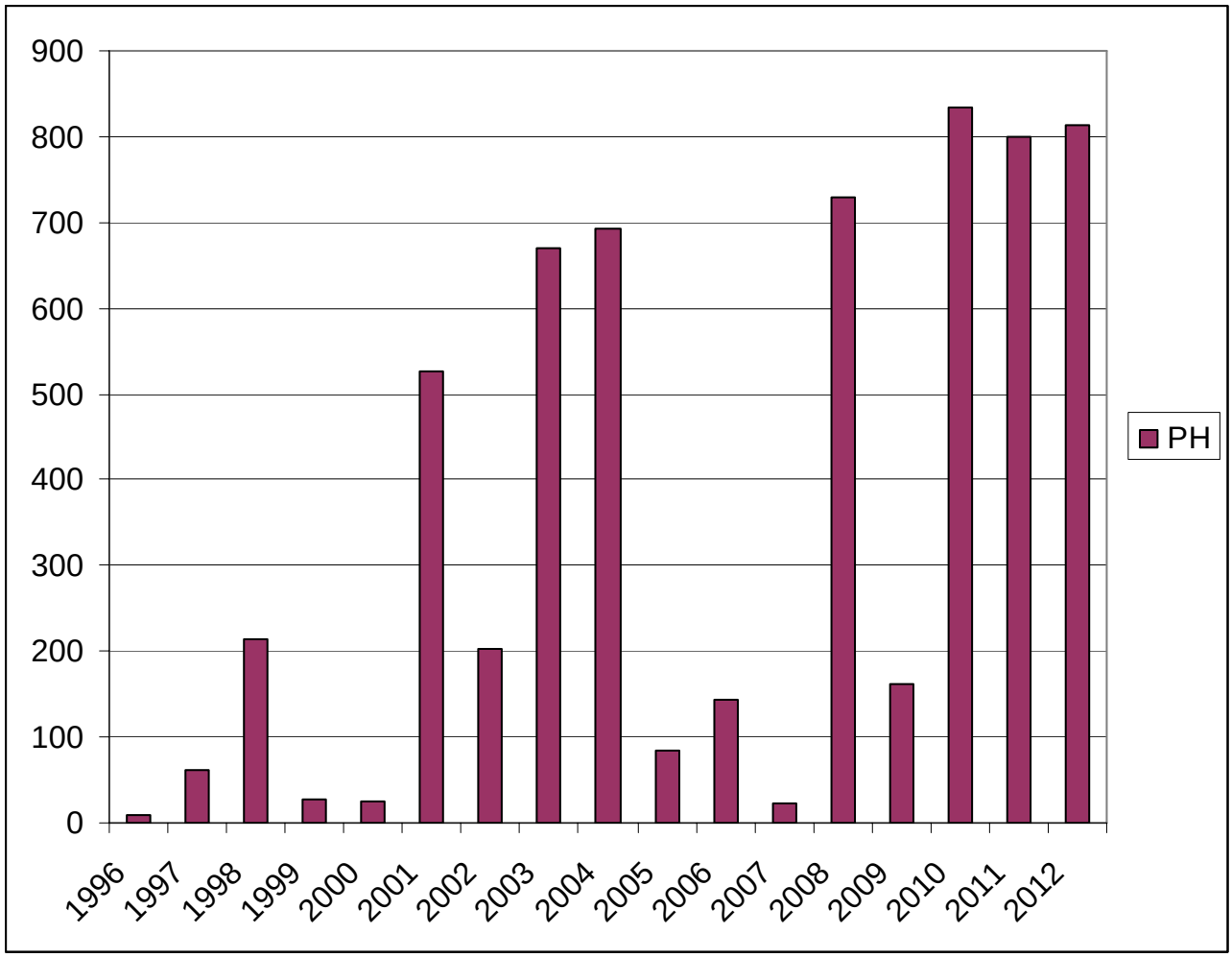

Figure 4. Labor in person-hours expended on the Lanphere Dunes Unit (and after 2009, including the Ma-le'l Dunes Unit) between 1996 and 2012).

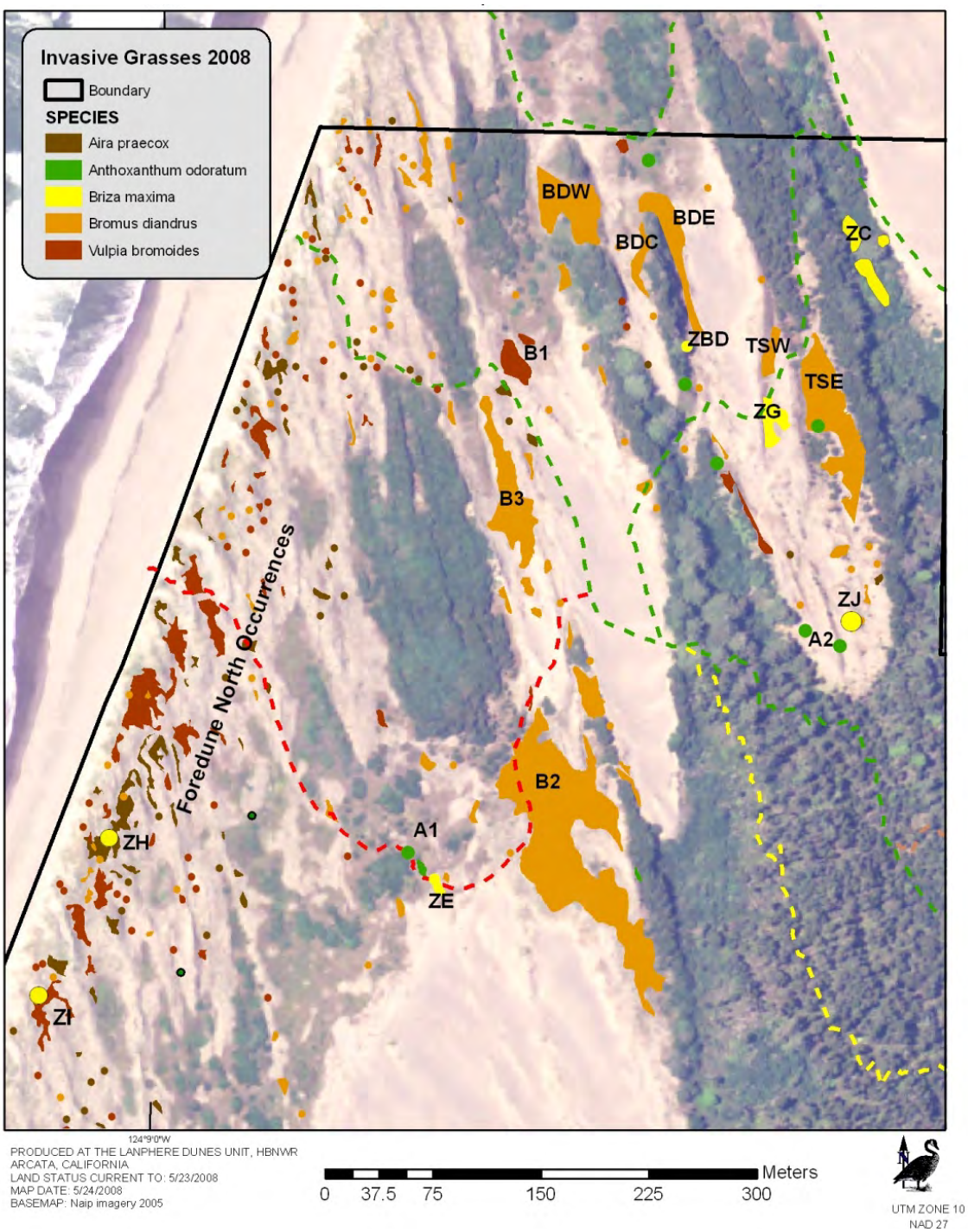

Figure 5a. Extent of annual grasses on north Lanphere in 2008 (mapping does not reflect reduction in density from management, although extirpated populations are removed from the map)

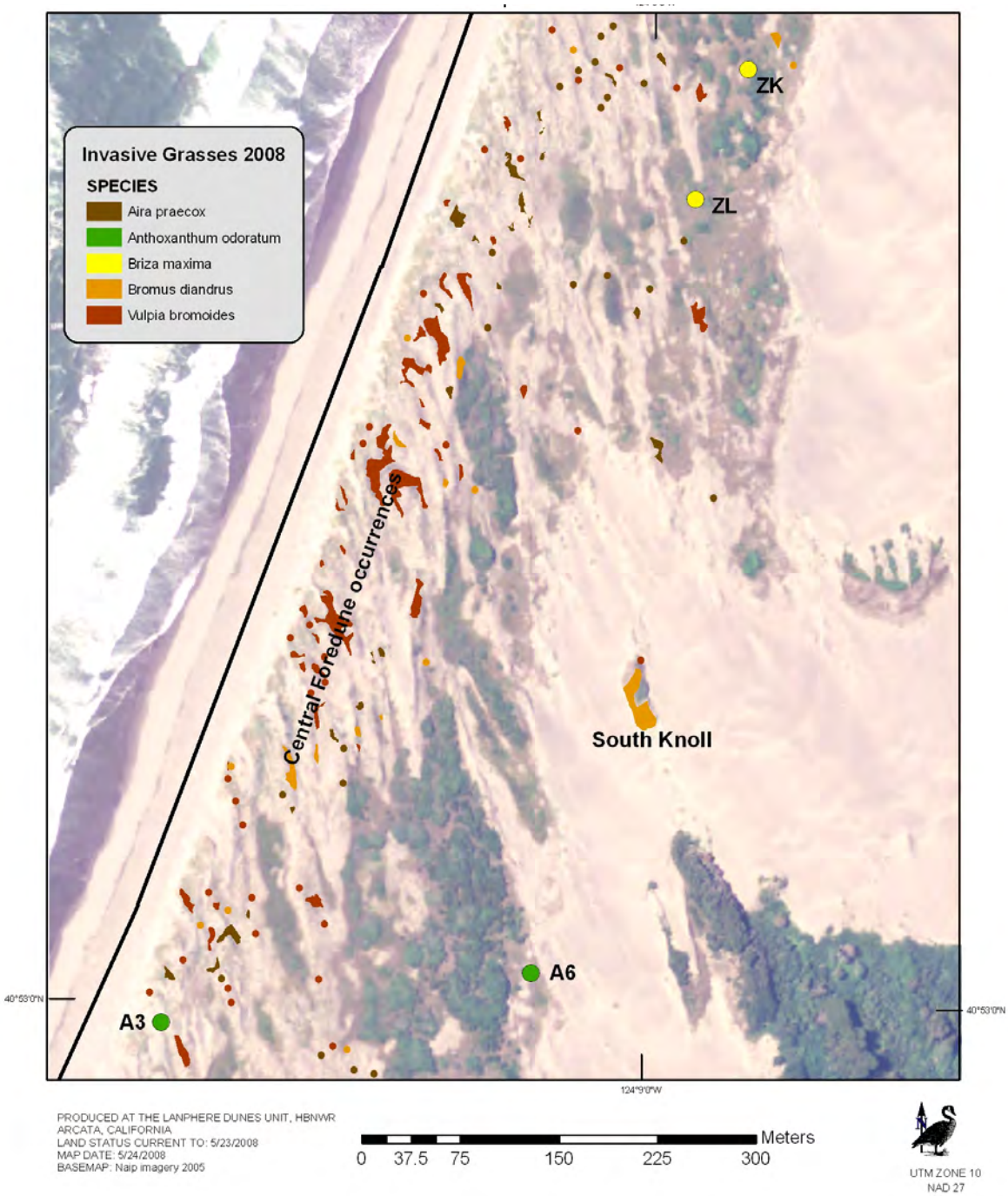

Figure 5b. Extent of annual grasses in central Lanphere in 2008 (mapping does not reflect reduction in density from management, although extirpated populations are removed from the map)

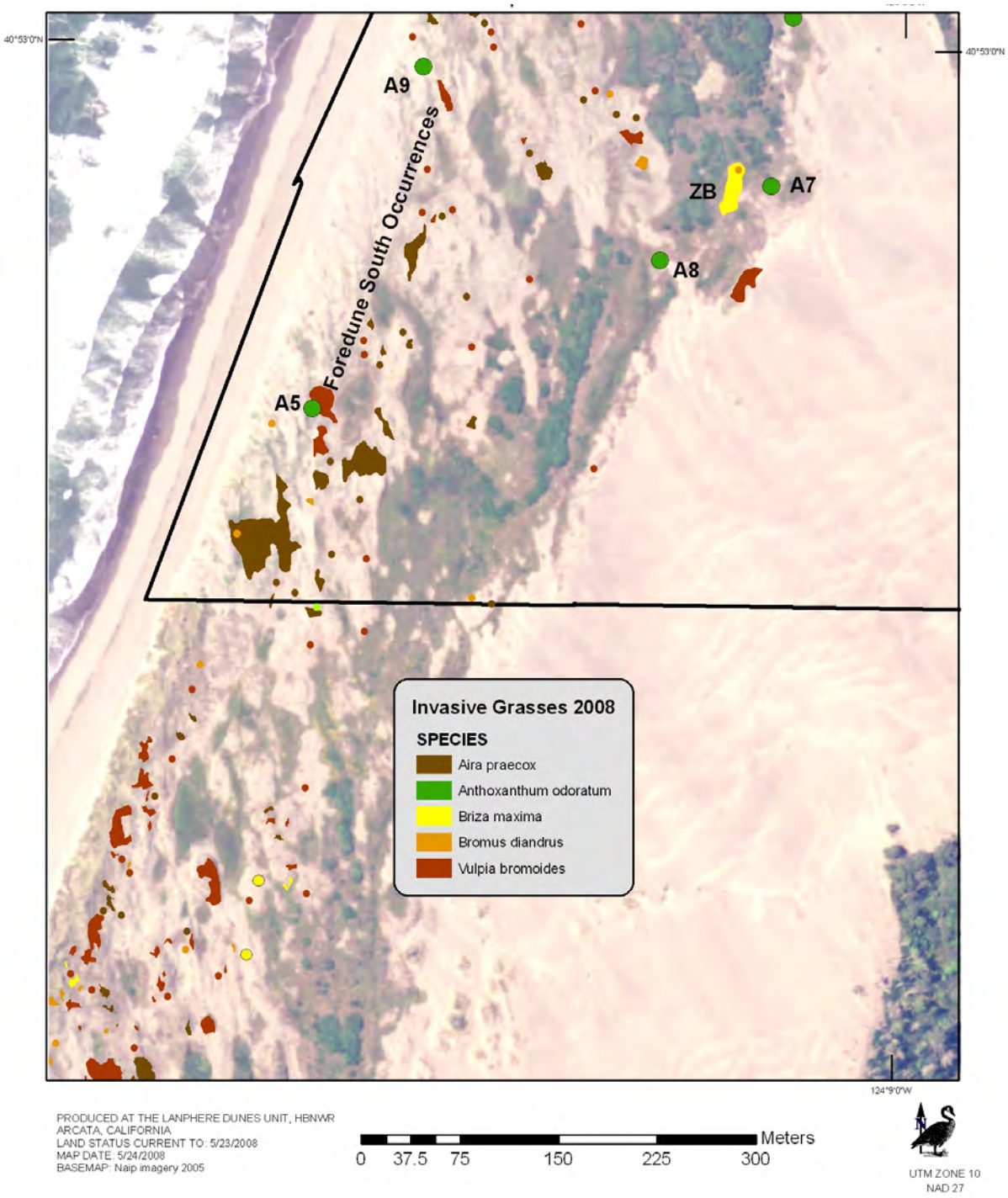

Figure 5c. Extent of annual grasses in south Lanphere in 2008 (mapping does not reflect reduction in density from management, although extirpated populations are removed from the map)

MANAGEMENT OBJECTIVES

1. Eradicate *Bromus diandrus* and *Briza maxima*. Reduce cover of *Vulpia bromoides* to less than 5%. Reduce cover of *Aira praecox* to less than 10% in all but targeted areas of biotic soil crusts or ground nesting bees.
2. Remove *Anthoxanthum* populations from swales on Ma-le'l Dunes by digging out plants and root systems annually as labor is available.
3. Pull up *Holcus lanatus* populations as detected, removing all roots (as labor is available).
4. Work to acquire properties in refuge boundary to north, and restore to remove sources of invasive grasses.
5. Work with Humboldt County Dunes Cooperative to prioritize and facilitate control of annual grass infestations on the North Spit and elsewhere.

MONITORING OBJECTIVE

Determine mean and 95% confidence interval of density of annual invasive grasses by species, with ability to detect 5% change, and measure recovery of native species as percent cover.

MONITORING DESIGN:

Three macroplots were established at the Lanphere Dunes (Fig. 6) and are monitored annually in May prior to removal of annual grasses.

1) Macroplot B1. A 20 m by 10.5 m macroplot was permanently established in area B1 prior to any management (Fig. 6). Rebar was installed, and GPS coordinates recorded for each end of the roughly north-south trending baseline. Ten transects are placed every 2 m (with a random start between 0 and 200 cm) beginning at the north end of the baseline. Each transect is 10.5m long, perpendicular to and east of the baseline. A nested quadrat is placed on the north side of the transect every 2 m, with a random start between 0 and 100 cm. The quadrat is placed with the No. 4 subframe corner aligned with the starting point along the tape (Fig. 7). The largest subframe is number 1, and the smallest 4. There are a total of 50 plots.

   Frequency. Frequency is recorded for all species, with the number of the subframe in which the plant is first encountered recorded. For example, a plant that falls in the smallest subplot is considered to fall within all 4 subplots and receives the number 4. This design allows flexibility in

choosing which frame size is most appropriate for detecting change in frequency.

Density. The density of *Bromus diandrus* is measured by counting all individuals within the entire .50m x .50 m plot.

2) Macroplots B2N and B2BS. These two macroplots were established in 2005 and replaced an earlier set of 3 that were not adequate to measure progress towards meeting monitoring objectives. Therefore, they do not measure change from pre-project conditions, but are able to detect trends from 3 years post-treatment on. Two 16 m by 15 m macroplots were established in the B2 area (the area had been previously subjected to flaming in 2003 and 2004). The 16 m baseline of each transect was oriented north-south with the two ends marked with rebar (Fig. 6). GPS coordinates were obtained for all 4 markers. Eight transects are placed on the east side of the baseline, at 2 m spacing, with a random start among .1 m increments between .5 and 2.0 m. Each transect runs perpendicular to the baseline (Fig.8). Five plots are located along each transect (with a random start, in .1 m increments, between 0 and 3 m). The sample size for each macroplot is 40. A .5 m x .5 m gridded quadrat is placed on the north side of the transect, with the west side of the quadrat at the meter mark.

   Cover. Cover of all species is estimated using a cover scale: 0, ≤1%, 2-5%, 6-10%, 11-20%, 21-30%, 31-40%, 41-50% 51-60%, 61-70%, 71-80%, 91-100%. Record the high number of the scale (1,5,10, etc).

   Density. Density of *Aira praecox, A. caryophyllea, Vulpia bromoides, Bromus diandrus, Briza maxima*, and *Erysimum menziesii* is recorded by counting the number of every rooted individual within the quarter-meter frame.

3) Photodocumentation

A series of permanent photopoints are visited each year prior to treatment (Appendix B).

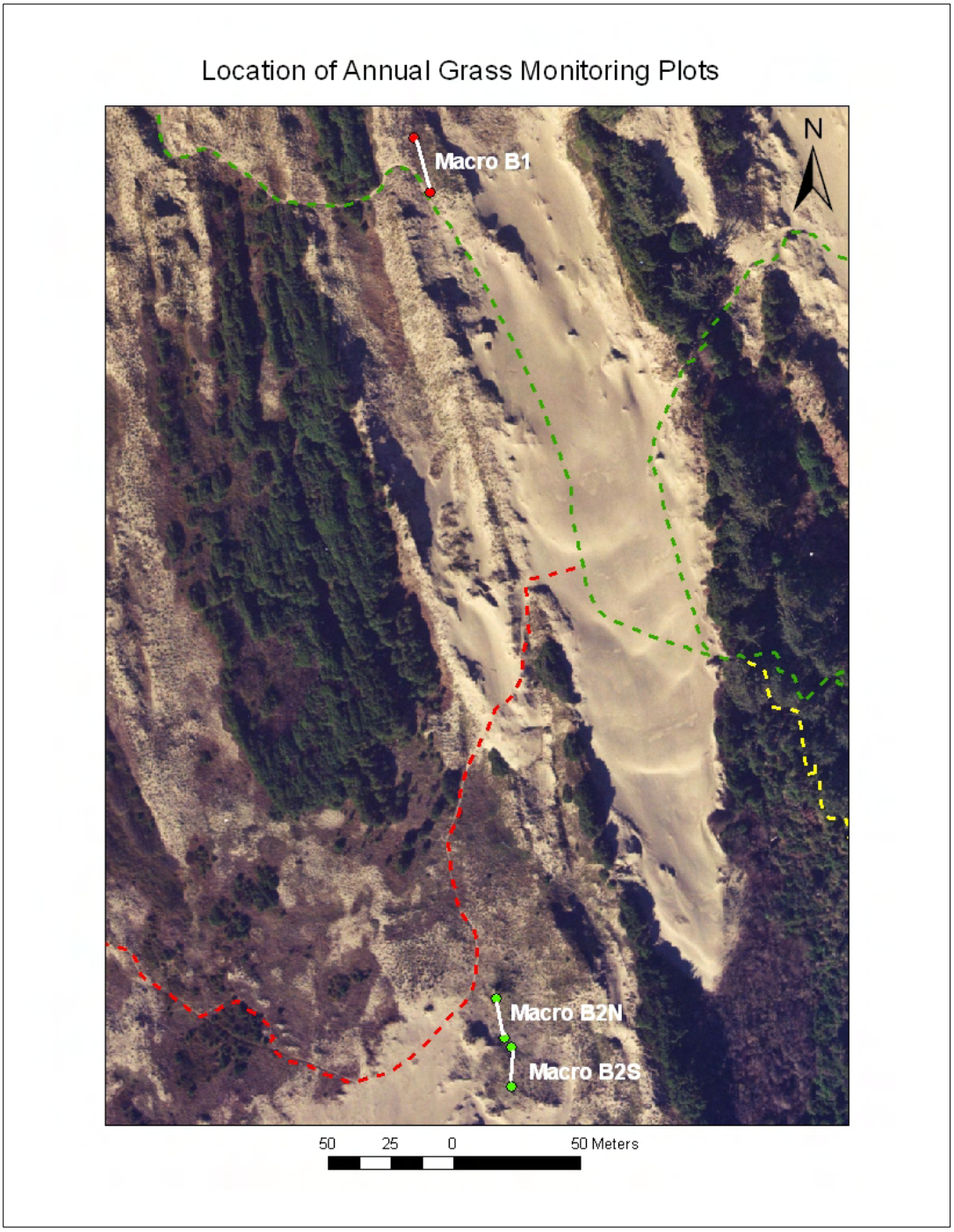

Fig. 6. Location of Macroplots B1, B2N and B2S.

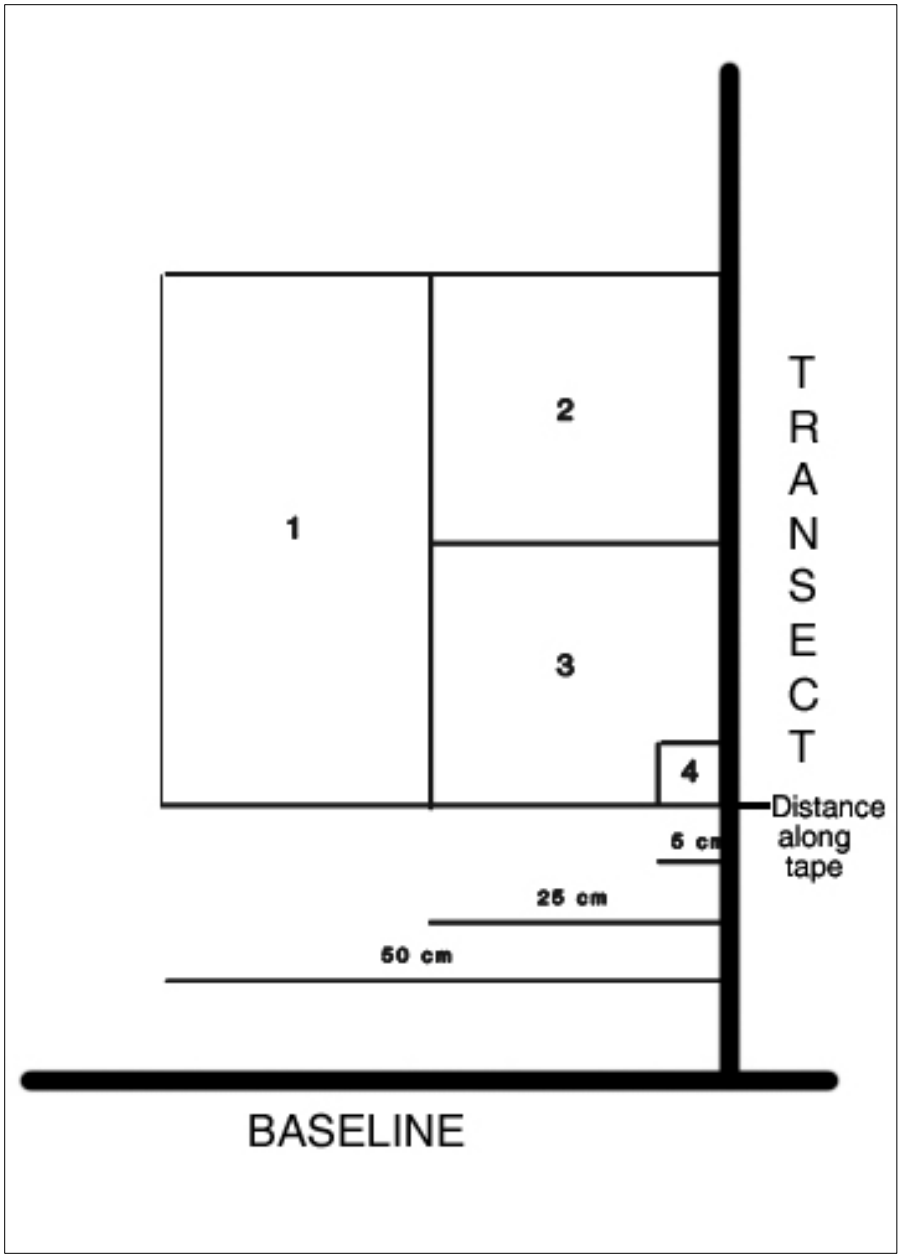

Figure 7: Nested frequency frame for Macroplot B1 showing numbering of subplots. Frequency is recorded as the number of the first subplot in which the plant is encountered, beginning with the smallest (4). The frame is placed with its right side (as shown) along the north side of the transect, and the smallest subplot pointing toward the baseline.

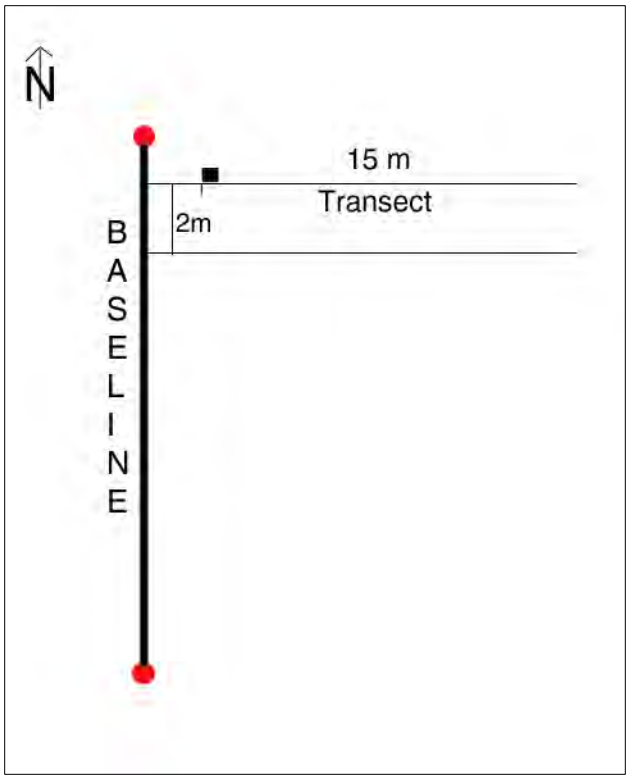

Figure 8: Layout of Macroplots in B2. The frame is placed on the north side of the transect, with the west side of the frame aligned with the measurement along the transect.

PROGRESS TOWARDS MEETING MANAGEMENT OBJECTIVES:

Because the southern macropolots (B2) had to be redesigned in 2005, only the northern macroplot (B1) shows a continuous history of control from pre-treatment through the present. In B1, the density of *Bromus* dropped from 327/m^2 pre-treatment to 74/m^2 the second year. Density continued to decline steadily until 2005 when it reached 3 individuals/m^2 (Fig. 9). However, after 2004 the differences were not statistically significant from each other at $p < .05$. The fact that these low densities have been maintained for so long after seeing such a steep drop in the first few years suggests that new seeds are dispersing into the site from populations to the north, rather than new plants emerging from the seed bank.

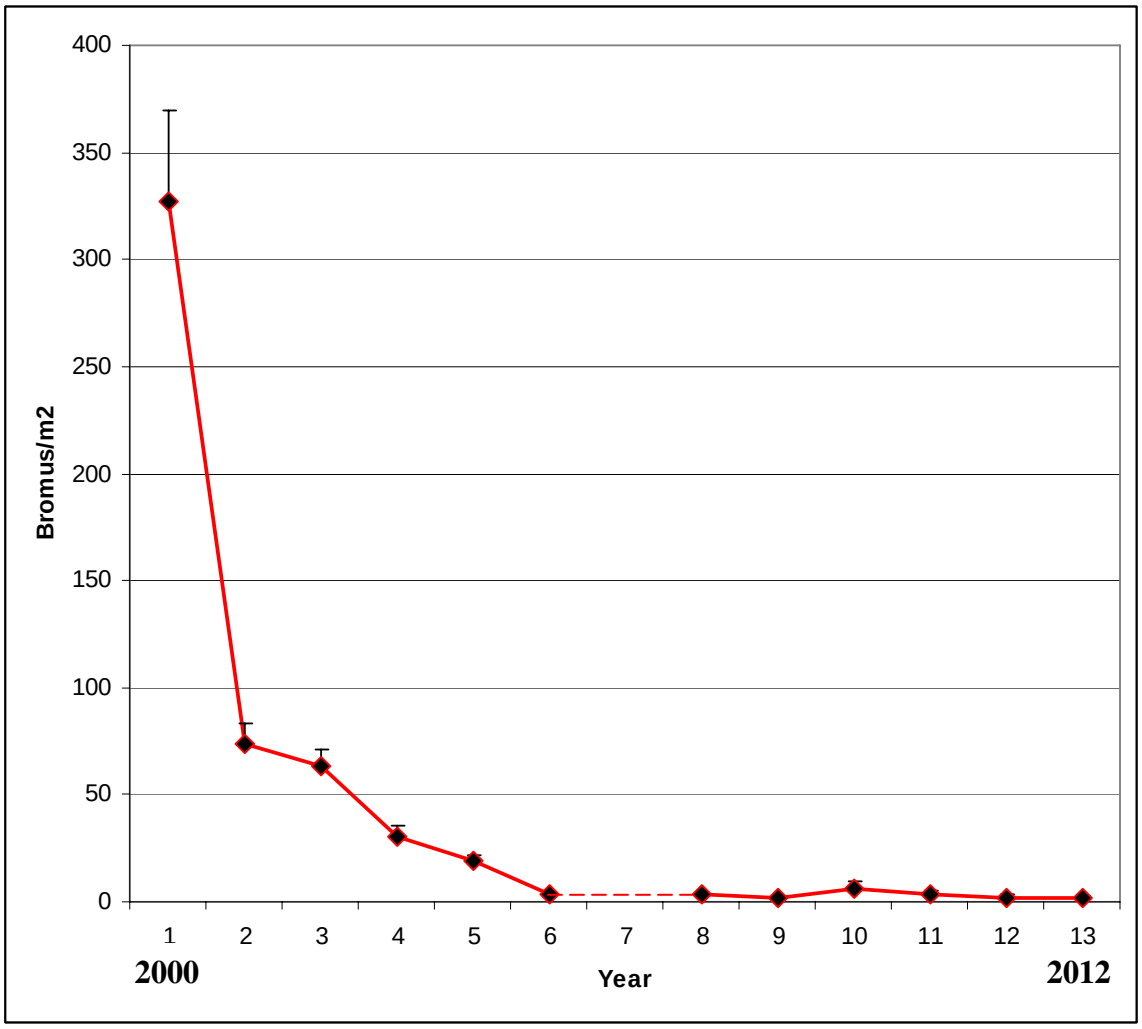

Figure 9. Changes in mean density of *Bromus diandrus*/m^2 from 2000 through 2012. Error bars represent standard error.

The southern macroplots (B2) were established in 2005, after two years of pulling *Bromus* and flaming *Vulpia* and *Aira* (earlier monitoring plots established pre-treatment were inadequate to detect change). The area was again flamed in 2006. From 2005 to the present, the density of *Bromus* has ranged between 3.4 and 22.4 individuals/m^2. These numbers reflect the relatively low densities expected after the first two years of treatment, so these macroplots are of more interest for tracking trends among other species, including native species. While *Bromus* remained at a low level, the smaller grasses *Vulpia* and *Aira* significantly

increased in density over time. Mean density of *Aira praecox* ranged from 31.2/m^2 to 108.8/m^2 between 2005 and 2009, but the densities during these four years were not significantly different from each other. However, by 2010 the mean density of 313.6/m^2 was significantly higher than all previous years, as was the mean of 412/m^2 in 2012 (Fig. 10). *Vulpia* showed a similar trend, remaining stable (i.e. no significant differences) from 2005-2009 (20.8-86.8/m^2), with significantly higher values in 2010 (132.8/m^2) and 2012 (240/m^2). These species, especially *Vulpia*, appear to be filling the niche left when flaming of the smaller grasses stops but *Bromus* continues to be removed. The effectiveness of the flaming treatment appears to last about three years. However, there is a parallel increase in overall native cover for the same time period, from 32.8% in 2009 to 71.5% in 2012 (Fig. 11). This increase is probably due to several factors: the recovery of natives from flaming, the release from competitive pressures of *Bromus*, and an overall successional trend for the B2 area. Photographs in Appendix B clearly show the encroachment of pines into the area, which appears to be transitioning from dune mat to forest.

A successional trend can also be observed from the shift in species composition detected in monitoring plots (Fig. 11). The early successional species *Lathyrus littoralis* and *Fragaria chiloensis* declined significantly ($p<.05$) while the biotic soil crust composed primarily of mosses (and some lichens) and indicative of a later successional stage, increased significantly. In addition, there was a significant increase in total native cover (excluding nonvascular).

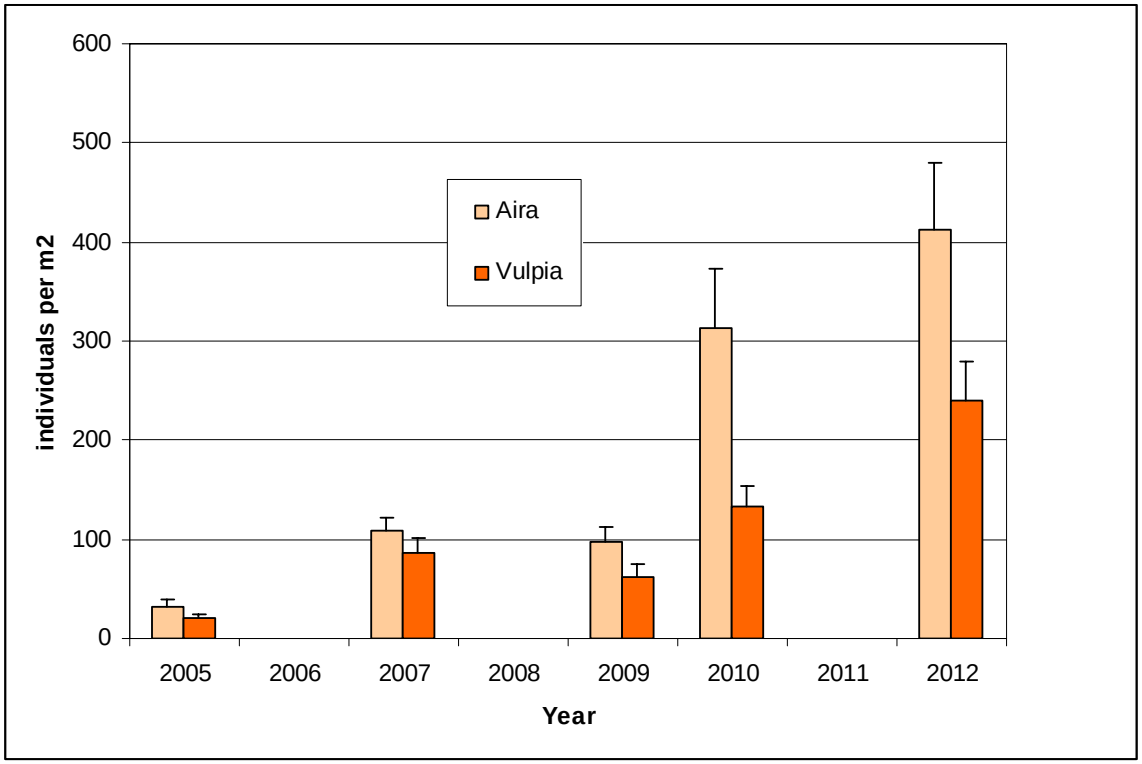

Figure 10. Changes in densities of *Aira praecox* and *Vulpia bromoides* between 2005 and 2012 (flaming treatments applied in 2003, 2004 and 2006)

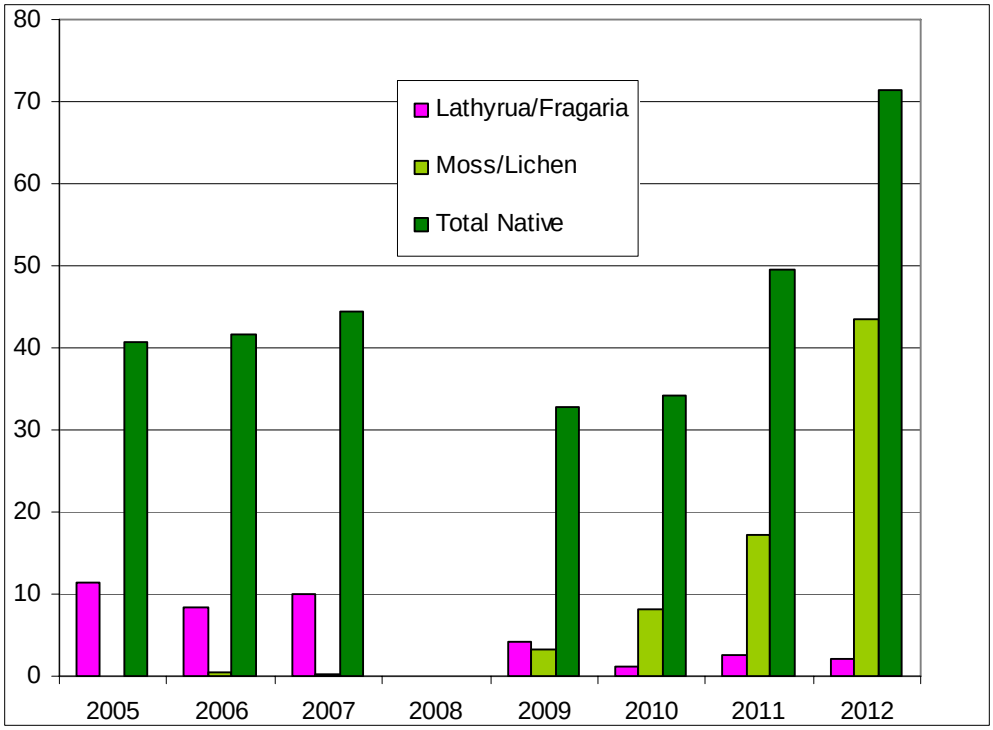

Figure 11. Changes in species composition of two early successional species (*Lathyrus littoralis/Fragaria chiloensis*), a late successional indicator (moss/lichen) and total native cover (excluding nonvascular) from 2005 to 2012 (flaming treatments applied in 2003, 2004 and 2006 Data were not collected in 2008).

There is no way to determine whether succession was accelerated by the presence of annual grasses. The B2 site is adjacent to both a stable forested swale, and remnant forest on the ridges adjacent to the parabolic dune to the north. Under these conditions, succession to forest would likely occur without the effect of the grasses, but might have been slower. In 2013 the B2 area was once again flamed to suppress *Aira* and *Vulpia*.

The labor needed to maintain annual grass areas increased steadily from 2002 (when the effort was expanded to all annual grass areas) to 2012. Years with lower labor during that time reflect a lack of resources in those years, where some annual grass areas were not treated. Labor has flattened out at about 700-800 ph/yr, although every year there is not enough labor to completely finish before grasses drop their seeds. Control is prioritized so that the areas with the longest history of removal are treated first. Although this protects the investment, it also means that satellite populations are sometimes left to expand when it would be much more efficient to treat them in an early detection/rapid response framework. The annual grass control effort has rarely received dedicated funding. Combined with the continuing source of seeds dispersed from the north, this effort will likely continue to require a steady source of labor until seed sources are dealt with.

RECOMMENDATIONS

1. Seek dedicated funding (through internal invasive species funding or external grants) to increase labor so that the entire area can be treated every year before seed set.
2. Carry out a complete updated mapping of annual grasses on Lanphere and Mal-le'l in 2014, using density classes to reflect progress.
3. Grant funding will be needed to carry out restoration of annual grass dominated areas to the north. Much of the invaded area is completely invaded and heavy equipment can be used to increase efficiency.
4. The acquisition of the Woll parcel is crucial to successful restoration of the Bair parcel, as well as to the ability to ultimately stop seed dispersal. Until annual grasses on these two parcels are controlled, we will continue to sink substantial resources into managing this invasion every year. However, if the invasion is left untreated, it will directly threaten the endangered plants *Erysimum menziesii* and *Layia carnosa*, as well as the rare dune mat community.
5. Continue to flame areas of high Aira and Vulpia cover at 3-4 year intervals as needed, but use a radiant heater in areas of *Megachile wheeleri* nesting habitat.
6. Update mapping in 2014 to reflect new occurrences of *Briza, Aira* and *Vulpia.*

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APPENDIX A. Labor expended by area and year.

Year	Area	Action	pH	Comments
1992	ZA[1]	*Briza* pulled	1	
		Total labor	*1*	
1996	ZA	*Briza* pulled, *Bromus* present but not controlled	8	
		Total Labor	*8*	
1997	ZA	*Briza* pulled	8	
	ZB	*Briza* pulled	30	
	ZC[1]	*Briza* pulled	24	
		Total Labor	*62*	
1998	ZA	*Briza* pulled	14	
	ZB	*Briza* pulled	93	
	ZC	*Briza* pulled	26	
	ZD[1]	*Briza* pulled	19	
		Total Labor	*214*	
1999	ZA	*Briza* pulled	27	
	ZB	*Briza* pulled		
	ZC	*Briza* pulled		
	ZD	*Briza* pulled		
		Total Labor	*27*	
2000	ZA	*Briza* pulled	16	
	ZB	*Briza* pulled		
	ZC	*Briza* pulled		
	ZD	*Briza* pulled		
	B1	*Bromus* pulled	10	
		Total Labor	*26*	
2001	ZA	*Briza* pulled	10	
	ZB	*Briza* pulled	9	
	ZC	*Briza* pulled	8	
	ZD	*Briza* pulled	0	
	B1	*Bromus* pulled	500	
	B2 (small area)	*Bromus* pulled		
		Total Labor	*527*	
2002	ZA	*Briza* pulled	16	
	ZB	*Briza* pulled	9	
	ZC	*Briza* pulled	9	
	ZD	Extirpated		
	B1	*Bromus* pulled	15	
	B3	*Bromus* pulled	4	
	Foredunes (FD)	*Bromus* pulled	150	
		Total Labor	*203*	
2003	ZA	*Briza* pulled	Included in total	
	ZB	*Briza* pulled		
	ZC	*Briza* pulled		
	B1	*Bromus* pulled	13	
	B2	*Bromus* pulled, *Vulpia Aira* early burn partial	657	
	B3			

	B4	*Bromus Vulpia Aira* late burn partial	Included in total	
		Total Labor	670	
2004	ZA	*Briza* pulled	Included in total	
	ZB	*Briza* pulled	156	
	ZC	*Briza* pulled	48	
	B1	*Bromus* pulled	Included in B3	
	B2	*Bromus* pulled, *Vulpia* burned	521	
	B3	*Bromus* pulled and *Vulpia Aira* burned	151	
	B4	All grasses burned	2	
	Foredunes	*Vulpia Aira* burned	18	
		Total Labor	*692*	
2005	ZA	*Briza* pulled	Included in total	
	ZB	*Briza* pulled	7	
	ZC	*Briza* pulled	7	
	B1	*Bromus* pulled	Included in B3	
	B2	*Bromus* pulled, *Vulpia Aira* burned	52	
	B3	*Bromus* pulled	19	
		Total Labor	*85*	
2006	ZA	*Briza* pulled	4	
	ZB	*Briza* pulled		
	ZC	*Briza* pulled	5	
	ZE	*Briza* pulled	1	
	ZF	*Briza* pulled	1	
	B1	*Bromus* pulled	4	
	B2	*Bromus* pulled, *Vulpia Aira* burned	91	
	B3	*Bromus* burned	6	
	Foredunes	*Bromus* burned	30	
	South knoll	*Bromus* burned	Included in foredunes	
	A1	*Anthoxanthum* pulled	1	
		Total Labor	*143*	
2007	ZA	*Briza* pulled	Included in total	
	ZB	*Briza* pulled	Included in total	
	ZC	*Briza* pulled	11	
	ZE	Not treated		
	ZF	Not treated		
	B1	*Bromus* pulled	11	
	B2	*Bromus* pulled	Included in B1	
	B3	*Bromus* pulled	NR	
	Foredunes	Not treated		
	South knoll	Not treated		

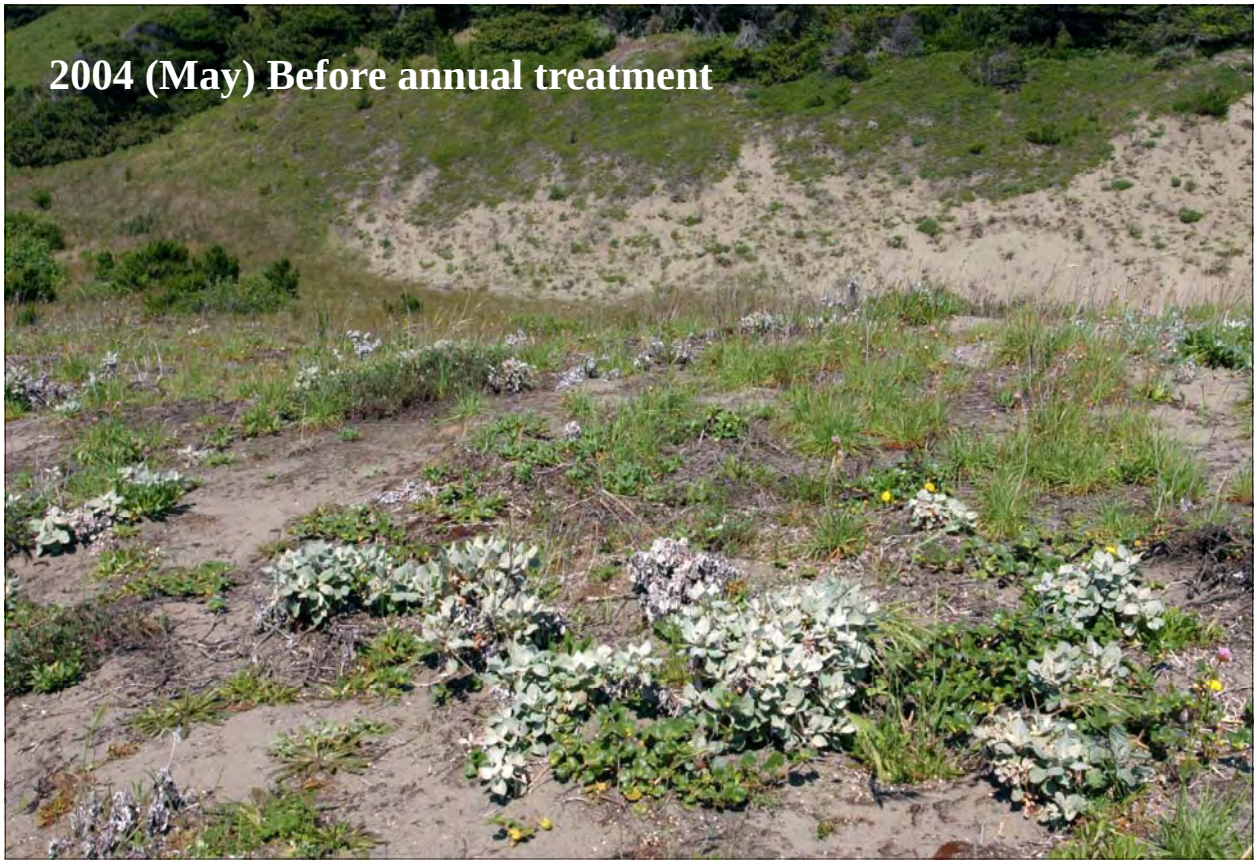
		Total Labor	*22*	
2008	ZA	Extirpated		
	ZB	*Briza* pulled	31	
	ZC	*Briza* pulled	4	
	ZE	*Briza* pulled	94	
	ZF	Extirpated		
	ZG	*Briza* pulled	15	
	B1	*Bromus* pulled	8	
	B2	*Bromus* pulled and *Vulpia Aira* burned	353	
	B3	*Bromus* pulled	51	
	B4	*Bromus* pulled	43	
	Foredunes	*Bromus* pulled	99	
	South knoll	*Bromus* pulled	30	
		Total Labor	*728*	
2009	ZB	Not treated		
	ZC	Not treated		
	ZE	Not treated		
	ZG	Not treated		
	ZJ	Not treated		
	B1	*Bromus* pulled	Included in total	
	B2	*Bromus* pulled	30	
	B3	Not treated	Included in total	
	Entrance Trail	Not treated		
	Big Dune	*Bromus* pulled	14	
	Lanphere Foredunes	*Bromus* pulled	118	
	South knoll	Not treated		
	Swale N of BD	Not treated		
	A1	Not treated		
	Ma-le'l Dunes	Not treated		
		Total Labor	*162.5*	
2010	ZB	*Briza* pulled	36	
	ZC	*Briza* pulled	Included in total	
	ZE	*Briza* pulled	Included in total	
	ZG	*Briza* pulled	Included in total	
	ZJ	*Briza* pulled	33	
	B1	*Bromus* pulled	Included in total	
	B2	*Bromus* pulled	154.5	
	B3	*Bromus* pulled	62	
	Entrance Trail	*Bromus* pulled	12	
	Big Dune	*Bromus* pulled	96	
	Lanphere Foredunes	*Bromus* pulled	180	
	South knoll	*Bromus* pulled	53.5	
	Ma-le'l Dunes	*Briza* and *Bromus* pulled	208	
		Total Labor	*835*	
2012	ZB	*Briza* pulled	Included in total	
	ZC	*Briza* pulled	Included in total	
	ZE	*Briza* pulled	Included in total	
	ZG	*Briza* pulled	Included in total	
	ZJ	*Briza* pulled	Included in total	

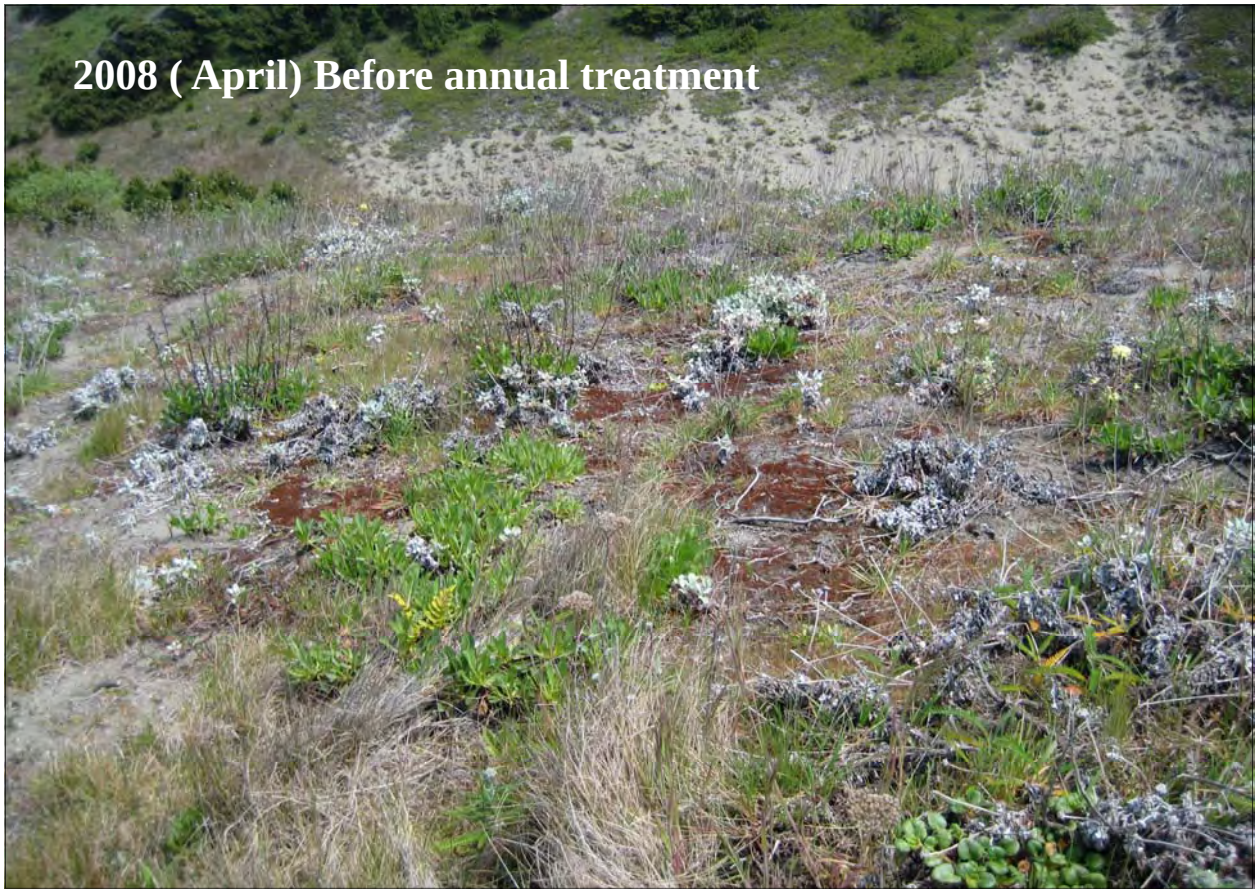
	B1	*Bromus* pulled	15	
	B2	*Bromus* pulled	132.5	
	B3	*Bromus* pulled	Included in total	
	Entrance Trail	*Bromus* pulled	Included in total	
	Big Dune	*Bromus* pulled	138.5	
	Lanphere Foredunes	*Bromus* pulled	437	
	South knoll	*Bromus* pulled	Included in total	
	Ma-le'l Dunes	*Briza* and *Bromus* pulled	91	
		Total Labor	814	

APPENDIX B. PHOTODOCUMENTATION OF ANNUAL GRASS CONTROL EFFORTS AT THE LANPHERE DUNES THROUGH 2013

B1

2000 (July) Before treatment started


2004 (May) Before annual treatment


2008 (April) Before annual treatment

2013 (April) Before annual treatment

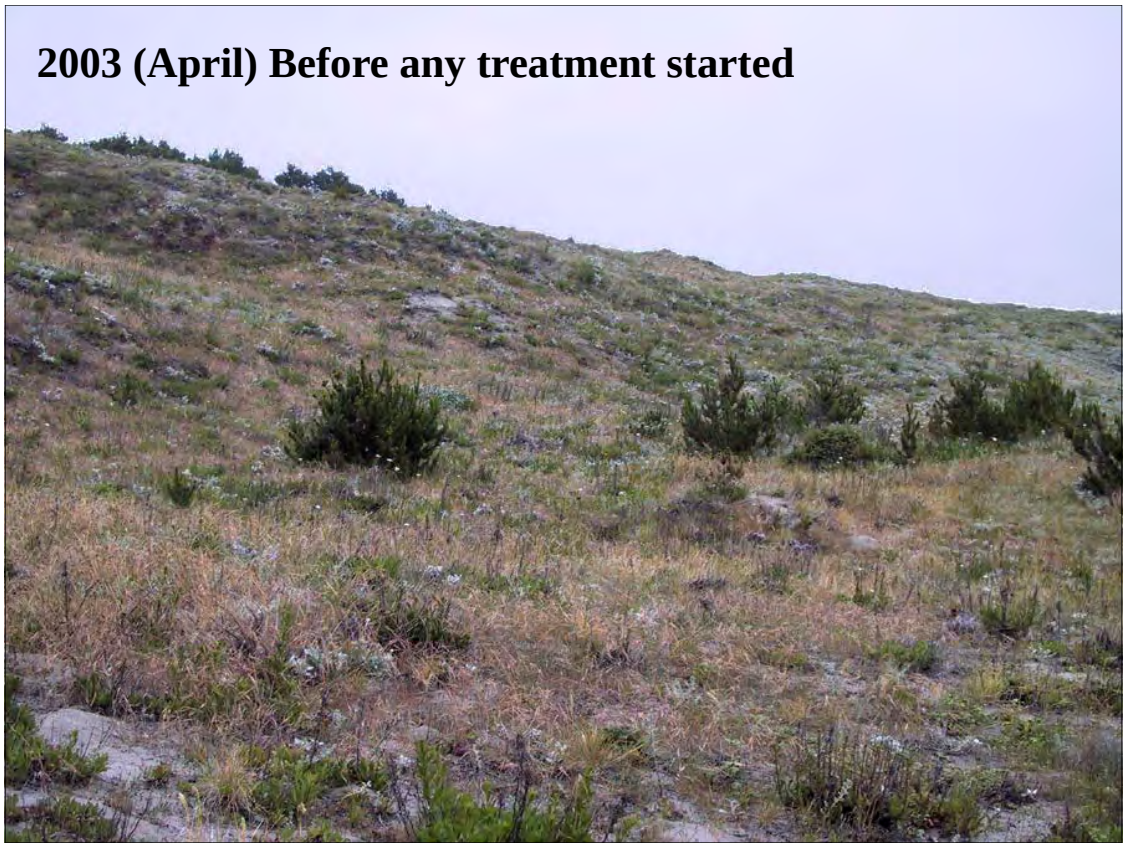
B2 F

2003 (June) Before any treatment

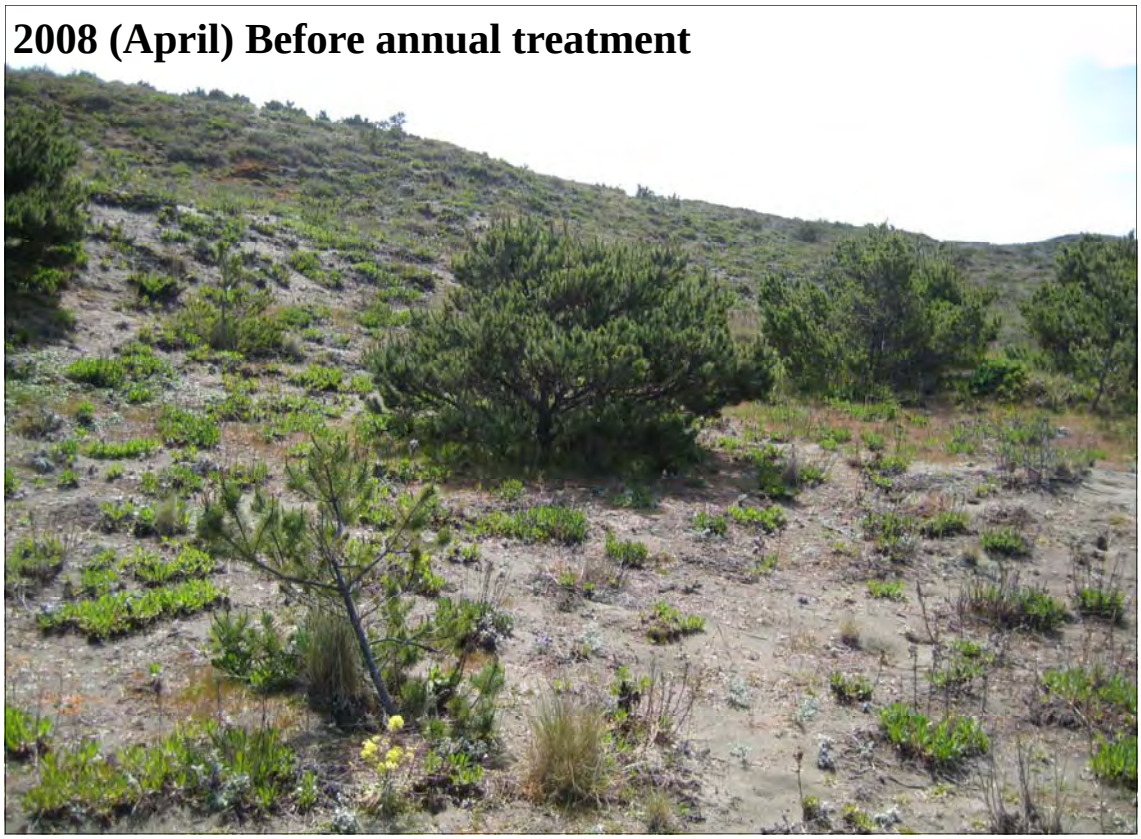
2004 (April) Before 2nd year treatment

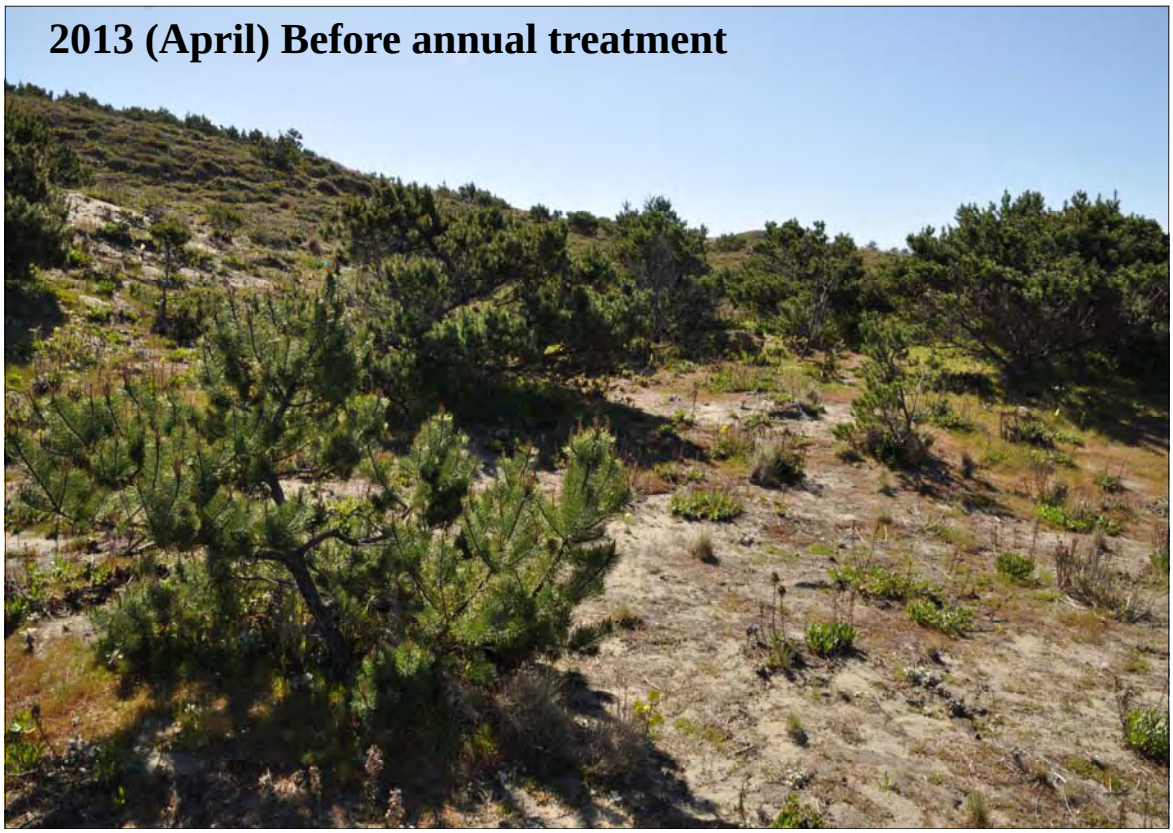
2008 (April) Before annual treatment

B2 D



2005 (April) Before third year treatment


2008 (April) Before annual treatment

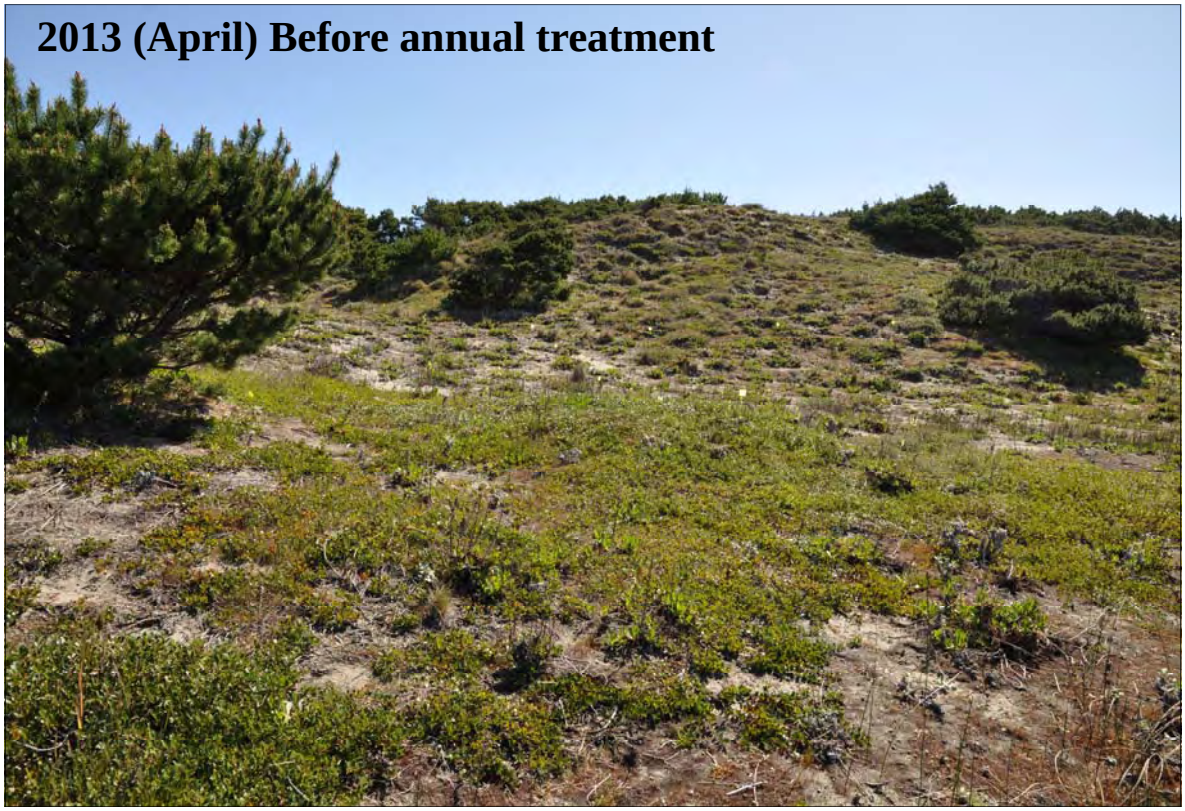

2013 (April) Before annual treatment

B2 E

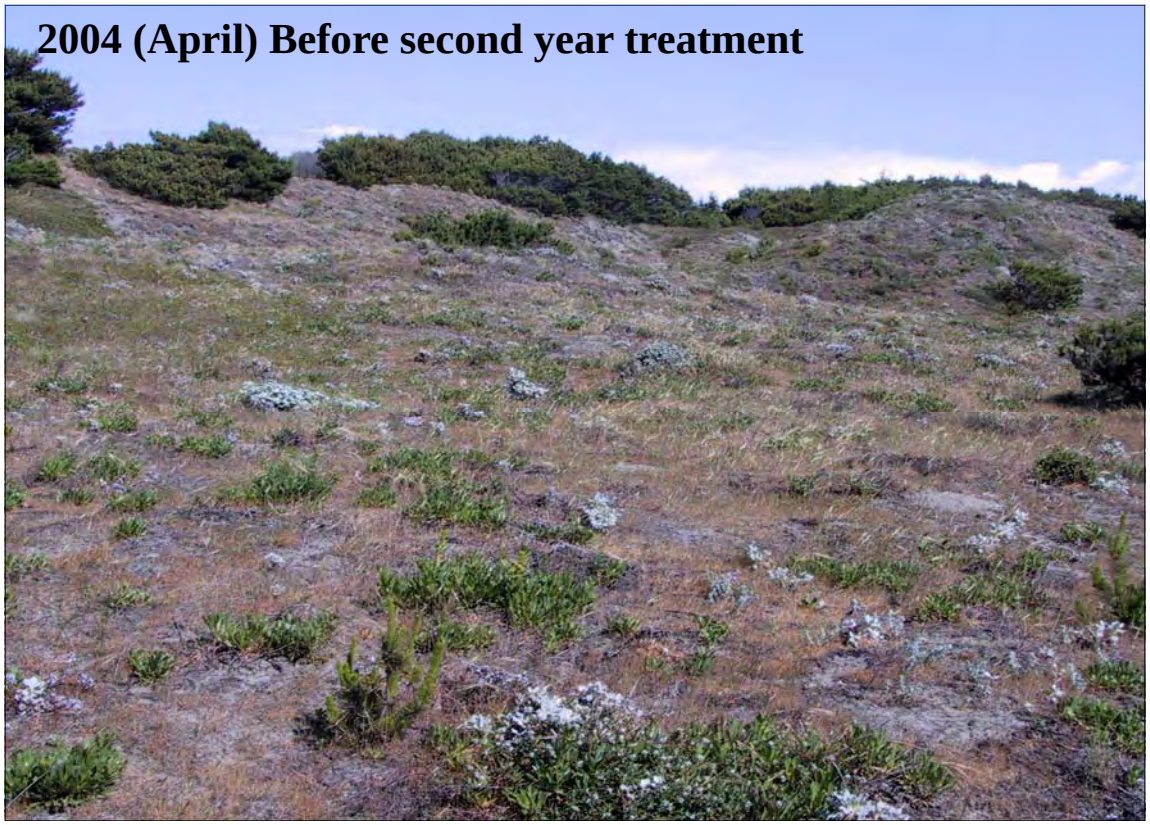
2004 (April) Before 2nd year treatment

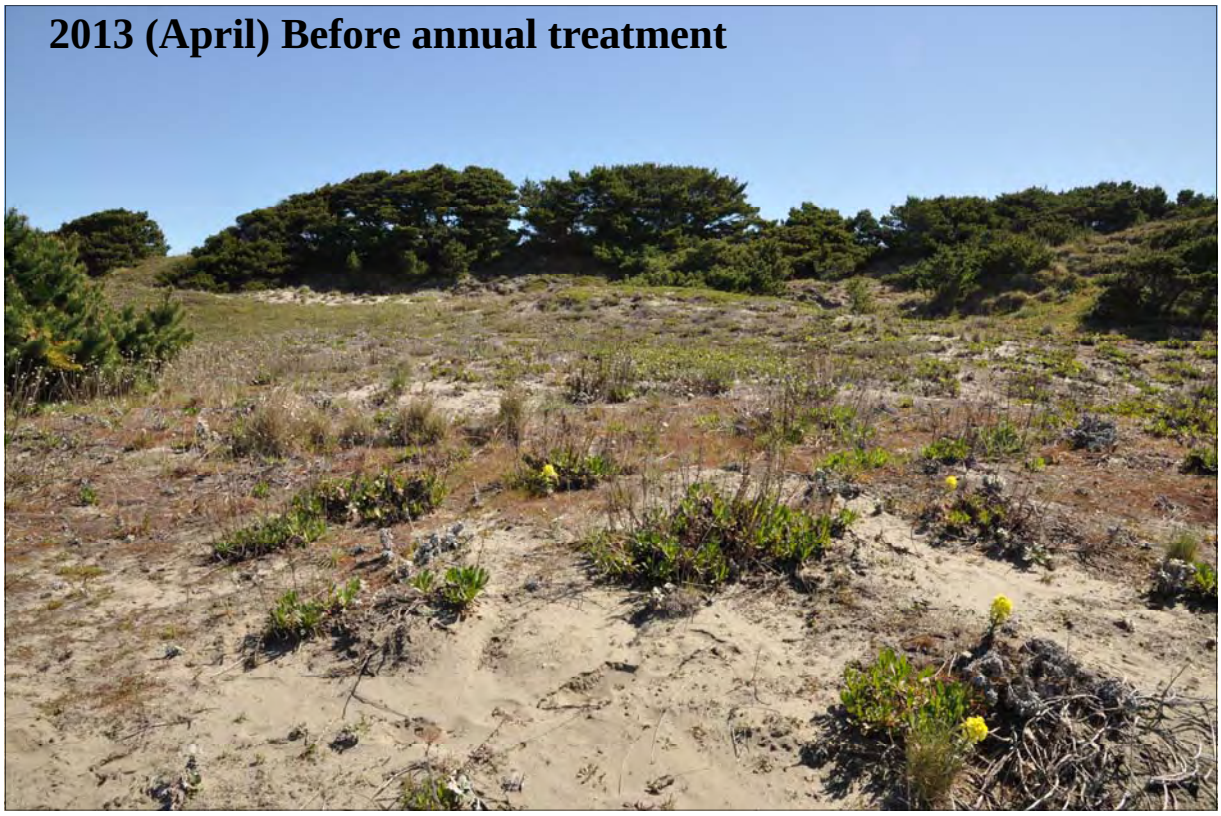
2005 (April) Before annual treatment

2008 (April) Before annual treatment


2013 (April) Before annual treatment

2003 (June) Before any treatment started


2004 (April) Before second year treatment


2013 (April) Before annual treatment

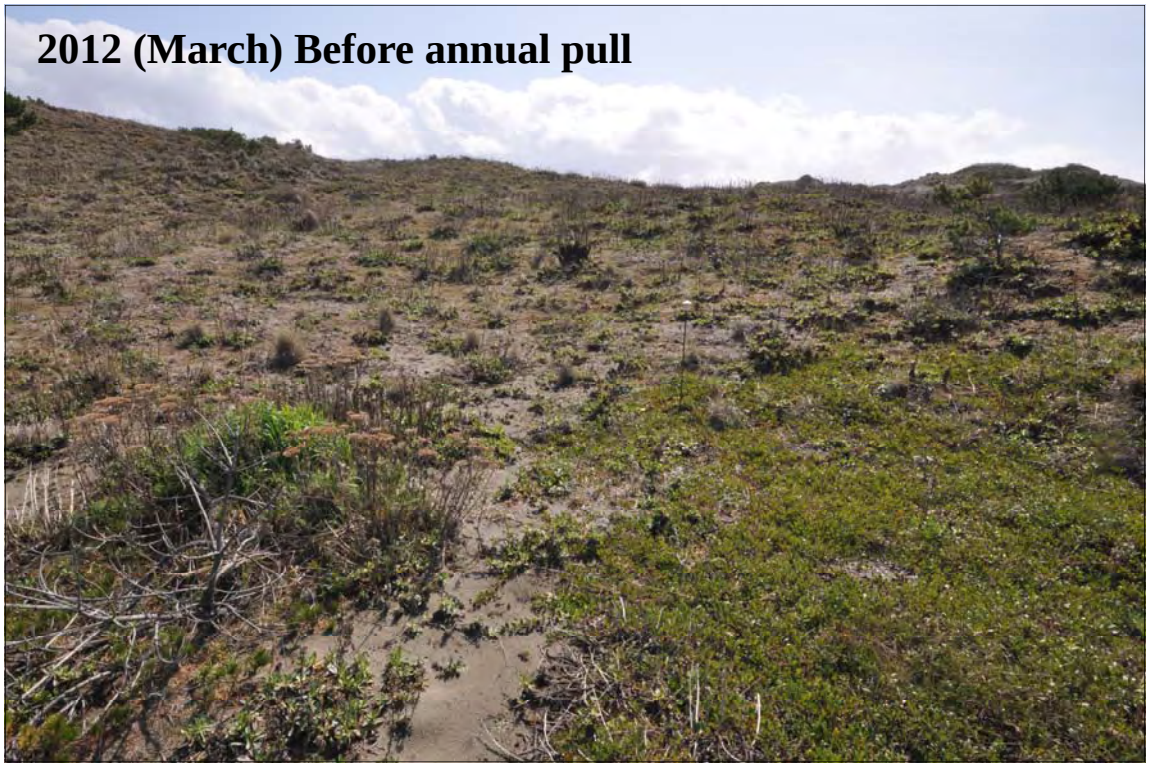
B2 A3

2004 (May) After two years of *Bromus* , before second year of *Vulpia* burn

2004 (May) After burn

Relatively low *Vulpia* returning in background

Arctostaphylos colonizing on right midground, *Vulpia* returning in background



Arctostaphylos increasing in foreground and *Vulpia* still somewhat moderate in background,

Arctostaphylos static and *Vulpia* now dense in background,

Juncus increasing from left to middleground

Juncus has colonized entire area but mixed with other native