Habitat and population monitoring for *Chloropyron maritimum* ssp. *palustre* and *Limonium californicum* on the Coos Bay North Spit

2015

Report to the Bureau of Land Management, Coos Bay District

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PREFACE

This report is the result of an agreement between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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Cover photograph: *Chloropyron maritimum* ssp. *palustre* (Point Reyes bird's-beak), and *Limonium californcium* at the Coos Bay North Spit.

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EXECUTIVE SUMMARY

In 2015 the estimated number of *Chloropyron maritimum* ssp. *palustre* plants on the Coos Bay North Spit land managed by the Coos Bay District of the Bureau of Land Management is ~1,516,000 (462,000 in the protected area and 1,053,000 in the unprotected area). This is the on par with the highest population estimate since monitoring began in 2011.

In 2015 the population of *Limonium californicum* is estimated to be ~791,000 with 743,000 and 47,000 in the protected and unprotected area, respectively.

Chloropyron maritimum ssp. *palustre* remained stable in both the protected and unprotected areas, while the population of *Limonium californicum* decreased from 2014-2015 (130,000 and 47,000 respectively).

The area occupied with these rare species is found in a long, narrow strip of appropriate habitat in a dynamic system. This narrow strip of land (~700m long with a maximum width of 50m) lies in a precarious location along the shoreline where minor fluctuations in sea level (due to natural or manmade activities), could cause significant loss of habitat. More immediate effects from ORV use are also evident.

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REPORT TO THE BUREAU OF LAND MANAGEMENT, COOS BAY DISTRICT

INTRODUCTION

ssp. *palustre*.

Chloropyron maritimum ssp. *palustre* (Point Reyes bird's-beak, still referenced as *Cordylanthus maritimus* ssp. *palustris* in USDA Plants Database; http://plants.usda.gov/core/profile?symbol=COMA5; Figure 1) is a USFWS Species of Concern, listed as Endangered by the state of Oregon, considered endangered or threatened throughout its range (List 1) by the Oregon Biological Information Center, and a Bureau Sensitive Species with the Bureau of Land Management. *Chloropyron maritimum* ssp. *palustre* is known to occur at 18 sites in Oregon, primarily the Coos Bay area, Yaquina Bay, and Netarts spit (Kaye 1991). *Limonium californicum* (Western marsh rosemary) is a Bureau Sensitive species and is also listed by the State of Oregon as critically imperiled due to rarity or vulnerability to potential extinction. Both species exist together in tidal flats on the North Spit, North Bend, Oregon.

The population of C. *maritimum* ssp. *palustre* at the Coos Bay North Spit has relatively recently been protected from Off Highway Vehicle (OHV) use which had caused severe damage to the population. The population at the Coos Bay North Spit is one of the only protected populations of C. *maritimum* ssp. *palustre*. The population increased substantially following protection; however, in recent years, it appears to be declining (J. Sperling, Coos Bay BLM, personal communication). It has been hypothesized that in the absence of disturbance, the density of other salt marsh plants, *Limonium californicum* (western marsh-rosemary) and *Salicornia depressa* (pickleweed) has increased, and may be inhibiting recruitment, growth, and/or reproduction of C. *maritimum* ssp. *palustre*. Changes in the plant community and industrial use of the surrounding bay may have also altered hydrology and sand accretion rates, thus changing site microtopography, and possibly contributing to altered salinity.

There are two primary objectives of this project.

1. Through a combination of annual mapping and monitoring of the population, we will track changes in population size and location through time of both C*hloropyron maritimum* ssp. *palustre* and *Limonium californicum*.
2. Evaluate differences in density of protected and unprotected portions of the populations of both C*hloropyron maritimum* ssp. *palustre* and *Limonium californicum*.

SPECIES BACKGROUND

Chloropyron maritimum ssp. *palustre*

Background information is repeated from Kaye (1991). Additional information can be found in Brian (2002).

Range

C*hloropyron maritimum* ssp. *palustre* (Figure 2) occurs along the Pacific Coast of North America from Morro Bay, San Luis Obispo County, California, and north to Netarts Spit, Tillamook County, Oregon. In Oregon, the majority of the populations are located in the Coos Bay area. *Limonium californicum* follows a similar distribution pattern along the western coastline.

Figure 2. C*hloropyron maritimum* ssp. *palustre* on the Coos Bay North Spit, note the two color variants, and the salt excretions on the bracts.

Habitat

C*hloropyron maritimum* ssp. *palustre* is a salt marsh species. It occurs in low-sand salt marshes dominated by *Salicornia depressa*, *Distichlis spicata*, and *Jaumea carnosa*. Elevations are typically at, or just above, sea level. The Pacific Ocean exerts a strong marine influence over the climate of coastal wetlands, moderating environmental extremes. The annual precipitation along the Oregon coast averages about 180 cm, with an average January minimum temperature of 2-5°C, and an average July maximum of 20°C (Franklin and Dyrness 1973). *Limonium californicum* similarly occupies salt-marsh habitat at elevations millimeters to centimeters above the elevations where C. *maritimum* are found (personal observation).

Description

Chloropyron maritimum ssp. *palustre* grows to 10 to 31 cm in height. Flowers are less than 3.5 cm in length, usually pinkish to purple, though some yellowish-white color variation is also seen. Floral bracts are oblong with a pair of short teeth at the tip. Foliage is grayish green and often villous (Eastman 1990; Figure 1; Figure 2).

Reproductive Biology

Chloropyron maritimum ssp. *palustre* is an annual, reproducing from seed each year. It blooms from June through September (or October) and forms fruits from August through November. Seedlings have been observed in February at Yaquina Bay (T. Kaye, personal observation) and seeds may germinate throughout the winter and early spring. Laboratory studies of the non-marine species of *Chloropyron* show that the seeds from low-elevation species germinate well at moderate temperatures (10°C) and not at high temperatures (27°C), and seeds of high-elevation species require a cold pre-treatment (-14 to -13°C) to germinate (Chuang and Heckard 1971). Seeds of C. *maritimum* ssp. *maritimum*, a different subspecies found in salt marshes in southern California, require fresh water and six weeks of cold storage for germination (Fink and Zedler 1990a, 1990b), and benefit from 1 or 2 years of after-ripening and scarification (Newman 1981). The flower and attendant bracts of C. *maritimum* ssp. *palustre* form showy inflorescences similar to Indian paintbrush (*Castilleja*, a related genus), but no insects have been observed visiting this subspecies to date (Kaye et al. 1990). It is possible that C. *maritimum* ssp. *palustre* flowers are pollinated by a nocturnal visitor that was not observed, but we suspect that the flowers are self-pollinating. Fruit-set and seed-set were fairly high on most individuals from which seeds were collected in 1990, a trait typical of self-pollinating, annual plants (Weins 1984). In contrast, solitary bees that nest in nearby upland habitats are required for pollination of C. *maritimum* ssp. *maritimum*, and where pollinators are lacking, seed production is reduced (Lincoln 1985).

Population Biology

At several sites in the Coos Bay area, C. *maritimum* ssp. *palustre* grows in dense patches and as dispersed individuals. Known populations across the Oregon coast, while rare (and scattered), often occur in dense patches and less often as dispersed individuals. This demographic pattern may relate to seed dispersal by water and to suitability of microsites for seedling establishment. Seeds dispersed by water and wind, may either spread over a wide area or accumulate in areas where suspended particles settle from the fluid (air or water). Work with C. *maritimum* ssp. *maritimum* indicates a heterogeneous microtopography causes seed entrapment and population establishment (Fink and Zedler 1990a).

Host Plants

All species of *Chloropyron* are hemi-parasites, i.e., they derive some of their resources directly through photosynthesis and also from other plants through underground root connections (Chuang and Heckard 1971). Some species of *Chloropyron* are facultative hemi-parasites in that they are capable of completing their life-cycle without a host under the favorable conditions of a greenhouse, but the plants are almost certainly parasitic in the wild (Chuang and Heckard 1971). The natural hosts for C. *maritimum* ssp. *palustre* are most likely *Salicornia depressa*, *Distichlis spicata*, *Limonium californicum*, *Deschampsia* *caespitosa*, and *Jaumea carnosa* (Chuang and Heckard 1971). Evidently, C. *maritimum* ssp. *palustre* lack host specificity. Instead, the species may have strong habitat preferences that maintain the associations with its standard hosts (Chuang and Heckard 1971). Vanderwier and Newman (1984) have shown that haustoria of C. *maritimum* ssp. *maritimum*, from southern California, are capable of inter- and even intra-specific parasitism in the field and the laboratory. It is not known how soon after germination a seedling in the field will establish a root-connection with a host.

Taxonomy

C*hloropyron maritimum* ssp. *palustre* is a member of the subgenus *Hemistegia*. Chuang and Heckard (1973) used seed coat morphology to identify relationships within the genus. They revised this species in 1973, recognizing the Oregon coastal plants as the more northern subspecies *palustre*, and retaining subspecies *maritimum* for the southern California and Baja California plants. The latter subspecies is also a candidate for listing by the USFWS.

Limonium californicum

Range

Limonium californicum occurs along the Pacific Coast of North America from San Diego County, California to isolated populations on the Southern Oregon Coast. In Oregon, the majority of the populations are located in the Coos Bay area.

Habitat

Limonium californicum is a salt marsh species found at elevations below 50m. It occurs in low-sand salt marshes dominated by *Salicornia depressa*, *Distichlis spicata*, and *Jaumea carnosa*. See the habitat description of C. *maritima* ssp. *palustre* for further details on salt marsh habitats.

Description, Reproductive and Population Biology

Limonium californicum is a perennial with a heavy, reddish, woody caudex. The leaves are oblong to oblong-obovate, mostly obtuse. The blades are generally 5-20 cm long, tapering into petioles. Flowering stems are stout and generally 20-50 cm, loosely paniculate with branches densely flowered. Flowers are pale violet to white, 5-6mm long and 2mm wide (Jepson 1993; Figure 3). Hundreds of tiny lavender flowers appear and dry on the stalks, much like its ornamental relative, Statice (*Limonium* spp.). There is commonly a crust of salt crystals on the underside of the leaves, and at times whole leaves are white from the dried brine. *L. californicum* reproduces both vegetatively and by seed. It is not known what pollinators play a role in *L. californicum* reproduction; however various species of bumblebees have been observed visiting *L. californicum* flowers by IAE staff during monitoring, as well as some small fly species.

Taxonomy

Limonium californicum is a member of the Plumbaginaceae family.

Figure 3. *Limonium californicum* on the Coos Bay North Spit. On the left, L. californicum can be seen co-occurring with C. *maritimum* ssp. *palustre*, the flowering stems of *L. californicum* stand above the surrounding vegetation, on the right, a close-up of the loose and branching panicle with many small flowers.

METHODS

Overview

This project was initiated in the C. *maritimum* ssp. *palustre* population on the Coos Bay North Spit Area of Critical Environmental Concern (T25S, R13W, Section 19, NNW) in Coos County, Oregon (managed by the Coos Bay District of the B LM) in summer 2010 (Table 1). In July 2010, we surveyed the population and delineated the population boundaries using GPS. This information was used to design the sampling and experimental protocols that were initiated in August 2010, and repeated in August 2011. In August 2011, the southwestern portion of the population (beyond the protective barrier) was surveyed for appropriate plot locations. In the protected area, transects were established in 2010, and 2011, with one additional transect added in 2014. In the unprotected area, transects were installed in 2011, and 2012. Twenty meter permanent monitoring transects were installed and marked with rebar topped with plastic caps at both ends. In the unprotected area the head of the transect was marked with rebar placed on the interior side of the road to prevent damage to vehicles using the area, and the monitored portion of the transect begins at the edge of vegetation on the east side of the 'road'. A summary of all transects installed and monitored as a part of this study are listed in Table 2. Transects are oriented perpendicular to the habitat margin, and extend 20m (Figure 4).

Habitat and Community Measurements

Community composition data was recorded for all transects in 2010-2015. Percent cover for all species was recorded in $1m^2$ increments along the right side of the transect, when viewed from the transect's origin. At each meter, on the 'right' side of the transect when standing at the origin, habitat classes were assigned. In 2014 and 2015, only 5-10 of the $1m^2$ plots were monitored for plant community, however all were assigned habitat classes. Photopoints were taken annually looking along each transect, from both the beginning and end and are available upon request.

Measurements of C. *maritimum* ssp. *palustre*

C. *maritimum* ssp. *palustre* sampling occurred on four transects in 2010 and all transects in 2011-2015. C. *maritimum* ssp. *palustre* measurements include counting the number plants, as well as the number of branches and flowers on each plant, in a randomly placed 0.25m x 0.25m frame. See Appendix for details regarding protocols for plant monitoring and sub-sampling, as well as habitat class assignments.

Measurements of *L. californicum*

Limonium californicum monitoring occurred on all transects in 2014 and 2015. In 2014, sampling was modified to include measurements of *L. californicum* in the same area sub-sampled for C. *maritimum* ssp. *palustre*. *L. californicum* measurements included the count of individuals (seedlings, vegetative or reproductive, and the presence of aborted flowering stems) in the randomly placed 0.25m x 0.25m sub-sampling frame.

Table 1. Timeline of activities from 2010-2016. Initial stages of the study were implemented in 2012 and have been both modified and augmented since that time. In 2014 and 2015, monitoring protocols were adapted to include measurements of *Limonium californicum*. Items in parentheses are scheduled pending funding for 2016.

	2010			**2011**			**2012**			**2013**			**2014**			**2015**			**(2016)**		
ACTIVITY	**Summer**	**Fall/Winter**	**Spring**	**Summer**	**Fall/Winter**	**Spring**	**Summer**	**Fall/Winter**	**Spring**	**Summer**	**Fall/Winter**	**Spring**	**Summer**	**Fall/Winter**	**Spring**	**Summer**	**Fall/Winter**	**Spring**	**Summer**	**Fall/Winter**	**Spring**
Delineate Population in Protected Area	x			x			x			x			x			x			(x)		
Design Sampling Protocol	x																				
Establish long-term monitoring transects and experimental plots	x																				
Monitor long-term transects	x			x			x			x			x			x			(x)		
Take photopoints along all transects	x			x			x			x			x			x			(x)		
Enter and analyze data, write annual progress report		x			x			x			x			x			x			(x)	
Delineate Population (in unprotected Area)				x			x			x			x			x			(x)		
Design Sampling Protocol (in Unprotected area)				x																	
Establish long-term monitoring transects and experimental plots in the unprotected area							x														

Table 2. List of long-term monitoring transects established as a part of this study.

AREA	TRANSECT #	YEAR ESTABLISHED	TAG # (ORIGIN)	TAG # (END)	BEARING	DISTANCE FROM ORIGIN TO VEG START (M)	TOTAL TRANSECT LENGTH (M)
PROTECTED	0	2010	750	871	132°	N/A	20
PROTECTED	2	2011	501	870	120°	N/A	20
PROTECTED	4	2010	751	873	130°	N/A	20
PROTECTED	7	2010	752	868	168°	N/A	20
PROTECTED	11	2010	753	867	255°	N/A	20
PROTECTED	13	2011	514	865	276°	N/A	20
PROTECTED	15	2010	754	869	252°	N/A	20
PROTECTED	16	2011	515	866	250°	N/A	20
PROTECTED	17	2011	517	872	125°	N/A	20
PROTECTED	18	2012	502	864	282°	N/A	20
PROTECTED	19	2014	862	863	200°	N/A	20
UNPROTECTED	20	2012	391	N/A	114°	16	36
UNPROTECTED	21	2012	400	N/A	128°	12	32
UNPROTECTED	22	2012	388	N/A	118°	11.5	31.5
UNPROTECTED	23	2012	385	N/A	124°	16	36
UNPROTECTED	24	2014	386	N/A	130°	17	37
UNPROTECTED	25	2014	387	N/A	124°	13 (right before SADE)	33
UNPROTECTED	26	2014	389	N/A	120°	24 (R of stream)	44 (end in tidal flat)
UNPROTECTED	27	2014	390	N/A	120°	11	31
TOTAL # OF TRANSECTS	**19**						

Population Estimates

In 2010, information from the sample-plots was used to estimate the total population size of C. *maritimum* ssp. *palustre* by multiplying the average number of plants m^{-2} (θ) by the total habitat area (N = 2294 m^2):

$$\textbf{\textit{population size estimate}} = \theta * N$$

In 2011, the sampling method was modified to increase sampling efficiency and accommodate the heterogeneity of the habitat at the site. In 2014, we began using the modified method to estimate the total population size for *L. californicum*. Along each 20m transect, a habitat class was assigned to each 1 m^2 plot (Table 3). To estimate total population size, the average number of plants per m^2 in each habitat type was determined and multiplied by the area covered by each habitat type.

Mapping

In addition to monitoring transects, the area occupied by the C. *maritimum* spp. *palustre* population was mapped by habitat class. Habitat classes were defined as described in Table 3. Boundaries between habitat classes were delineated using an Oregon GPS 450 handheld unit. Data was compiled using MapWindow, an open source GIS software, to delineate boundaries between habitat types. In 2012-2015, the unprotected area was also mapped using the same habitat class delineations used in the protected area.

Table 3. Habitat codes used for mapping in 2011-2015. Heavily disturbed areas (with rutted tire tracks) were also noted in the unprotected area.

Code	**Habitat**	**Description**
CF	*Chloropyron* flat	*Chloropyron* cover ≥ 50%
LCF	*Limonium-Chloropyron* flat	*Limonium, Chloropyron* codominant
LF	*Limonium* flat	*Limonium* cover ≥ 50%
GT	Grass transition	Differentiated by presence of *Ammophila* or *Leymus,* marks transition into small stabilized dune habitat. Some *Chloropyron* present but only in trace amounts. This is the absolute upper boundary of COMAPA habitat.
SD	*Salicornia* depression	*Salicornia* dominant species; area of higher water during the tide. Differs from waterway by abundant *Salicornia*, and little to no bare sand.
SDD	*Salicornia-Distichlis* depression	*Salicornia* dominant, but *Distichlis* cover ≥ 25%
Sand	*Sand*	Highest reach of the tide, but water does not linger here for long. At least some COMAPA in trace amounts.
Waterway	Waterway	Other plants may be here, but not appropriate habitat for COMAPA. Various courses throughout entire area, usually adjacent to SD, SDD.
D-Rise	*Distichlis* rise	Small hill, *Distichlis* dominated, with minor patches of *Jaumea carnosa* nearest to the ocean.
Marsh	Marshy area	Marshy area dominated by *Scirpus sp.*, area inundated by tides.

Figure 4. Area surveyed for *Chloropyron maritima* ssp. *palustre*. Blue lines indicate monitoring transects established in 2010-2012. See Appendix A for maps and information regarding all monitoring transects.

Figure 5. Monitoring transect in the protected area showing the patchiness of the habitats, which are greatly influenced by microtopography. Photopoints from each monitoring transect are included in Appendix A.

Community Analysis

We used a common ordination method, non-metric multidimensional scaling (NMS; (Kruskal 1964), to assess relationships of individual species cover relative to primary gradients in the plant community (ordination axes). NMS is an ordination method that is best used for community analyses, often with non-normal data with non-linear relationships (McCune and Grace 2002). Due to heterogeneity in the data set, rare species that occurred in 5% or less of the plots were deleted and species cover data was log(x+1) transformed to reduce skewness. Outliers (those greater than 2 SD from the mean) were removed. We assessed species data relative to an environmental matrix with cover data of bare ground, litter, and habitat type (protected/unprotected). NMS ordinations were performed using PC-ORD version 6.0 (McCune and Mefford 2011) with the autopilot setting "slow and thorough" mode, Sørensen distance measure, and no penalty for ties. We ordinated data from 2015 only to look at trends related to the plant community in protected and unprotected areas. In addition, we conducted an ordination on data from seven years in the protected area only.

Differences in plant community between protected and unprotected areas (in 2015 only) were tested with multi-response permutation procedure (MRPP; Mielke and Berry 2001) using the Sørensen distance measure, in PC-ORD. Due to differences found using MRPP, we conducted an Indicator Species Analysis to investigate if species were associated with the protected or unprotected area. Indicator Species Analysis combines relative abundance and relative frequency of a species in defined groups, and produces indicator values (IVs), which are the percentage of perfect indication for a species within a particular group (McCune and Grace 2002). Statistical significance of indicator values (*p*-value) is evaluated using a Monte Carlo method of randomizations; 1000 randomizations were run to determine the proportion of random trials that gave indicators equal to or greater than the observed.

RESULTS

Population Survey

Chloropyron maritimum ssp. *palustre*

The edges of the C. *maritimum* ssp. *palustre* population at the North Spit were defined by *Pinus contorta* var. *contorta*/*Cytisus scoparius* scrub transitioning to *Ammophila arenaria*/sand with scattered *Leymus mollis*. This drops off into an area more regularly impacted by tides/waves. *Chloropyron maritimum* ssp. *palustre* distribution is patchy, from clumps of plants scattered in dense stands of *S. virginica*, to large swathes interspersed with *L. californicum*. Until 2014, *L. californicum* was nearly absent in the disturbed area. Both color morphs (green and purple) of C. *maritimum* ssp. *palustre* were evenly represented throughout the population.

Variation in density and size of C. *maritimum* ssp. *palustre* may be due to a combination of plant community and abiotic factors. Microtopographic variations also effect the levels of inundation experienced on site. The establishment (and subsequent stabilization) of substrate has been noted particularly in the protected area, where *L. californicum* cover has increased; most likely due to decreases in disturbance to this perennial species.

We estimated that in 2010, the total number of C. *maritimum* ssp. *palustre* in the protected area at the North Spit was 380,991 plants. In 2011-2015, due to the patchiness of the population, the population size in the protected area was estimated by calculating the average number of plants per m^2 in all habitat classifications and then multiplying by the areal cover of each habitat class (Table 4). In the protected area, the population of C. *maritimum* ssp. *palustre* has ranged from a high of ~916,000 in 2011 to a low of ~124,000 in 2012. In 2015 the population of C. *maritimum* ssp. *palustre* is estimated to be ~462,000 (Table 5). The precipitous drop of C. *maritimum* ssp. *palustre* between 2011 and 2012 in the protected area coincides with decreases in the cover of C. *maritimum* spp. *palustre* dominated habitat classes (CF and less so LCF) and increases in the cover of *Limonium* dominated habitat types (LF).

In 2012, the population in the unprotected area was estimated to contain ~545,000 C. *maritimum* spp. *palustre* plants, and in 2013, this number decreased to ~296,000 (Table 5). Values rebounded in 2014 and 2015 (Figure 6). In the unprotected area, the population of C. *maritimum* spp. *palustre* has ranged from a low of ~296,000 in 2013 to and a high of ~1,053,000 in 2015 (Table 5).

Both the protected and unprotected populations have followed similar trends indicating that similar factors are influencing the population dynamics in both portions of the population (Figure 6). Continued monitoring of transects combined with habitat surveys is recommended on at least a three-year cycle to elucidate the population trends for both listed species in the protected and unprotected portions of the site. More regular monitoring is recommended if activities that could affect microtopography at the site are to be undertaken (including but not limited to dredging activities).

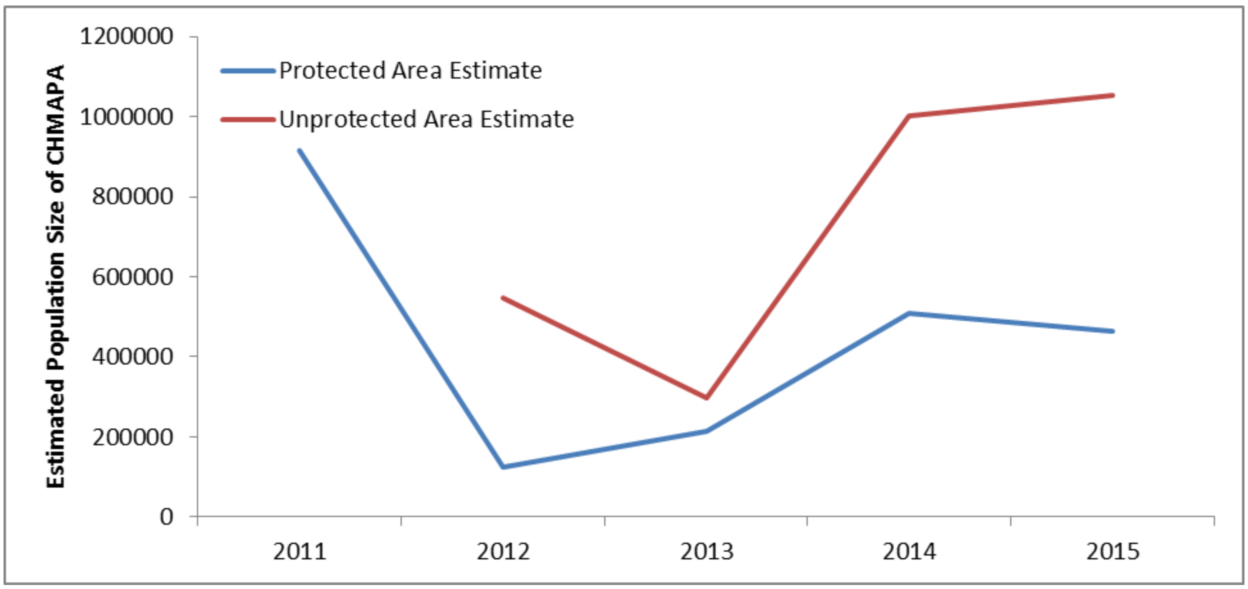

Figure 6. Estimated population size of Chloropyron maritimum ssp. palustre on the Coos Bay North Spit from 2011-2015.

Table 4. Areal cover of each habitat type and number of *Chloropyron maritimum* spp. *palustre* plants per m^2 in protected and unprotected areas at North Spit from 2011-2015. The unprotected area was not mapped in 2011.

		Area (m^2)					CHMAPA/m^2				
	Habitat Code	**2011**	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**
PROTECTED	CF	293	3	7	8	300	978	256	256	1094	731
	DRise	393	353	271	213	488	0	0	0	0	0
	GT	928	930	435	487	388	0	0	0	0	0
	LCF	1468	337	693	576	198	425	254	254	577	404
	LF	498	1398	1386	2198	1940	12	15.5	15	60	48
	Marsh	214	353	178	577	200	0	0	0	0	0
	Sand	110	72	33	417	609	0	0	0	0	0
	SD	1011	1662	2379	431	3388	0	1.8	2	23	16
	SDD	747	1492	1339	2349	193	0	9	9	16	69
	Waterway	645	681	626	868	1727	0	0	0	0	0
UNPROTECTED	CF		1268	973	213	780		331	181	784	864
	DRise		-	1268	1621	1646		-	0	0	0
	LCF		0.0	-	719	16		245	-	700	304
	Marsh		66	36	65	-		0	0	0	-
	SD/SDD		0.0	-	0.0	0.0		19	-	17	10
	SD/SDD		20310	19297	20079	20089		6	6	26	19
	Waterway	N/A	132	92	110	-	N/A	0	0	0	-

Table 5. Population estimates for *Chloropyron maritimum* spp. *palustre* by habitat in protected and unprotected areas at North Spit. The unprotected area was not mapped in 2011.

		CHMAPA				
	Habitat Code	**2011**	**2012**	**2013**	**2014**	**2015**
PROTECTED	CF	286554	768	1675	8314	219429
	DRise		0	0	0	0
	GT		0	0	0	3725
	LCF	623900	85598	175995	320206	79992
	LF	5976	21674	20291	132019	92207
	Marsh		0	0	0	0
	Sand		0	0	0	0
	SD		2955	4229	9968	53643
	SDD		13428	12047	37589	13381
	Waterway		0	0	0	0
UNPROTECTED	CF	-	419285	176354	166678	673920
	DRise	-	0	0	0	0
	GT	-	0	0	0	0
	LCF	-	0	0	503150	4864
	LF	-	0	0	0	0
	Marsh	-	0	0	0	0
	Sand	-	0	0	0	0
	SD	-	0	0	0	0
	SDD	-	126373	120069	333620	374995
	Waterway	-	0	0	0	0
Protected Area Estimate		**916430**	**124423**	**214238**	**508096**	**462377**
Unprotected Area Estimate			**545659**	**296422**	**1003448**	**1053779**
TOTAL			**670081**	**510660**	**1511544**	**1516156**

Limonium californicum

In 2014 monitoring plots were also assessed for *L. californicum*. Over the course of this study, it was noted that the cover of *L. californicum* was increasing in both the protected and unprotected areas (Table 6, Table 7). Increased monitoring efforts allowed us to make populations estimates using the same methodology employed for C. *maritimum* ssp. *palustre*; by calculating the average number of *L. californicum* plants in each mapped habitat class and scaling based on the area occupied by each habitat class. In 2014, the estimated population size of *L. californicum* in the unprotected area was 130,210, and in 2015, decreased to 47,678 (Table 7). This decrease was noted in all size classes (reproductive, vegetative and seedlings; (Table 6). In the protected area, the population was estimated to be 832,518 in 2014 and has decreased in 2015 to 743,000 (Table 7).

Table 6. Areal cover of each habitat type, and number of *Limonium californicum* seedlings, vegetative and reproductive plants per m^2 in the unprotected and protected areas at North Spit in 2014 and 2015.

		seedlings/m^2		veg/m^2		repro/m^2		Total LICA/m^2	
	Habitat Code	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
PROTECTED	CF	10	3.6	56	62.8	13	10.1	79	76.4
	D-rise	0		37.3		21.3	0	58.7	0
	GT	6.4	6.4	0	44.8	0	16	6.4	67.2
	LCF	4.8	0.6	128	117.1	39.9	17.7	172.6	135.4
	LF	15.8	1.2	207.1	268.1	92.5	39.7	315.4	308.9
	SD	3	0.2	6.2	16	1.8	2.6	11	18.7
	SDD	0	0	4.7	21.3	3.3	8	8	29.3
UNPROTECTED	CF	2.9	0	8.7	16	4.4	0	16	16
	D-rise	0	0	1.5	0	0	0	1.5	0
	LCF	8	0	76	16	56	16	140	32
	Marsh		0		0	0	0		0
	SD	0	0	1.2	1.5	0	0.2	1.2	1.7
	SDD	0.2	0	4.6	0	0.7	0	5.5	0

Table 7. Population estimates for *Limonium californicum* by habitat in protected and unprotected areas at North Spit. Areal cover of each habitat type by year are listed in Table 4.

		LICA	
	Habitat Code	**2014**	**2015**
PROTECTED	CF	593	22933
	DRise	12496	0
	GT	3123	26006
	LCF	99608	26815
	LF	693166	598898
	Marsh	0	0
	Sand	0	0
	SD	4740	63435
	SDD	18792	5661
	Waterway	0	0
UNPROTECTED	CF	3392	12480
	DRise	2358	0
	GT	0	0
	LCF	100660	512
	LF	0	0
	Marsh	0	0
	Sand	0	0
	SD	23800	34686
	SDD	0	0
	Waterway	0	0
Protected Area Estimate		**832518**	**743748**
Unprotected Area Estimate		**130210**	**47678**
TOTAL		**962728**	**791426**

Community Analysis

The NMS ordination of sample units in species space (Figure 7) in the protected habitat (2010-2015) resulted in a 3-dimensional stable solution (final stress = 11.8, final instability = 0.000). A randomization test confirmed that final stress was lower than expected by chance ($p = 0.000$). Sample units from all years tended to be intermixed in species space. *C. maritimum* ssp. *palustre* (COMAPA) was strongly positively correlated with Axis 1 (r = 0.47), along with natives *L. californicum* (LICA; r = 0.89), *Plantago maritima* (PLMA; r = 0.53), and *J. carnosa* (JACA; r = 0.44). *S. depressa* (SADE) had a strong negative correlation with Axis 1 (r = -0.89), along with *Distichlis spicata* (DISP; r = -0.24). The distribution of these species suggests that they do not co-occur with many others in the plant community at this site. Ordination scores were similar to those in recent years, suggesting that these species associations remain over time, but can shift slightly (Figure 7). From 2010 to 2013, sample units shifted downward along Axis 2, which was most associated with *D. spicata* (r = -0.61) and *C. album* (r = -0.35). Trends from 2010-2013 suggested that these communities could be slowly moving toward species associations that are not necessarily supportive of *C. maritimum* ssp. *palustre*. In 2014 and 2015, sample units were more contained in species space. The closer proximity of sample units in species space indicates that in 2015 species composition was more similar than in previous years. *C. maritimum* ssp. *palustre* continued to be associated with species such as *L. californicum* and *J. carnosa* which are known as potential host plants for the hemi-parasite. These trends are similar to those observed in previous years. *S. depressa* and *D. spicata* were associated with each other but few other species, indicating that these species do not co-exist well with *C. maritimum* ssp. *palustre* or others that are prevalent in the community.

Protected and unprotected habitats differed significantly in community composition in 2015 (MRPP; A = 0.17, $P < 0.0000$). Species richness was greater in protected habitat than in unprotected habitat (17 and 10, respectively). Many species were identified as indicators of either the protected or unprotected habitats (Table 8). *C. maritimum* ssp. *palustre* was an indicator of the protected area ($p < 0.01$) in both 2013-2015. Indicators of the protected area also included *Cuscuta pacifica, C. album, J. carnosa, L. californicum, P. maritima, S. macrotheca,* and *T. maritima*. Similar to previous years, indicator species of the unprotected habitat were *D. spicata* and *S. depressa*. *C. maritimum* ssp. *palustre* occurred in both habitats, but had higher average cover in the protected area than in the unprotected (12% and 1%, respectively). Cover in the protected area increased from 2014 slightly (10.9%). *L. californicum* occurred in both habitats, but was much more prevalent in the protected area than in the unprotected area (34% and 0.6%, respectively). Cover increased slightly from 2014 (31.9%).

C. maritimum ssp. *palustre* had patchy abundance within the unprotected area, however, these patches remained in the same geographic location within the unprotected area throughout the years (Figure 10). Within those patches, *C. maritima* ssp. *palustre* is very abundant. These results were consistent with the percentage of transects located in specific habitat classes; protected habitats had greater composition of *Limonium* flat than unprotected habitats in 2014 and 2015 (Table 4). Likewise, transects in the unprotected habitat had greater percentages of *Salicornia* depression and *Salicornia-Distichlis* depression than in protected habitats (Table 4). *Chloropyron* flat had similar amounts in both protected and unprotected habitats.

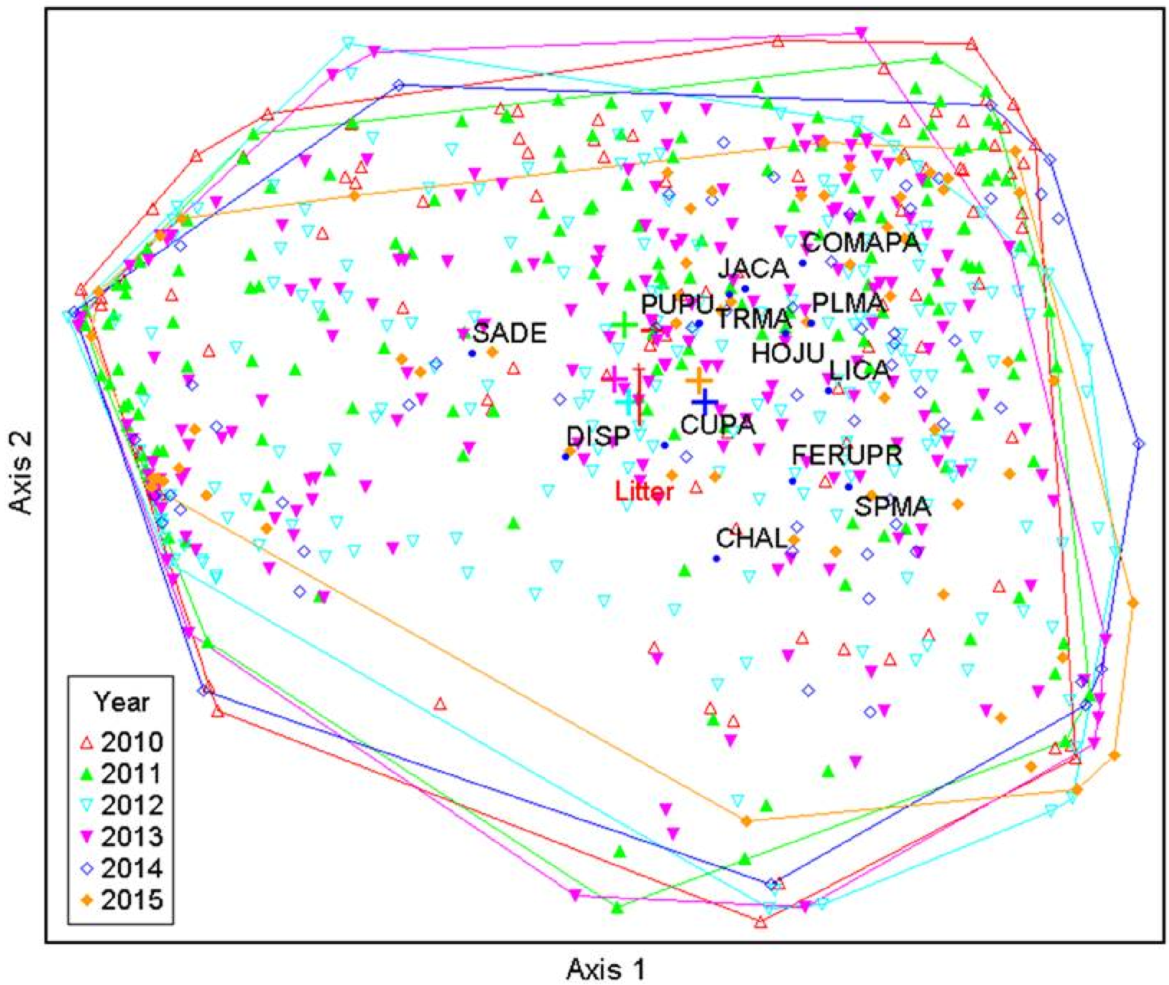

Figure 7. NMS ordination of community composition within the protected area of the C*hloropyron maritimum* ssp. *palustre* population at the Coos Bay North Spit (2010--2015). Triangles represent sample units (quadrats along transects) in species space, and distance between points indicates similarity of community composition by quadrat. Polygons outline the extent of all of the sample units. Blue dots and species abbreviations (Table 7) indicate the centroid for species locations. Variance explained by Axis 1 was 67%, while Axis 2 explained 15% of the variance.

Table 8. Species list including nativity from plots within the *Chloropyron maritimum* ssp. *palustre* population at the Coos Bay North Spit in 2015. Species codes are from the USDA PLANTS database (USDA NRCS 2012). Species included in the indicator species analysis noted Indicator Species column, 'Habitat' refers to the area they indicate and '*P* value' is associated with the indicator value for that species. * indicates species that occurred in less than 5% of the sample units and were not included in the Indicator Species Analysis.

Species	Code	Nativity	Indicator species?	Habitat	*P* value
Ammophila arenaria	AMAR	Exotic	*		
Cerastium glomeratum	CEGL	Exotic	*		
Chenopodium album	CHAL	Exotic	Y	Protected	0.0044
Chloropyron maritimum ssp. *palustre*	COMAPA	Native	Y	Protected	0.0002
Cuscuta pacifica	CUPA	Native	Y	Protected	0.0016
Distichlis spicata	DISP	Native	Y	Unprotected	0.01
Grindelia stricta	GRST	Native	*		
Holcus lanatus	HOLA	Exotic	*		
Hordeum jubatum	HOJU	Native	*		
Jaumea carnosa	JACA	Native	Y	Protected	0.0.002
Juncus sp.	Juncus	Native	*		
Leymus mollis	LEMO	Native	*		
Limonium californicum	LICA	Native	Y	Protected	0.0002
Plantago maritima	PLMA	Native	Y	Protected	0.0002
Puccinellia pumila	PUPU	Native	*		
Rumex acetosella	RUAC	Exotic	*		
Salicornia depressa	SADE	Native	Y	Unprotected	0.0002
Spergularia macrotheca	SPMA	Native	Y	Protected	0.0002
Triglochin maritima	TRMA	Native	Y	Protected	0.0002

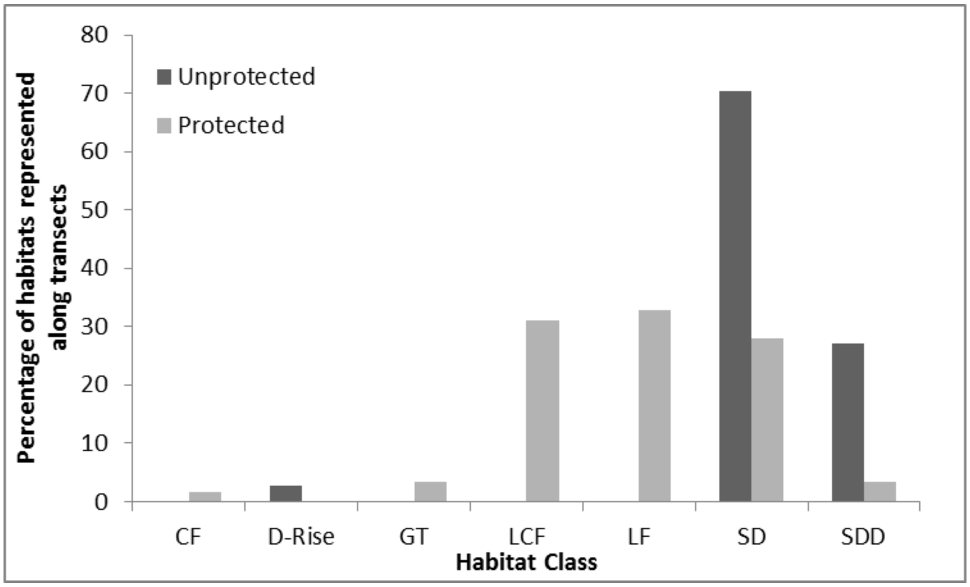

Figure 8. Percent of habitat classes represented along transects in both protected and unprotected habitats in 2015. Habitat classes correspond to Table 3.

Vegetation Removal

In 2011-2013, we compared the percent change in community composition and population size of C. *maritimum* ssp. *palustre* in treated plots to that of untreated plots to determine if vegetation removal had any effect on C. *maritimum* ssp. *palustre*. Removal of vegetation did not have a significant effect on the cover of C. *maritimum* ssp. *palustre*. There was a significant positive effect of vegetation removal on the cover of *Jaumea carnosa,* and *Limonium californicum*. Removal of vegetation had a slight negative effect on *Salicornia depressa* in the first year after vegetation removal, however this was not accompanied by increases in vegetation but rather increases in bareground. *Puccinellia pumila* and *Distichlis spicata* cover was lower in areas where vegetation removal had occurred, however the overall cover of these species is low. In the first year following treatment bare ground increased, however by 2012 vegetation had filled in and there was not a significant change in cover of bare ground. Decreases in C. *maritimum* ssp. *palustre* in 2012 and 2013 were consistent with decrease in cover of the species throughout the site.

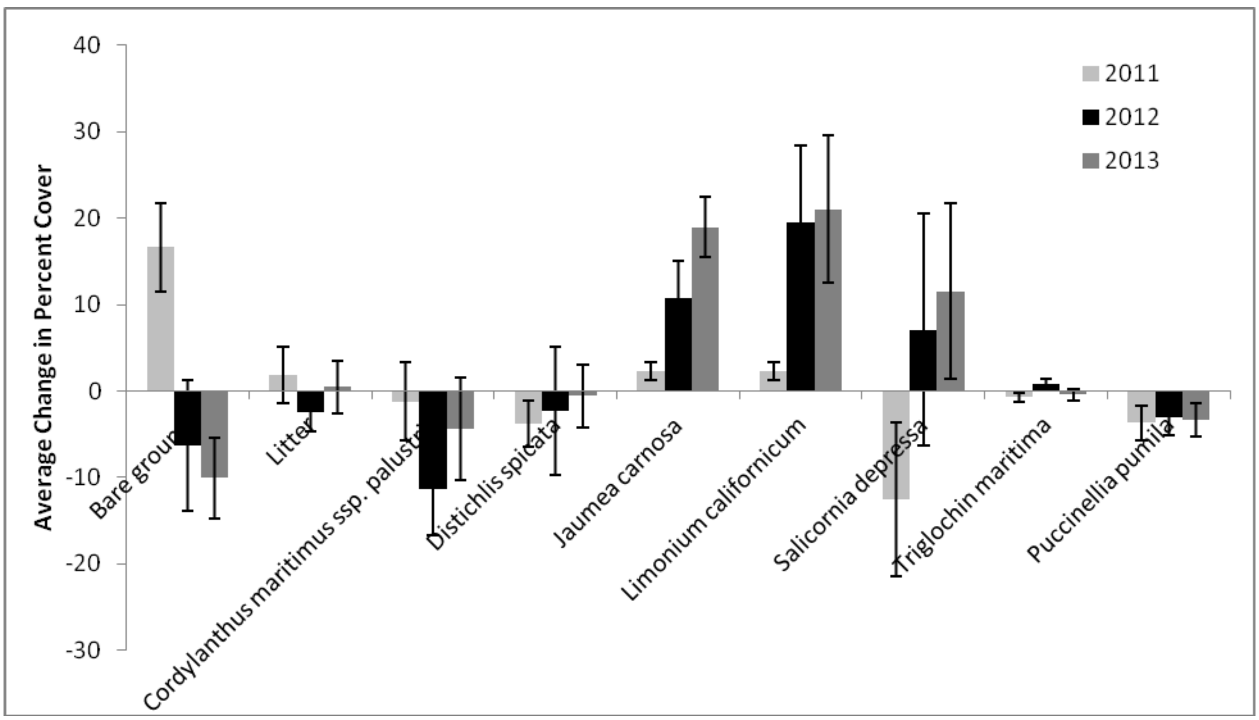

Figure 9. Average change in percent cover of select species in vegetation removal plots. Vegetation was removed so that total vegetative cover was approximately 70%. Plots were monitored in 2011-2013 to evaluate the effectiveness of vegetation removal. Species not shown above had a less than 1% change in cover from 2010 to 2013. Error bars represent ± 1 SE.

Habitat Mapping

In 2011-2015 a habitat map was created using the habitat classes listed in Table 3 (Figure 10). The map has been updated annually to detect shifts in habitat type that may affect the success of C. *maritimum* ssp. *palustre* and *L. californicum*. In both the areas, the density of C. *maritimum* ssp. *palustre* has fluctuated annually, (range 181-1064 plants/m2), however in each year, the changes in density have been consistent between protected and unprotected areas. For example, in years where density of C. *maritimum* ssp. *palustre* was low in CF habitats in the protected area, the density was also low in the unprotected area (Figure 6, Table 4). In 2014 and 2015, in the protected area, the density of *L. californicum* was consistently higher than in the unprotected area, in CF and LCF habitat types (Table 6).

Protected Area

In 2011, we surveyed ~7,000m^2 of occupied habitat in the protected area, with 293 m^2 mapped as "*Chloropyron* Flat" (CF) and 1,468 m^2 *Limonium*-*Chloropyron* Flat (LCF). In 2012, there were changes in cover of all habitats associated with C. *maritimum* ssp. *palustre*; CF cover decreased to only 3m^2, and the cover of LF increased considerably from 498m^2 in 2011 to 1398 m^2 in 2012. From 2011-2012, there were also increases in both the "*Salicornia* Depressions" (SD) and "*Salicornia-Distichlis* Depressions" (SDD) cover. In 2013 and 2014, this trend continued with a shift towards *Limonium* dominated plant communities and lower cover of C. *maritimum* ssp. *palustre*. In 2015, the cover of CF habitat increased, with a concomitant decrease in *L. californicum* dominated habitat types. From 2011-2015 the relative cover of each of the habitat types occupied by the sensitive species (CF, LCF and LF) has varied from being C. *maritimum* spp. *palustre* dominant to *L. californicum* dominant, although the total cover of occupied habitat types has remained relatively stable at ~2,500 m^2 collectively in the protected area.

Unprotected Area

In 2012, the habitat in the southern, disturbed portion of the area was also mapped using the same habitat classifications. Because the southern area is so much larger than the protected area, (~22,000 m^2 compared to ~7,200 m^2), the habitat mapping in the unprotected area is at a much coarser resolution than that in the protected area. In the southern unprotected area the dominant habitat class is SDD with *Distichlis spicata* co-occurring with *Salicornia* in more than 90% of the habitat. "*Chloropyron* Flats" were the next most common habitat type covering approximately 1,200 m^2 in 2012 and ~1,000m^2 in 2013. Cover of LCF has increased since mapping began, and in 2015 300 m^2 of LCF was mapped in the unprotected area. In addition to habitat classes, the boundaries of the disturbed area were marked in 2012-2015 and overlaid onto the habitat map (Figure 10).

CONCLUSIONS

There was high variability in the number *Chloropyron* from 2010-2015, with population estimates ranging from a low of ~124,000 in 2012 to ~916,000 in 2011, in the protected area. In the unprotected area, the population has ranged from a low 296,000 in 2013 to a high of just over 1,000,000 in 2014 and 2015. Vegetation removal experiments did not elucidate any potential effects of competitors on *Chloropyron* growth. As this species is a hemi-parasite and known to be associated with higher cover of select species, it is not surprising that we did not find a positive effect of our vegetation treatment. While it is known that the species is a hemi-parasite, with limited host specificity, it is unknown which adjacent plant species are being parasitized by *Chloropyron*.

Populations estimates of *Limonium californicum* calculated in 2014 and 2015 indicate that the population is stable (but relatively smaller) in the unprotected area, and has been decreasing in the protected area. In the protected area, the population has decreased from a high of ~832,000 in 2014 to ~791,000 in 2015. In the unprotected area, the population of *L. californicum* had a low of ~47,000 in 2015 and 130,000 in 2014. This apparent decrease in the number of plants in the protected area, may reflect the increasing size of long lived plants, as the areal cover of the species has increased over the course of the study.

From 2011-2015 there were fluctuations in the cover of different habitat classes in the protected area; particularly in the cover of habitat types associated with *Limonium californicum*. It is likely that this perennial plant is benefitting from the lack of disturbance in the protected area. Very little *L. californicum* was found in the unprotected area, and rarely enough to classify the habitat as "LCF" or "LF" at the scale mapped. Additionally, it was noted that the C. *maritimum* ssp. *palustre* was commonly associated with the disturbed areas in the unprotected area, and patches were found in the same locations across years (Figure 11). Continued habitat mapping and population surveys will elucidate general population trends of these two bureau sensitive species, which will allow for more targeted management recommendations to be made.

RECOMMENDATIONS

It is recommended that transects in both the protected and unprotected area continue to be monitored into the future on at least a three year cycle unless natural or manmade activities could cause substantial changes in microtopography or local sea-level. We also recommend continued (and coincident) data collection be continued on the Bureau Sensitive *Limonium californicum* in the area. The presence of C. *maritimum* ssp. *palustre* in the disturbed portion of the unprotected area, and the increasing dominance of *L. californicum* in the protected area indicates that further work may be necessary to balance the needs of both species.

Future work on the species may include further investigation and characterization of the parasitic relationship between C. *maritimum* ssp. *palustre* and its hosts; identification of pollinators (of both sensitive species) as well as microtopographical effects on the presence, abundance and establishment of both species. Future work can also begin to examine potential causes for changes in the cover of habitat classes over our study period. In the protected area, we have seen a dramatic shift towards increasing cover of *Limonium californicum*, in the protected area, whereas little to none is found in the unprotected area. Comparing the observed changes against local climate factors, land-uses changes, or other physical factors including both local and global sea level changes could potentially provide valuable information for management of these populations into the future.

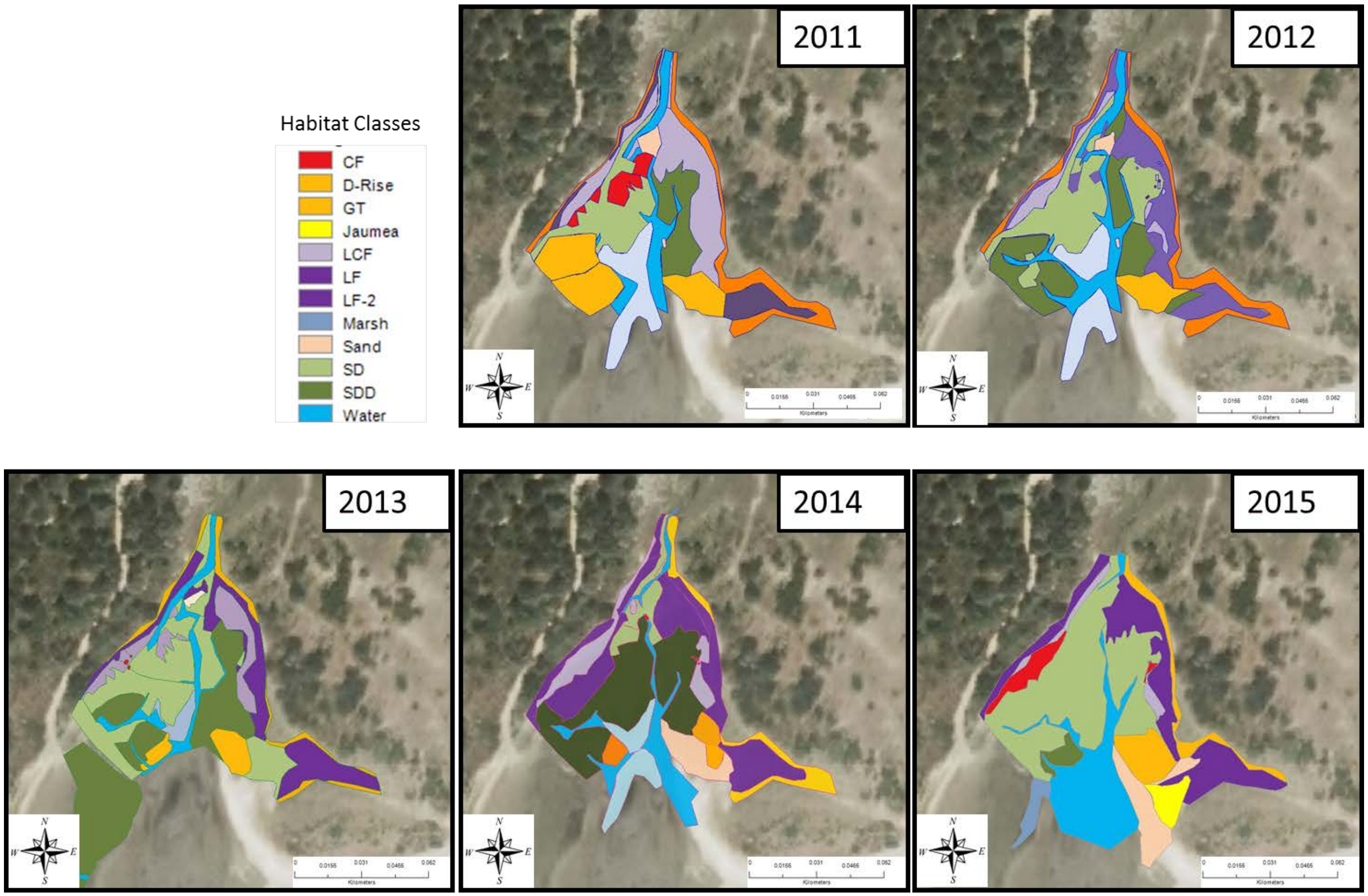

Figure 10. Habitat map of the C. *maritumus* ssp. *palustre* population at the Coos Bay North Spit, created in 2011-2013. Habitat codes are listed in Table 3. Major changes from 2011-2013 include a decrease in the cover of both "*Chloropyron* Flat" (CF) and increases in the cover of "*Limonium Chloropyron* Flat, (LCF) and "*Limonium* Flat" (LF).

Figure 11. 2013-2015 habitat maps for unprotected area. The remaining 'vegetated' area is classified as either SD or SDD based on habitat classes described in Table 3. Note that while the presence of C. *maritimum* ssp. *palustre* is quite patchy in this area, the location and extent of these patches have remained relatively stable over the course of this study.

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APPENDIX A. SAMPLING TRANSECT PHOTOPOINTS

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	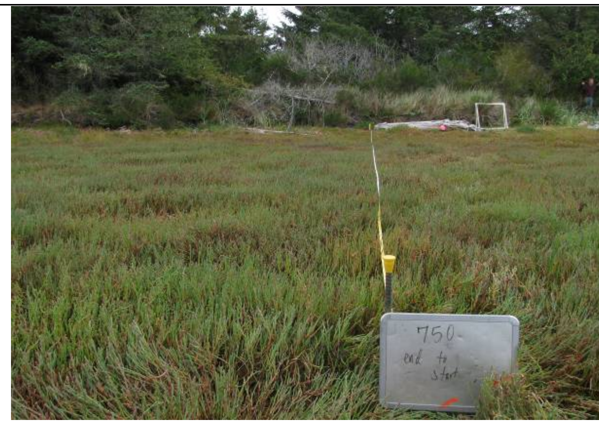
2011	
	
2012	
	
2013	


CoMaPa
2013 Tag# 750
Transect 0
0-20m


CoMaPa
2013 Tag# 750
Transect 0

2014

2015

Transect 2, Tag #516 (501)

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2014	
	
2015	
	

Transect 4, Tag #751

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2013	
	
2014	
	
2015	
	

Transect 7, Tag #752

0m-20m	20m-0m
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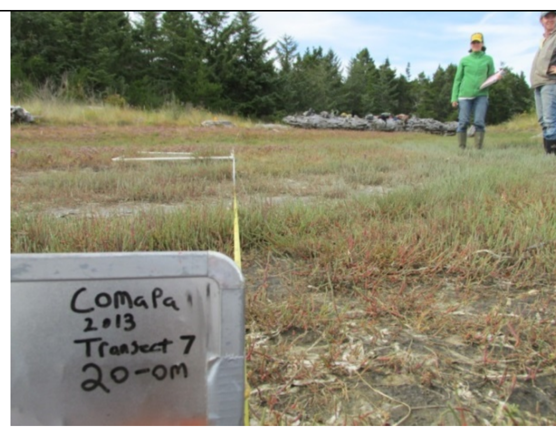
2012	
	
2013	
	

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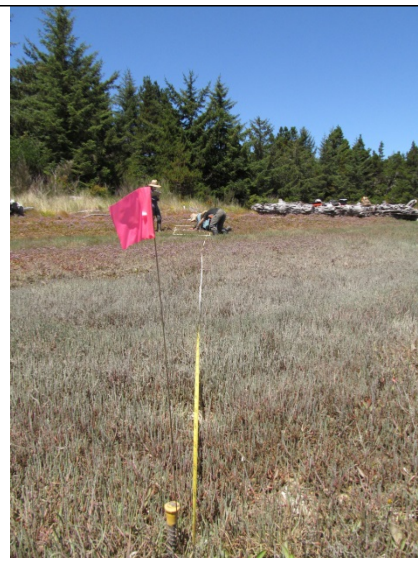
<tr><td></td><td></td></tr>
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 	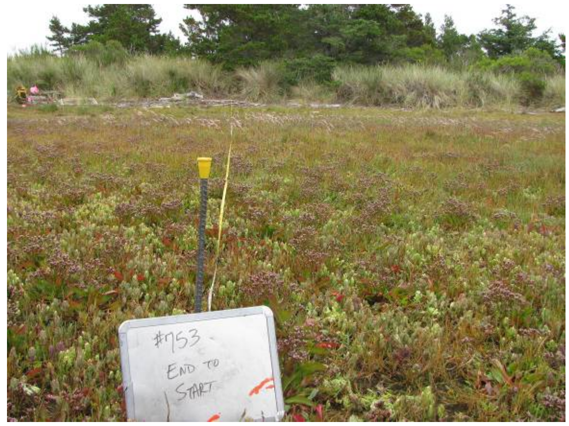
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2012	
 	

2013	
	

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	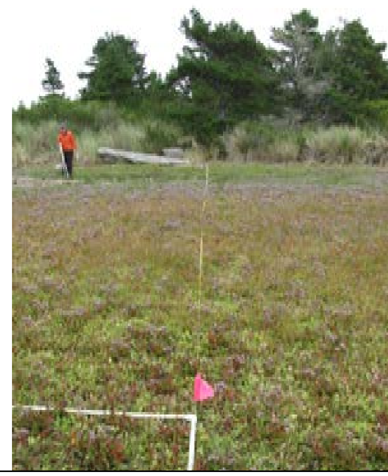
2015	
	

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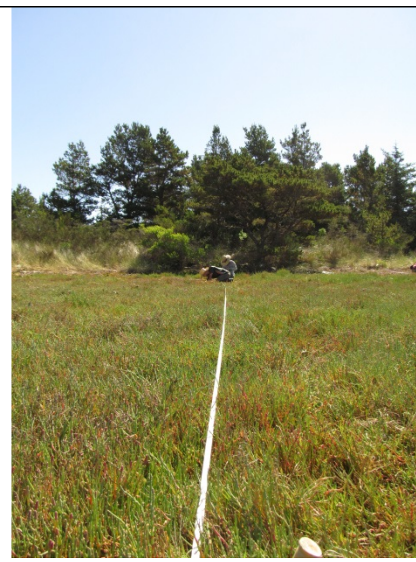
2012	
	
2013	
	

2014	
	
2015	
	

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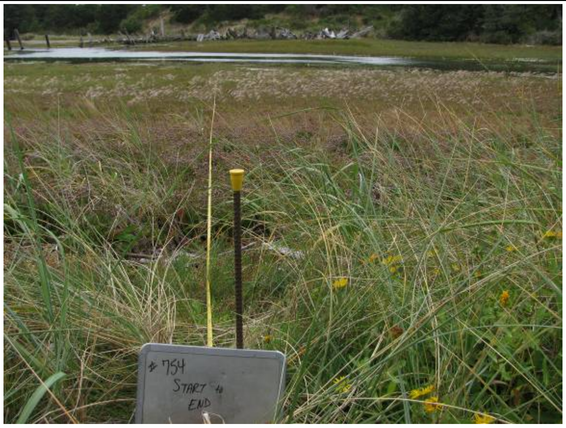
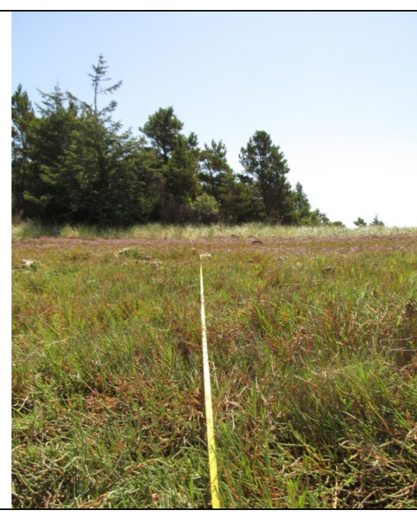
	
2011	
	
2012	
	

2013

2014

2015



Transect 16, Tag #515

0m-20m	20m-0m
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2012	
	
2013	
	

2014	
	
2015	
	

Transect 17, Tag #517

<table>
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<tr><th colspan="2">2011</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">2012</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">2013</th></tr>
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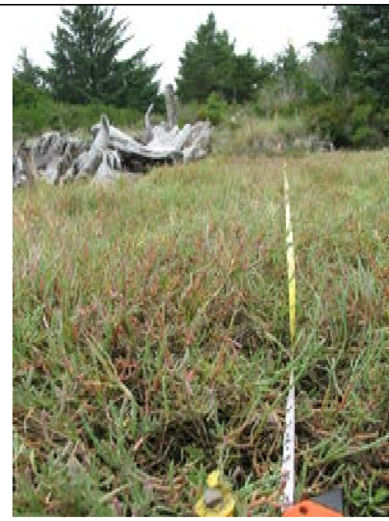
<tr><td></td><td></td></tr>
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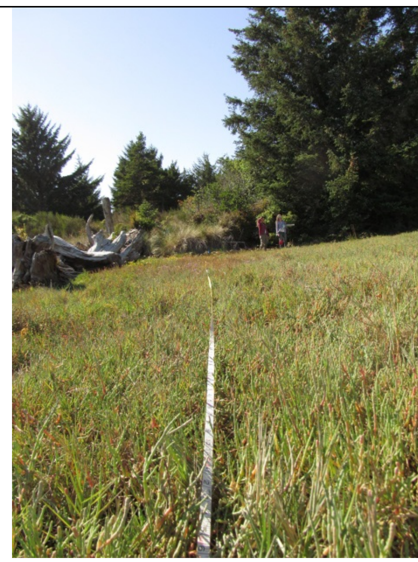
<tr><td></td><td></td></tr>
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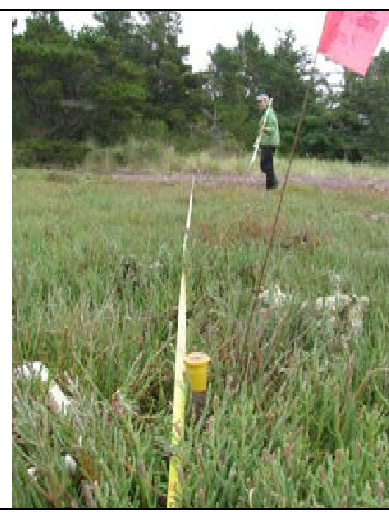
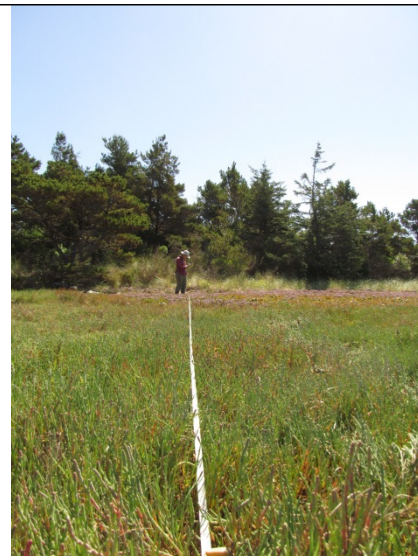
Transect 18, Tag #502

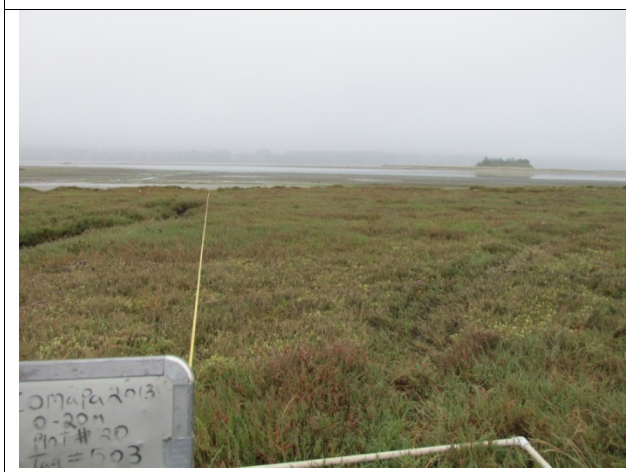
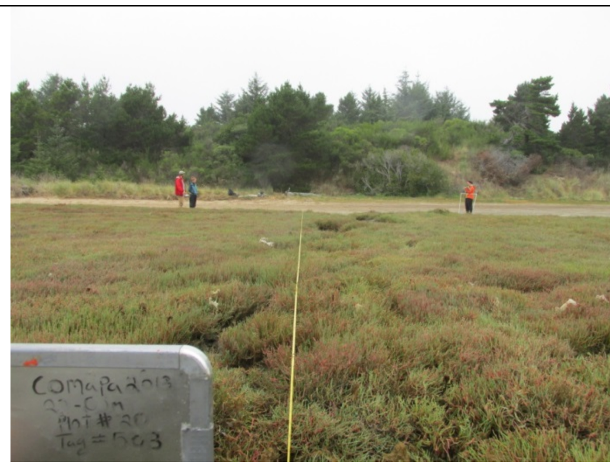
0m-20m	20m-0m
2012	
	
2013	
	
2014	
	

2015	
	

Transect 19, Tag #862 **New 2014**

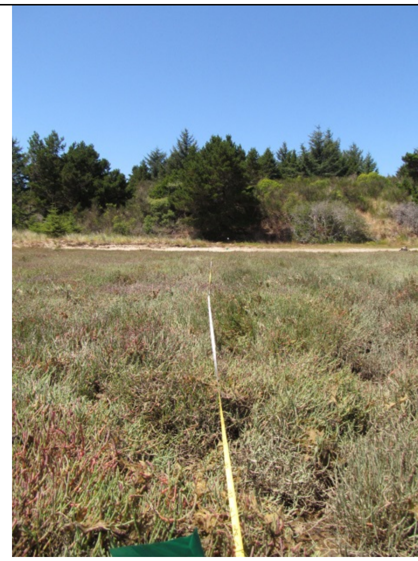
0m-20m	20m-0m
2014	
	
2015	
	

Transect 20, Tag #391 (503/997)

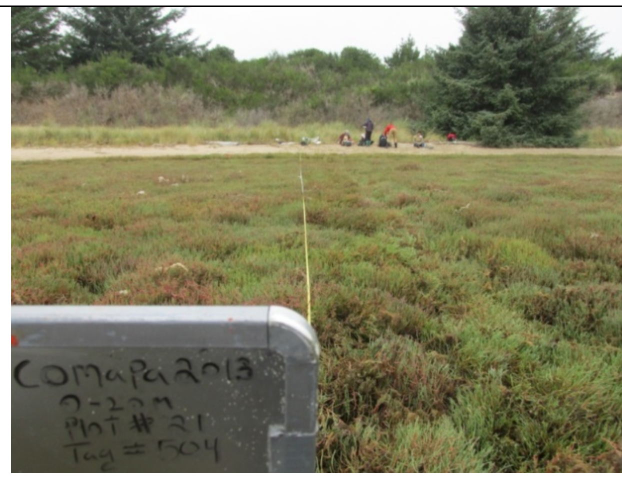
0m-20m (start of veg)	20m-0m
2012	
	
2013	
	
2014	
	

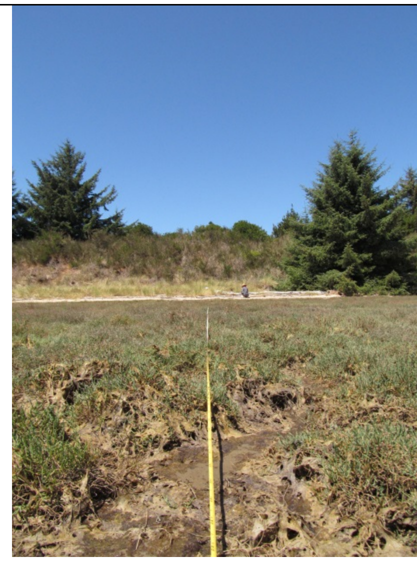
2015

(transect start photo taken from rebar, no photo of veg start available)



Transect 21, Tag #400 (504/999)

0m-20m (start of veg)	20m-0m
2012	
	
2013	
	
2014	
	

2015 **(transect start photo taken from rebar, no photo of veg start available)**	
	

Transect 22, Tag #388 (505)

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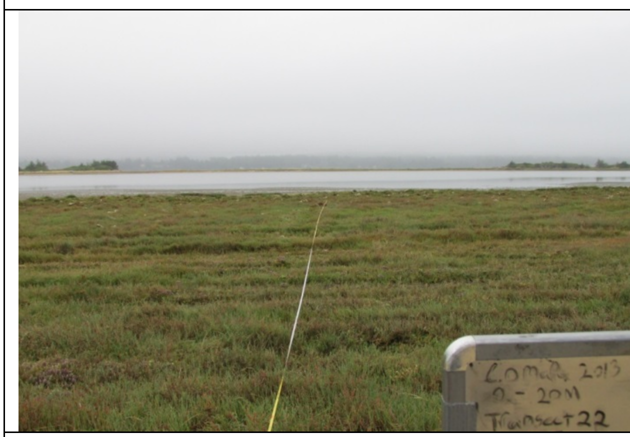
<tr><td></td><td></td></tr>
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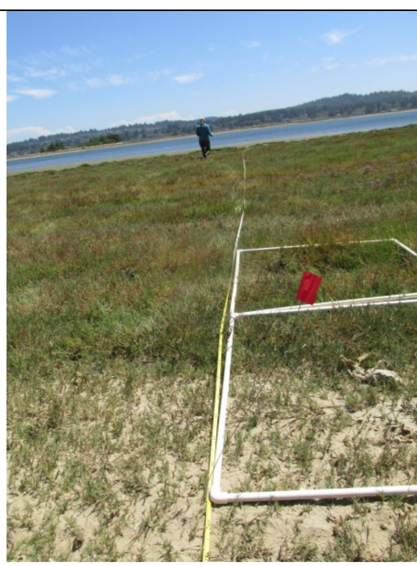
<tr><td></td><td></td></tr>
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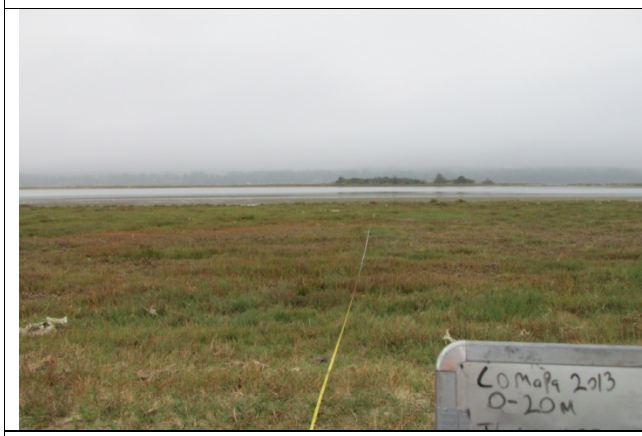
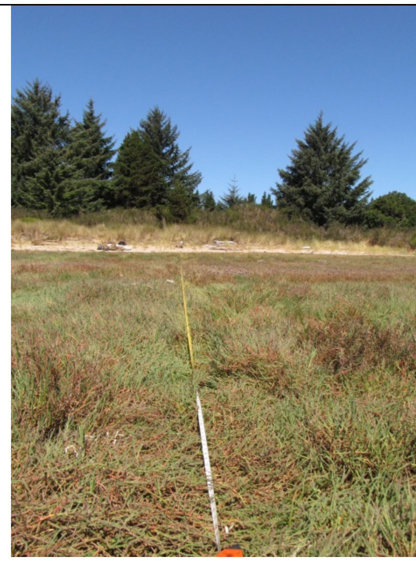
2015 **(transect start photo taken from rebar, no photo of veg start available)**	
	

Transect 23, Tag #385 (506)

0m-20m (start of veg)	20m-0m
2012	
	
2013	
	
2014 (transect start photo taken from rebar, no photo of veg start available)	
	

2015 **(transect start photo taken from rebar, no photo of veg start available)**	
	

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<tr><td>0m-20m</td><td>20m-0m</td></tr>
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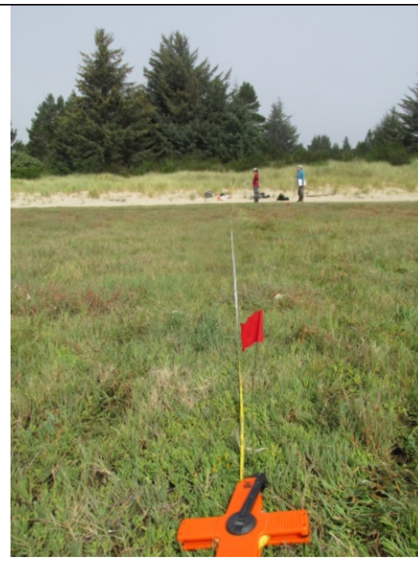
(transect start photo taken from rebar, no photo of veg start available)</td></tr>
<tr><td></td><td></td></tr>
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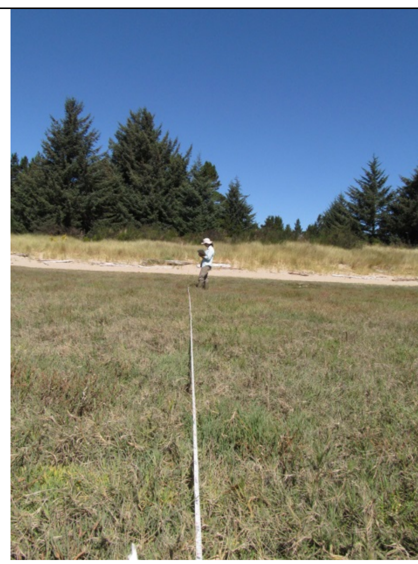
<tr><td></td><td></td></tr>
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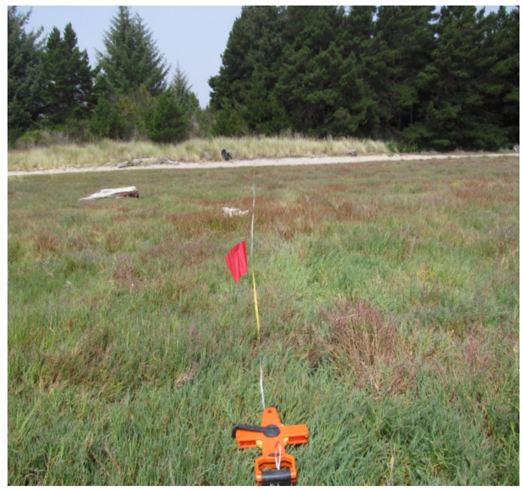
(transect start photo taken from rebar, no photo of veg start available)</td></tr>
<tr><td></td><td></td></tr>
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(transect start photo taken from rebar, no photo of veg start available)</td></tr>
<tr><td></td><td></td></tr>
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<table>
<tr><td colspan="2">Transect 26, Tag #389 (1000) **New 2014**</td></tr>
<tr><td>0m-20m</td><td>20m-0m</td></tr>
<tr><td colspan="2">2014
(transect start photo taken from rebar, no photo of veg start available)</td></tr>
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(transect start photo taken from rebar, no photo of veg start available)</td></tr>
<tr><td></td><td></td></tr>
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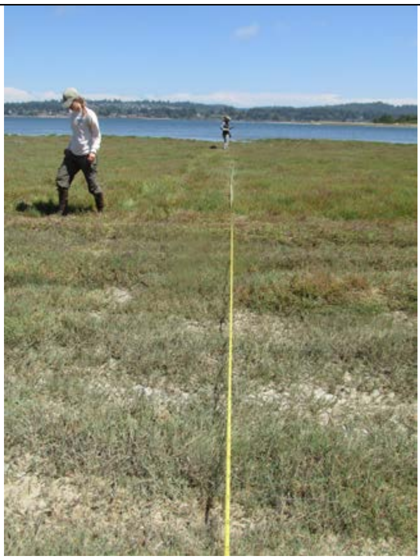
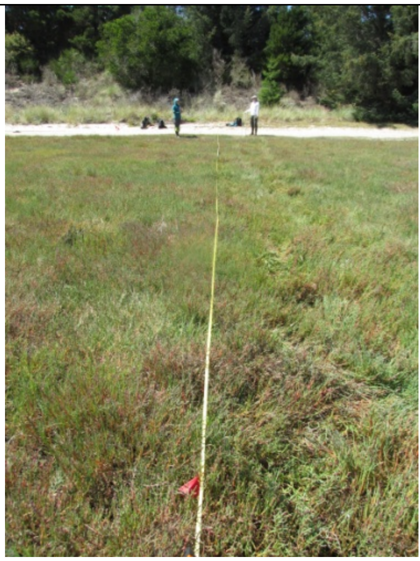
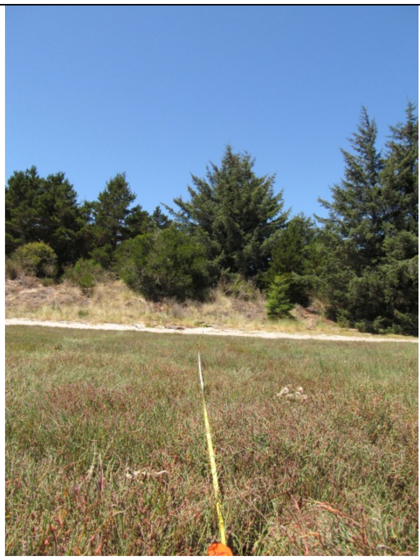
Transect 27, Tag #390 (998) **New 2014**

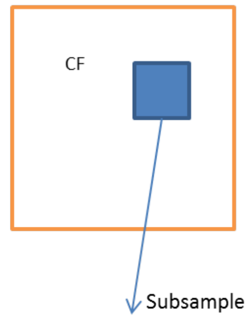
0m-20m (start of veg)	20m-0m
2014	
	
2015 (transect start photo taken from rebar, no photo of veg start available)	
	

APPENDIX B. SAMPLING METHODOLOGY FOR C. *MARITIMUM SSP. PALUSTRE* AND *L. CALIFORNICUM*.

COMAPA/LICA Sub-sampling

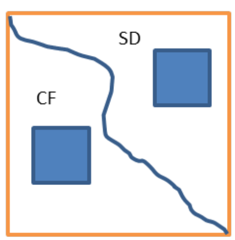
Transects are 20 m long
Sampled on the RIGHT side when looking from the origin to the end post.

- In each 1m^2 you will assign a habitat class (See table on next page).
- In each 1m^2 a 25 cm x 25 cm square will be subsampled for COMAPA and LICA . (Use the list of random coordinates to place the sub-sample frame.)
  - COMAPA- count number of individuals, branches and flowers.
  - LICA- count number of vegetative and reproductive rosettes

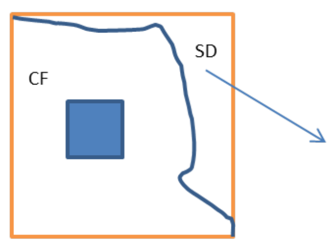


Subsample for COMAPA/LICA is placed using list of random coordinates.

- If there is more than one habitat class....



- (Example A) Two habitat types are present. Each area is large enough to accommodate the subsample frame.
- Do two subsamples. Use the random coordinates to guide your plot placement in BOTH habitat types. Skip coordinates that would place the frame in more than one habitat type.



Do not subsample in areas that cannot accommodate the sampling frame.

- (Example B) Two habitats are present, but only one area is large enough to accommodate the subsample frame.
- Do one subsample. In this example, the SD habitat can not accommodate the subsample frame, thus this portion is not subsampled.

Code	**Habitat**	**Description**
CF	Chloropyron flat	Chloropyron cover ≥ 50%
LCF	Limonium-Chloropyron flat	Limonium, Chloropyron codominant
LF	Limonium flat	Limonium cover ≥ 50%
GT	Grass transition	Differentiated by presence of Ammophila or Leymus, marks transition into small stabilized dune habitat. Some Chloropyron present but only in trace amounts. This is the absolute upper boundary of COMAPA habitat.
SD	Salicornia depression	Salicornia dominant species; area of higher water during the tide. Differs from waterway by abundant Salicornia, and little to no bare sand.
SDD	Salicornia-Distichlis depression	Salicornia dominant, but Distichlis cover ≥ 25%
Sand	Sand	Highest reach of the tide, but water does not linger here for long. Some COMAPA in trace amounts.
Waterway	Waterway	Other plants may be here, but not appropriate habitat for COMAPA. Various courses throughout entire area, usually adjacent to SD, SDD.
D-Rise	Distichlis rise	Small hill, Distichlis dominated, with minor patches of Jaumea carnosa nearest to the ocean.
Marsh	Marshy area	Marshy area dominated by Scirpus sp., area inundated by tides.

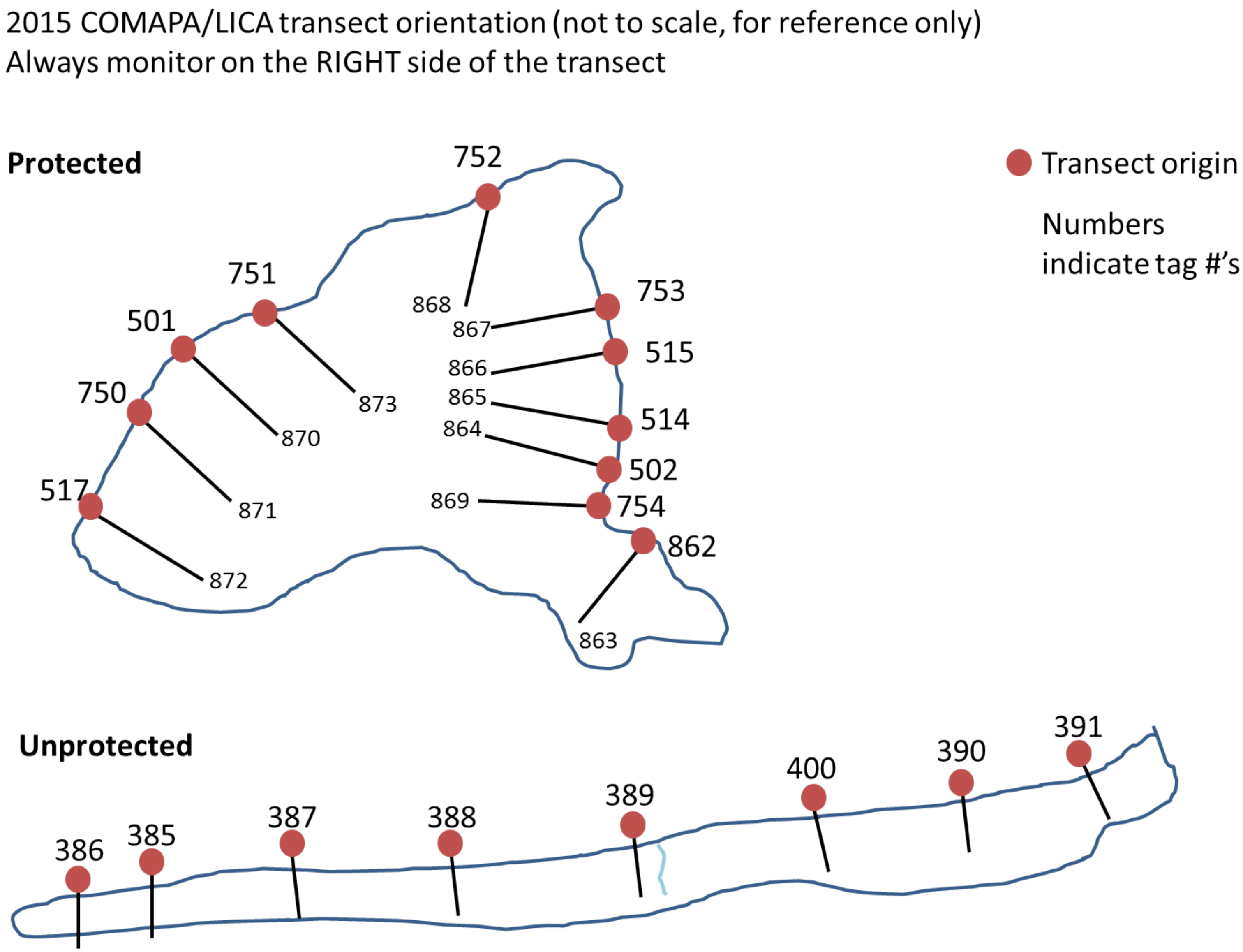


Figure 12. Schematic diagram (not to scale) of transects in both the protected and unprotected areas as of 2015.

COMAPA species ID cheatsheet

Ammophila arenaria- European beachgrass

Chenopodium album

Cuscuta pacifica on *Salicornia depressa*

Distichlis spicata

Festuca rubra

Hordeum jubatum

Jaumea carnosa

Leymus mollis- American dunegrass

Spergularia macrotheca

Limonium californicum

Plantago maritima

Puccinellia pumila

Triglochin maritima