Impacts of Mechanical *Spartina* Treatments on Rare Plants in Humboldt Bay Salt Marshes

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Introduction

The purpose of this two-year study was to evaluate the direct impacts of mechanical control measures for Spartina (*Spartina densiflora*) on two rare native plants that grow in high-elevation salt marshes at Humboldt Bay. The rare plants are Humboldt Bay owl's clover (*Castilleja ambigua* var. *humboldtiensis*) (Figure 1) and Point Reyes bird's beak (*Cordylanthus maritimus* ssp. *palustris;* synonym *Chloropyron maritimum* ssp. *palustre*, as recognized by CNPS, follows a revised classification by Tank et al. (2009) based on recent molecular research of subtribe Castillejinae (Orobanchaceae) (Figure 2). Both rare taxa are small annual plants that are locally abundant but considered imperiled by loss of habitat. Both are listed by the California Native Plant Society (CNPS 2010) as Rare, Threatened, or Endangered in California and Elsewhere and Fairly Threatened in California (CNPS List 1B.2). Neither have state or federal listings. Humboldt Bay owl's clover has a limited distribution, occurring only from Humboldt Bay south to Tomales Bay, California (Grewell et al. 2007, CNPS 2010, Calflora 2011). Point Reyes bird's beak extends into Oregon, where it is also considered endangered. In California, the subspecies has been reported as far south as Santa Clara County (CNPS 2010, Calflora 2011). Both taxa are facultative hemi-parasites: they parasitize other plant species by root connections called haustoria, but also derive some of their energy through photosynthesis.

Humboldt Bay owl's clover and Point Reyes bird's beak co-occur in high-elevation salt marshes in Humboldt Bay (Eicher 1987). The life histories of these two rare annuals were studied on islands and on the mainland of Mad River Slough in north Humboldt Bay (Bivin et al 1991). The U.S. Fish and Wildlife Service maintains an ongoing monitoring program for these species on Refuge lands. Both species have exhibited high annual fluctuations in population numbers in over a decade of monitoring in Mad River Slough (Pickart and Miller 1988, Pickart 2001, Pickart 2011b).

Pickart (2001) mapped Humboldt Bay owl's clover in May-June 1998 and Point Reyes bird's beak in June 1999 in salt marshes throughout Humboldt Bay in conjunction with mapping Spartina. In general, distribution and abundance of the rare species are negatively correlated with Spartina. The rare plants do not occur within dense Spartina stands except along the margins of the stands or in small openings.

S. densiflora is a non-native cordgrass inadvertently introduced to Humboldt Bay in the 1870s (Spicher and Josselyn 1985). The persistence and expansion of Spartina threatens the rare plants through displacement and by altering the natural character of salt marshes throughout the region (Figure 3). Along with three other non-native Spartina species, it is the target of a coast-wide eradication program (Boe et al. 2010). A regional eradication plan and EIR are currently being developed (H.T. Harvey & Associates, in prep). Successful mechanical methods for eradicating Spartina have been developed by the Humboldt Bay National Wildlife Refuge (Pickart 2005a, Pickart 2008a, Pickart 2008b, Pickart 2011a, Pickart 2011b).

Ultimately, the eradication of Spartina and the restoration of native salt marsh communities at Humboldt Bay are expected to increase available habitat for both rare plants. Nontheless, it is important to consider potential direct impacts to the rare plants associated with all proposed control activities. The control technique assessed in this investigation is mechanical removal of Spartina using hand-held brushcutters. The brushcutters are used to first mow above-ground plant material and then to grind rhizomes (shallow horizontal stems that creep below the soil surface) to a depth of approximately 8-15 cm (3-6 in). Potential direct impacts to the rare plants posed by mowing include trampling of plants by the labor crew, inadvertent cutting by the brushcutter, and/or smothering by Spartina debris after cutting.

Figure 1. Humboldt Bay owl's clover.

Figure 2. Pt. Reyes bird's beak.

Figure 3. Dense stand of Spartina in Humboldt Bay.

Proposed region-wide eradication measures could include mowing Spartina at all times of the year. During this two-year study, treatment was applied on 6/15/2009, a time at which the rare plants were flowering/fruiting and vulnerable to direct injury. The showy floral bracts present at this time made the plants highly visible, which facilitated avoidance measures. The owl's clover shed their seeds and senesce by mid-late summer. Mowing conducted in the fall and early winter (before plants start emerging, typically in Feb) would not pose direct threats to plants, however, the seedbank could be disturbed by sub-surface mowing. Rare plant populations were monitored throughout both the 2009 and 2010 growing seasons (from pre-treatment to one year post-treatment) to assess any potential impacts associated with treatment.

Study Site

The study site selected for the investigation is the Jacoby Creek Unit of the Humboldt Bay National Wildlife Refuge, located on the northeast shoreline of North Humboldt Bay, bordering the mouth of Jacoby Creek (Figure 4). The site contains high elevation salt marsh that supports populations of both rare salt marsh plants, with Spartina cover ranging from sparse to dense. The site was described in more detail by Pickart (2005b).

Methods

Selection of plot location began in February 2009 by conducting reconnaissance to determine where sufficient rare plant seedlings were emerging in close enough proximity to Spartina to place 1m x 1m study plots (Figure 5). Prospective plots were established and monitored approximately every two weeks. Plots that had insufficient rare plant seedlings by the end of March 2009 were discarded and new plots established to result in a total of 20 study plots. These were marked with pvc and geospatial data was collected to record plot location (Figure 6).

The pvc plot frame was built oversized so that the permanent stakes could be placed outside the actual plot perimeter in a manner that would not interfere with control activities conducted within the plot. The plot itself was divided into a ten by ten grid by stringing cord at 0.1m intervals (Figure 7). Data sheets were set up so that the location and abundance of rare plants and Spartina could be mapped by grid within each plot.

Monitoring continued every two weeks continued through senescence in both 2009 and 2010 growing seasons. The number of days between sampling periods varied depending on suitable tide conditions for sampling. At each monitoring session, the number of rare plants within each $0.01m^2$ grid section was counted (Figure 8). Once, in June of each study year (pre-treatment in 2009), the abundance of Spartina in each study plot was estimated by recording presence/absence within each grid section (only counted if rooted in the grid section) and also by recording an ocular estimate of cover within 12 cover classes (not restricted to where plants were rooted). In addition, plant species composition for each plot was recorded, with an ocular estimate of relative cover by all vascular plant species using the same 12 cover classes (Table 1). Plant species composition and cover was assessed pre-treatment (6/11/2009), 2 wks post-treatment (6/26/2009), and 1 yr post-treatment (6/27/2010).

Table 1. Relative cover of all vascular plant species was assessed within 12 cover classes.

1 = <1%	4 = 11-20%	7 = 41-50%	10 = 71-80%
2 = 1-5%	5 = 21-30%	8 = 51-60%	11 = 81-90%
3 = 6-10%	6 = 31-40%	9 = 61-70%	12 = 91-100%

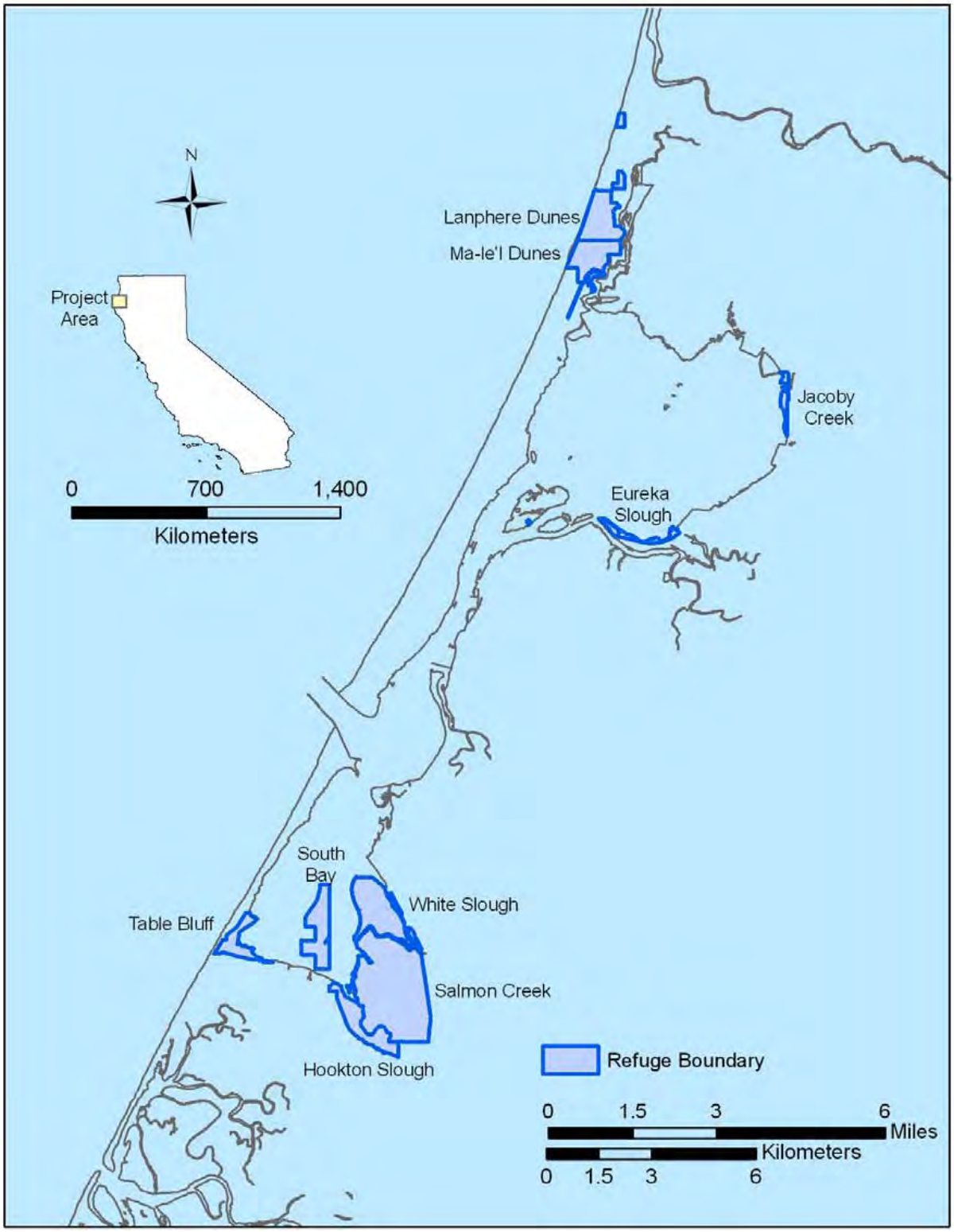

Figure 4. The study was located in the Jacoby Creek Unit of the Humboldt Bay National Wildlife Refuge on the northeastern shore of Humboldt Bay.

Figure 5. Humboldt Bay owl's clover seedling emergence (photo taken March 10, 2009, at the Jacoby Creek Unit of the Humboldt Bay National Wildlife Refuge).

When plants were fruiting, a subsample of twenty Humboldt Bay owl's clover individuals per study plot were randomly selected to assess vigor and reproductive output (or fewer if less than twenty plants were present in the plot at the time of sampling). The height of each plant, the number of branches, and the number of fruits were recorded. Phenological development was later in 2010 than in 2009; hence the plants were sampled at a slightly later date (06/04/2009 and 06/21/2010).

In June 2009, 10 plots were randomly selected to receive a sub-surface mowing Spartina treatment. The brushcutter Spartina treatment was applied 6/15/2009. Each study plot was photographed once before treatment and once following treatment in 2009 (Figure 9) and once in June 2010.

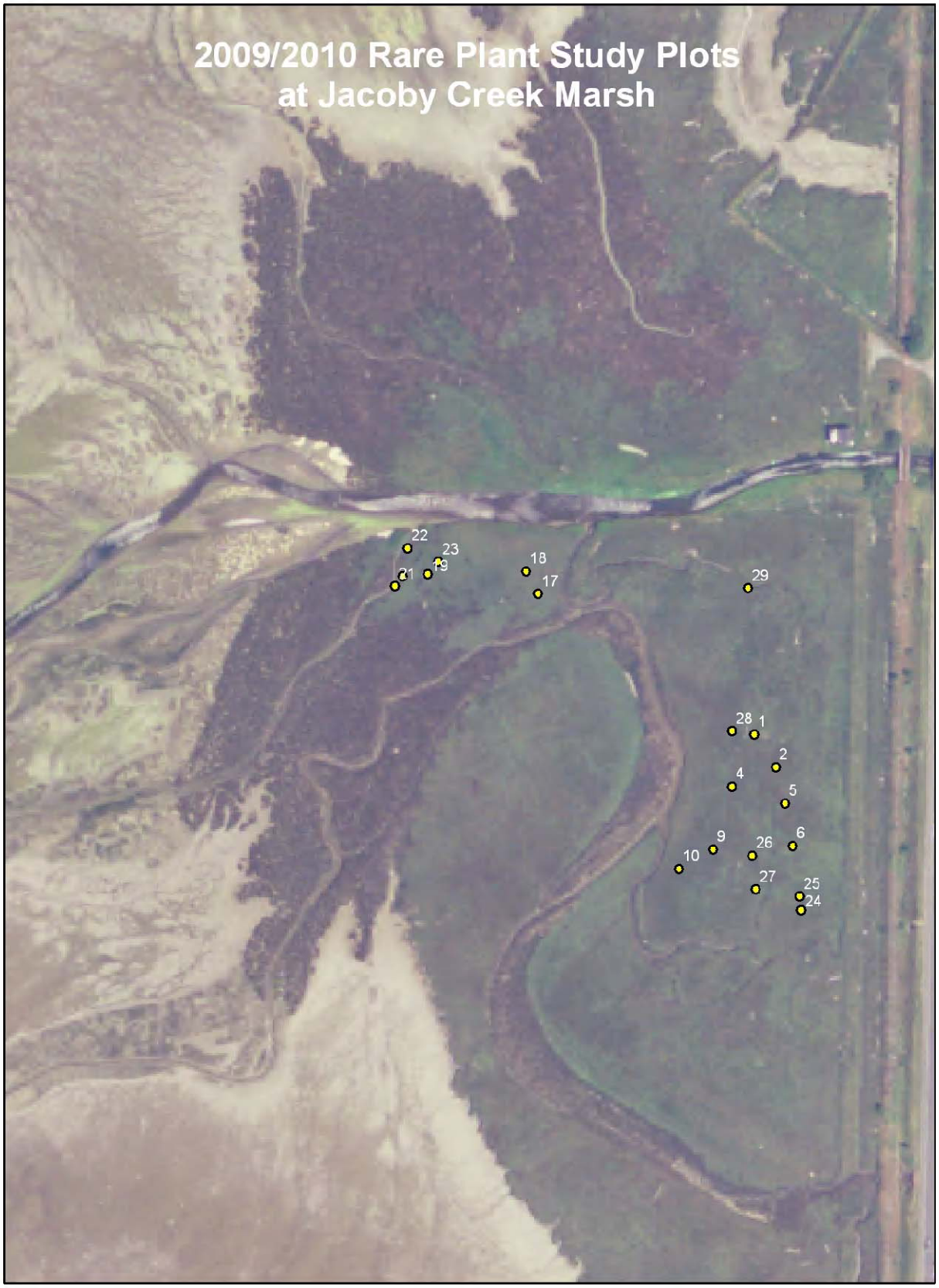

Figure 6. Location of study plots at the Refuge's Jacoby Creek Unit.

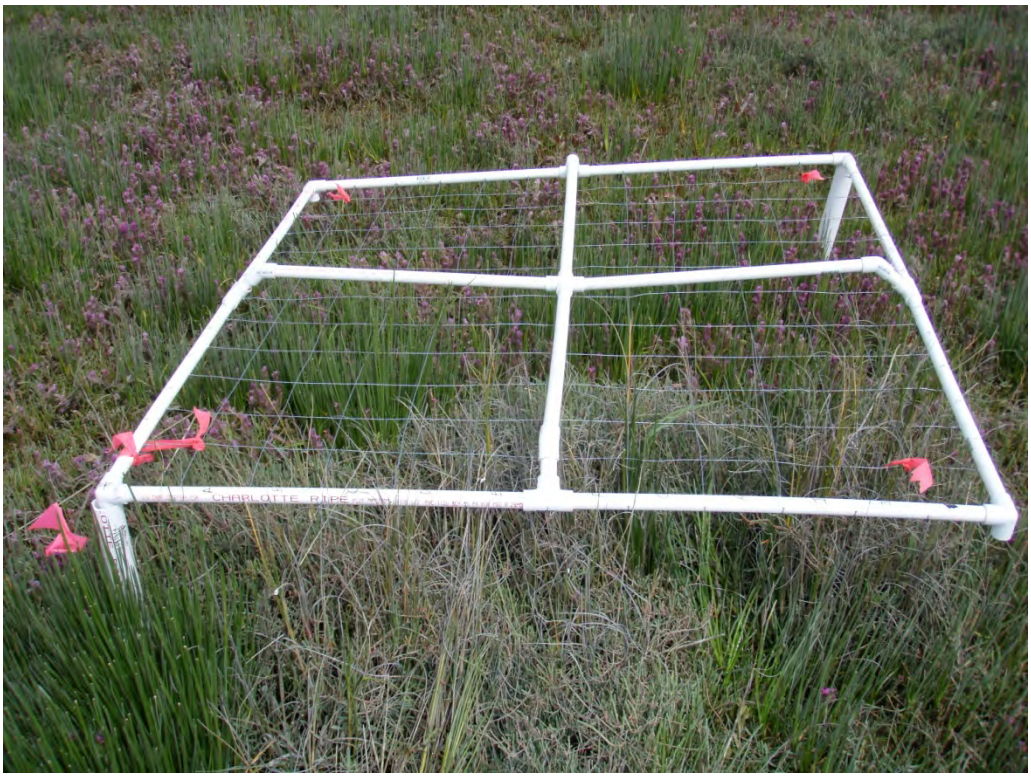

Figure 7. Plot frame used for sampling

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Figure 8. Humboldt Bay owl's clover individuals were counted within 100 $0.01m^2$ grid sections.

Figure 9. Post-treatment photo of study plot; a clump of Spartina has been removed from right side of the plot, leaving a bare area.

Results and Discussion

Point Reyes bird's beak was present in only eight of the 20 study plots, with too few sample size numbers overall to be included in the analysis, hence results presented here are for Humboldt Bay owl's clover only. These two closely related taxa share many life history characteristics and they commonly co-occur in high elevation tidal marshes in the study area. Presumably, the two would exhibit a similar response to mechanical Spartina treatment, and this conclusion is supported by observations associated with pilot restoration projects at the Lanphere and Ma-le'l Dunes Units of the Humboldt Bay National Wildlife Refuge (Pickart 2011b).

Humboldt Bay owl's clover seedlings typically start emerging in February; the plants flower/fruit in May-June; and they senesce shortly after fruit maturation and seed dispersal. Figures 10-11 depict Humboldt Bay owl's clover survivorship curves for the 2009-2010 growing seasons, showing patterns of emergence and mortality of individuals over time. The patterns were similar between treatment and control plots both years but varied between years. In general, the patterns are consistent with previous research, including annual variation in response to weather and other factors (Bivin et al 1991, Pickart and Miller 1988, Pickart 2001, Pickart 2011b).

Most of the data gathered in 2009 represents pre-treatment conditions. The last date of sampling for that year, 6/26/2009, was conducted 11 days post-treatment, however application of the brushcutter Spartina treatment on 6/15/2009 coincided with the period of natural plant senescence, and a decline in plant numbers between 6/12/2009 and 6/26/2009 was evident both in control plots (60% decline) and in treatment plots (76% decline).

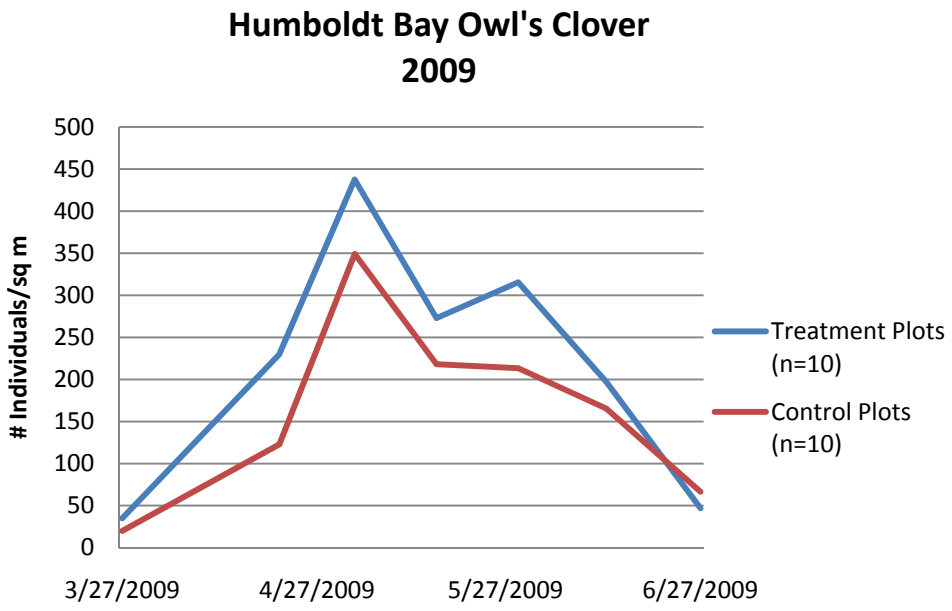

Figure 10. Survivorship of Humboldt Bay owl's clover in study plots at Jacoby Creek Unit, 2009.

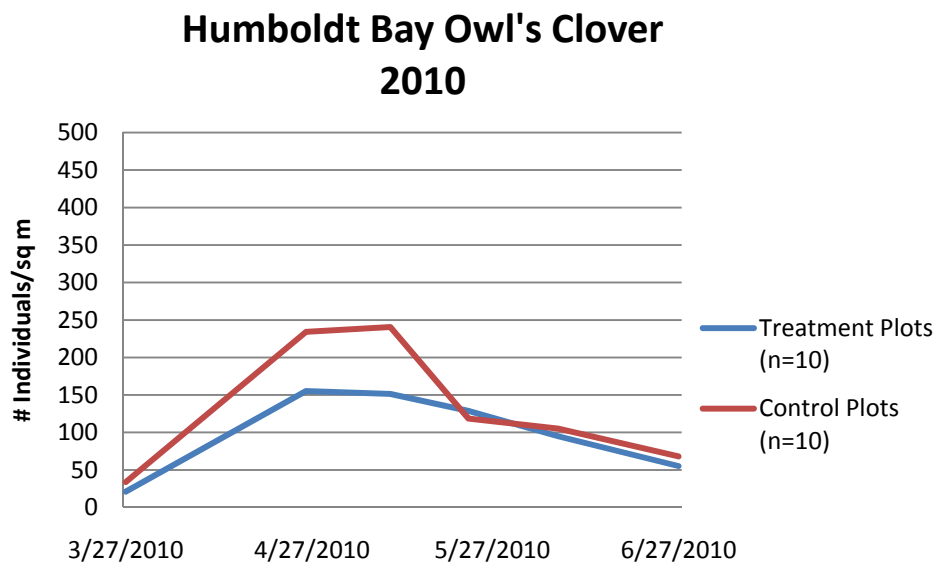

Figure 11. Survivorship of Humboldt Bay owl's clover in study plots at Jacoby Creek Unit, 2010.

The 2010 data set represents post-treatment conditions the growing season following treatment. No significant impacts associated with mechanical Spartina treatment on population numbers of Humboldt Bay owl's clover were detected. In a 2-way ANOVA assessing date and treatment status, the only significant difference detected was for date (p=0.04) (Table 2).

Table 2. Results of 2-Way Analysis of Variance (SPSS).

Source	**Factors Compared**	**Significance**
Date	Pre-Treatment vs.1 yr Post-Treatment	0.040
Treatment	Control Plots vs. Treatment Plots	0.780
Date * Treatment	Interaction of Factors	0.585

Overall, abundance of Humboldt Bay owl's clover was lower in 2010 than in 2009, for both control and treatment plots (Figure 12). Pre-treatment abundance of mature plants (6/12/2009) was 160/m^2 (SE=50, n=10) in control plots and 197/m^2 (SE=35, n=10) in treatment plots. One year post-treatment (6/7/2010), the number of mature plants was 105/m^2 (SE=37, n=10) in control plots and 95/m^2 (SE=27, n=10) in treatment plots. Annual fluctuations in population numbers are well-documented for Humboldt Bay owl's clover in the study area (Pickart and Miller 1988, Pickart 2001, Pickart 2011b).

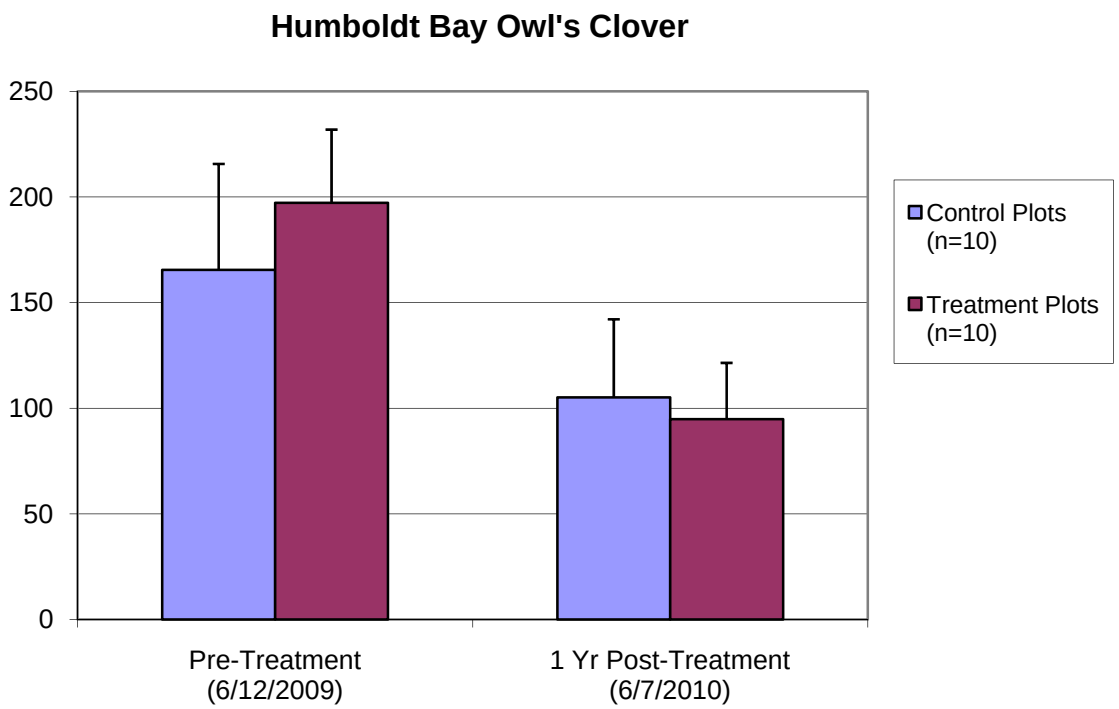

Figure 12. Changes in abundance of Humboldt Bay owl's clover at maturity in study plots at Jacoby Creek Unit, pre-treatment (6/12/2009) and one year following mechanical Spartina treatment (6/7/2010).

No significant impacts associated with mechanical Spartina treatment on plant vigor or reproductive output by Humboldt Bay owl's clover were detected. Plant height, number of branches, and number of fruits produced was similar between control and treatment plots in both years (Table 3).

Table 3. Reproductive output by Humboldt Bay owl's clover in control and treatment plots, pre-treatment and one year post-treatment.

	Humboldt Bay Owl's Clover Characteristics of Reproductive Individuals		
Pre-Treatment (6/4/2009)	Plant Height (mm)	# of Branches	# of Fruits
Control Plots (n=200)	141.7 ± 30.6	1.0 ± 0.1	3.0 ± 1.6
Treatment Plots (n=200)	144.1 ± 32.7	1.0 ± 0.2	3.0 ± 1.5
1 Yr Post-Treatment (6/21/2010)			
Control Plots (n=178)	153.6 ± 33.2	1.1 ± 0.3	4.0 ± 1.9
Treatment Plots (n=180)	151.4 ± 35.7	1.0 ± 0.2	4.0 ± 2.0

Plant species composition was assessed pre-treatment, two weeks post-treatment, and one year post-treatment. The treatment was successful in eliminating *Spartina densiflora*, with a slight amount of re-growth evident one year following treatment (Figure 13). *Sarcocornia pacifica* showed a slight decline in treated plots and *Triglochin* spp. a slight increase, with no other notable changes in species composition (Table 4).

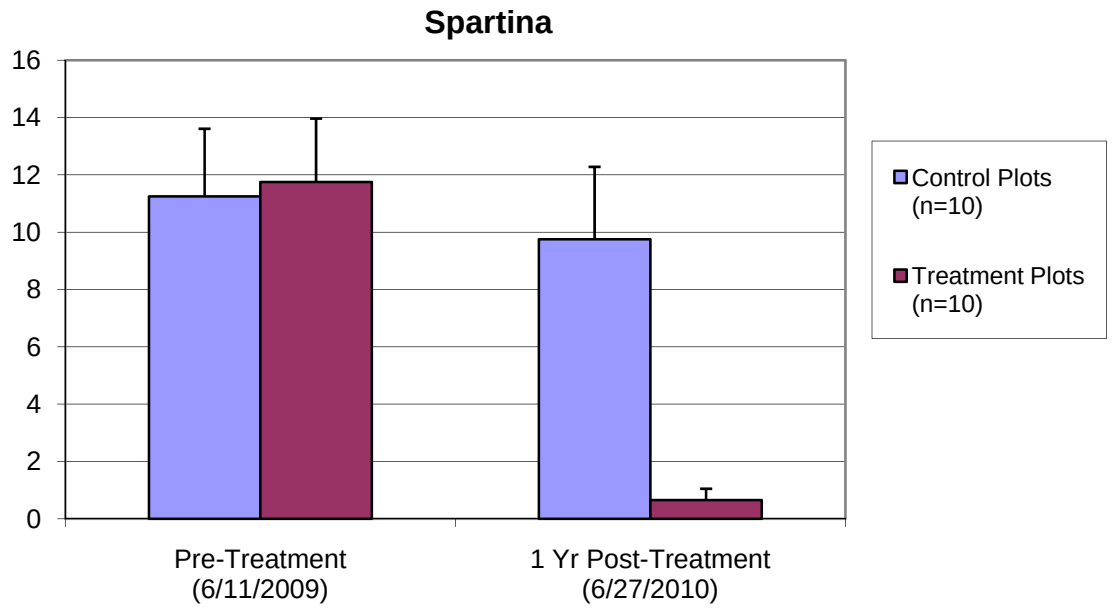

Figure 13. Changes in abundance of Spartina in study plots at Jacoby Creek Unit, pre-treatment (6/11/2009) and one year following mechanical Spartina treatment (6/27/2010).

Table 4. Plant species composition in study plots before and following application of mechanical Spartina treatment.

	Mean % Cover					
	Pre-Treatment		Post-Treatment (2 wks)		Post-Treatment (1 year)	
	6/11/2009		6/26/2009		6/27/2010	
Plant Species	Control (n=10)	Treatment (n=10)	Control (n=10)	Treatment (n=10)	Control (n=10)	Treatment (n=10)
Castilleja ambigua	8.3	9.0	0.8	0.5	4.3	4.3
Cordylanthus maritimus	0.7	0.4	1.1	0.1	2.5	0.4
Distichlis spicata	31.3	19.0	39.5	28.5	38.3	33.7
Grindelia stricta	1.5	0.7	1.5	1.1	1.8	0.7
Jaumea carnosa	2.8	2.8	4.5	2.0	6.8	4.7
Limonium californicum	2.3	3.3	2.3	2.8	2.3	2.4
Parapholis strigosa	0.3	0.1	0.1	0.1	0.3	0.3
Plantago juncoides	2.8	1.0	5.3	1.5	5.9	1.3
Sarcocornia pacifica	10.3	14.0	15.8	5.3	12.3	5.8
Scirpus cernuus	0.4	0.7	0.4	0.7	0.9	0.9
Spartina densiflora	11.3	11.8	10.5	0.0	9.8	0.7
Spergularia macrotheca	0.4	0.3	0.8	0.4	0.5	0.5
Triglochin spp.	11.0	15.5	12.2	15.9	14.0	30.0
Total	83.0	78.3	94.4	58.7	99.4	85.3

Spartina treatment at the Lanphere-Ma-le'l Pilot Restoration Project has had a positive effect on rare plant populations. The rare plant Humboldt Bay owl's clover has been censused and mapped at the site periodically since 1988. Pre-treatment population size fluctuated between 1,000-3,800 individuals, while post-treatment numbers reached 6,213 the first year following restoration and have increased every year since, with an estimated 99,485 in 2011. A nearby control site peaked in 2008, but has declined every year since. The rare plant Point Reyes bird's beak was observed to have a similar post-treatment positive effect, although the population was not quantitatively monitored due to its more cryptic nature (Pickart 2011b).

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