California Department of Fish & Wildlife
U.S. Fish and Wildlife Service: Endangered Species Act (Section-6) Grant-in-Aid Program

Final Performance Report

1.	**State:**	California
	FBMS/FAIMS Grant No.	F12AP00240
	Grant Name:	Benicia State Recreation Area, Southampton Bay Natural Preserve *Lepidium latifolium* (Perennial Pepperweed) Control Project for Endangered Species and Tidal Marsh Habitat Rehabilitation
	Grant Year:	2011
2.	**Report Period:**	August 1, 2011 – May 31, 2015
	Grant Period:	August 1, 2011 – May 31, 2015

3. Location of work
The project is located in Southampton Bay Natural Preserve (Preserve) at Benicia State Recreation Area, Solano County, CA.

4. Objectives and Expected Results:
Perennial pepperweed (*Lepidium latifolium*) is by far the most widespread invasive weed that directly co-occurs and competes with soft bird's-beak (*Chloropyron molle* ssp. *molle*), a state rare and federal endangered plant that occurs at the Preserve. In addition, perennial pepperweed is also directly displacing native vegetation occupied by breeding California Black Rail (*Laterallus jamaicensis coturniculus*), a state threatened species. Although impacts of this weed have not yet been fully determined, its invasion into pickleweed (*Salicornia pacifica*) dominated marshes also poses a threat to the habitat of the California Clapper Rail (*Rallus longirostris obsoletus*) and salt-marsh harvest mouse (*Reithrodontomys raviventris*), which are both state and federally-listed as endangered, along with many other native tidal marsh species. The project goal is to enhance salt marsh habitat for native tidal marsh species, including the endangered plant and animal species known to occur in Southampton Marsh.

- **Objective 1:** Improve habitat quality to facilitate recovery of native species in the Preserve by eradicating established perennial pepperweed infestations where feasible.
  Expected Results: The project is expected to benefit multiple species in the Preserve by reducing and/or eradicating established perennial pepperweed stands and rehabilitating degraded critical habitat.

- **Objective 2:** Reverse and/or reduce direct negative impacts to threatened and endangered species resulting from perennial pepperweed invasion and spread.
  Expected Results: The project is expected to result in a reversal and/or reduction in negative impacts to multiple endangered plant and animal species known to occur in Southampton Marsh.

- **Objective 3:** Increase knowledge for an improved weed management program that anticipates the arrival of new invaders, provides rapid response strategies tailored to the site, maximizes weed control efficacy, and minimizes non-target effects and cost.
  Expected Results: The project is expected to result in increased knowledge of weed management efficacy, which will lead to an improved weed management program.

5. If the work in this grant was part of a larger undertaking with other components and funding, present a brief overview of the larger activity and the role of this project.

In 2009, the California Department of Parks and Recreation, Diablo Vista District (DPR) and project partners implemented a project to address invasive weed infestation and habitat loss in the Preserve. The 2009 project was reviewed and approved by State and federal resource agencies based on the proposal submitted in March

of 2009 to the U.S. Fish and Wildlife Service (USFWS) by DPR and their project partners and approved under Section 7 of the Endangered Species Act. DPR developed a management strategy and began experimental use of herbicide to treat areas infested by perennial pepperweed. Weed treatments initiated in 2010 show promising results, and the careful application of herbicide to avoid impacts to sensitive species demonstrates the benefits of the project. This project will continue weed eradication efforts and implement a multi-year treatment of perennial pepperweed paired with concurrent monitoring of special status species, evaluation of treatment efficacy, and rare plant response.

6. Describe how the objectives were met.

- **Objective 1:** Improve habitat quality to facilitate recovery of native species in the Preserve by eradicating established perennial pepperweed infestations where feasible.

    - Weed control activities were conducted annually in spring in 2013, 2014, and 2015. Field crews entered the marsh on foot and used high resolution Global Positioning System (GPS) units loaded with annual mapping data of weed distributions, soft bird's-beak distribution, California Clapper Rail breeding habitat, and California Black Rail habitat to guide spatially stratified management methods. A two percent (2%) solution of Aquamaster® herbicide (Monsanto) with one percent (1%) Competitor ® surfactant (Wilbur Ellis) as an additive, and a low toxicity colorant/spray indicator dye (HiLight) was used. Crew members hiked into the areas and applied herbicide to perennial pepperweed with backpack sprayers outside of the endangered species protection zones. All chemicals were mixed by restoration professionals who are trained and licensed to handle and apply herbicides.

    - Rare plant protection zones were established and mapped to protect soft bird's-beak populations. For all pepperweed within one meter of a soft bird's-beak individual or sub-population, the leaves of the weed were hand-wiped or hand-wicked with herbicide solution using a sponge attachment to the spray wand, and a drizzle application (very low pressure, <3 lbs. at the nozzle tip) down the stem.

    - Total area of pepperweed in the marsh in 2012 (prior to grant initiation) was 63,893 m^2 (15.79 acres); in 2014, total area was reduced to 44,834 m^2 (11.08 acres)..

    - The tidal marsh community responded very positively to initial treatment activities. Native marsh butterweed (*Senecio hydrophilus),* which grows channel-side with perennial pepperweed increased in abundance after the treatments and showed no herbicide damage. In the pretreatment year, a single plant of the special status plant species Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*) was observed. Two years after herbicide treatments, Delta tule pea is common along tidal sloughs. Other native plant species were observed to respond positively to perennial pepperweed suppression, including increases in stands of native salt marsh fleabane (*Pluchea odorata*)*,* yarrow (*Achillea millefolium*), marsh gumplant (*Grindelia stricta* var. *angustifolia*), western goldenrod (*Euthamia occidentalis*), and slender aster (*Symphyotrichum subulatum* var. *parviflorum*).

- **Objective 2:** Reverse and/or reduce direct negative impacts to threatened and endangered species resulting from perennial pepperweed invasion and spread.

    - Weed control activities were conducted as described above.

    - Avian surveys conducted in spring 2013, 2014, and 2015 detected a high density of California Black Rail in the marsh. California Black Rail habitat was completely avoided each year, with the exception of minimal access in 2015 on the periphery of the California Black Rail habitat in the northern marsh area. Entry was necessary in this area to treat the heavy infestation of pepperweed that is resulting in habitat conversion, which can lead to a high risk of nest abandonment. Surveys did not detect the California Clapper Rail, but its habitat was avoided during the nesting season (February 1 – September 30), with the exception of assisted entry by

a small spray crew directly following behind an approved avian biologist clearing the area(s) within the habitat daily for avian species.

- The distribution of soft bird's-beak decreased from an occupied area of 15,185 m^2 in 2012 to 11,311 m^2 in 2014. The recent decline in soft bird's-beak was observed primarily in the upland edge habitat sections of the marsh and the drier sections of the marsh plain. There were more unoccupied patches than observed in previous years; most 2014 unoccupied patches were individual points that were previously composed of less than ten individual plants each. In addition, several polygons that had merged in previous years contracted back into separate smaller polygons in 2014. Even with this decrease, the 2014 occupied area was still greater than observed in 2009 or 2010, and the population size observed in spring 2013 is the largest population of soft bird's-beak ever recorded at this location, occupying and area of 16,696 m^2.

- **Objective 3:** Increase knowledge for an improved weed management program that anticipates the arrival of new invaders, provides rapid response strategies tailored to the site, maximizes weed control efficacy, and minimizes non-target effects and cost.

  - It was documented that there are increased threats to the tidal marsh in the Preserve from secondary invaders and other non-native weeds, including black rush (*Juncus gerardii*), and wild celery (*Apium graveolens*), among others. The distribution of invasive black rush continues to expand in the marsh, and increased by 5 percent from 2013 to 2014, occupying an area of 8,541 m^2 (2.11 acres) in the marsh.

  - In 2014, the treatment of wild celery was prioritized and included in project activities that spring. The area occupied by live wild celery following one year of treatment dropped by 50 percent from 2,434 m^2 (0.60 acres) in 2013 to 1,209 m^2 (0.30 acres) in 2014.

7. Discuss differences between work anticipated in grant proposal and grant agreement and that actually carried out with Federal Aid grant funds; include differences between expected and actual costs. N/A

8. List any publications or in-house reports resulting from this work.

The project is summarized in an in-house report submitted to CDFW by DPR. The report is available upon request.

This project continues weed eradication efforts that began in 2009 prior to the onset of this grant. Work conducted in the previous project is summarized in the following report:

Grewell, B.J., C.J. Futrell and M.J. Skaer. 2013. Ecologically based adaptive management of invasive *Lepidium latifolium* for endangered species and tidal marsh recovery at Southampton Bay Wetland Natural Preserve in the San Francisco Estuary. USDA-ARS Exotic & Invasive Weeds Research Unit, University of California-Davis report to: U.S. Fish and Wildlife Service Endangered Species Division, Recovery Branch, Sacramento, CA; California Department of Parks & Recreation, Diablo Vista District, Petaluma, CA; and California Department of Fish & Wildlife Habitat Conservation Planning Branch, Sacramento, CA.

9. Name, title, phone number, and e-mail address of person compiling this report

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Introduction

In 2009, the California Department of Parks and Recreation, Bay Area District (DPR) and project partners implemented a project to address invasive weed infestation and habitat loss in the Southampton Bay Natural Preserve within Benicia State Recreation Area in Solano County, CA (Preserve). The 2009 project was reviewed and approved by State and federal resource agencies based on the proposal submitted in March of 2009 to the U.S. Fish and Wildlife Service (USFWS) by DPR and their project partners and approved under Section 7 of the Endangered Species Act. DPR developed a management strategy and began experimental use of herbicide to treat areas infested by perennial pepperweed. Project activities funded by the 2011 U.S. Fish and Wildlife Service Endangered Species Act (Section-6) Grant-in-Aid Program (F12AP0024) (administered by the California Department of Fish and Wildlife, DFW) allowed for the continuation of the weed eradication efforts paired with concurrent monitoring of special status species, evaluation of treatment efficacy, and rare plant response.

Project Objectives

Project objectives included:

- Through habitat enhancement and subsequent native plant recovery, reverse and/or reduce direct negative impacts to threatened and endangered species resulting from perennial pepperweed (*Lepidium latifolium*) invasion and spread; and

- Increase knowledge for an improved weed management program that anticipates the arrival of new invaders, provides rapid response strategies tailored to the site, maximizes weed control efficacy, and minimizes non-target effects and cost.

The project was expected to benefit multiple species in the Preserve by reducing and/or eradicating established perennial pepperweed stands and rehabilitating degraded critical habitat. The project was also expected to enhance salt marsh habitat for multiple endangered plant and animal species known to occur in the Preserve. The project was also expected to increase the knowledge of weed management efficacy, which will lead to an improved weed management program within the Bay Area District of DPR.

Methodologies

The first project objective included the enhancement of native species habitat and subsequent native plant recovery, and the reduction of direct negative impacts to threatened and endangered species resulting from perennial pepperweed invasion and spread. This was to be accomplished by establishing a strong project team, identifying and implementing treatment, deploying well founded project efficacy and native community impact tracking methodologies, and continuously adapting management according to findings.

Project Team and Adaptive Management

Prior to grant initiation, which occurred in March 2013, DPR held a meeting with the project team, whose members were selected at the onset of the project for their expertise in weed management, tidal wetland ecology, and extensive knowledge with the local native flora and sensitive species. Specifically, the team consists of Christina Freeman, DPR project manager, Mike Forbert, herbicide application contractor and president of West Coast Wildlands Dr. Brenda Grewell, rare plant and tidal marsh specialist from the USDA-ARS Exotic & Invasive Weeds Research Unit, and Jules Evens, avian specialist and president of Avocet Research Associates. This annual meeting offered a forum for discussion of project outcomes from the previous year, including weed control efficacy, sensitive species and community responses, and project management improvements. The meeting also served as a platform for the project team to receive updates from species specialists regarding population characteristics, avoidance and protective measure efficacy, and any new data or ideas that could be integrated into the project methodology for the coming year. All management strategies were reviewed annually by USFWS and DFW for approval prior to implementation.

This adaptive management approach is key to successfully implementing a weed control project in an area with high native biodiversity and listed species in direct proximity of activities, and is the only way to do so while remaining within the boundaries of the State Parks Mission directive. The Mission vows to preserve biodiversity - the goal of the non-native plant removal - while protecting the natural resources on the

landbase, which is the objective of integrating well- founded and conservative species and community protective measures. Specifically, the team members have worked annually to adapt project methodology, including species habitat and avoidance zone delineations, specialized treatment zone delineations for rare plant protection, weed treatment methodology plans, including access and scheduling, field mapping and weed treatment oversight planning, and integration of ongoing rare species data collection and response tracking into project actions.

During the annual meetings, Jules Evens provided concise and direct recommendations for avian protective measures based on annual surveys he performs under a State and federal permit. The protection of avian species in the marsh is of utmost priority to DPR, and Jules' recommendations act as a foundation for adapting management actions each year. For several years the project aim has been to completely avoid disturbing vulnerable *Laterallus jamaicensis coturniculus (*California black rail) (CBR) habitat year round, given there is a resident population in the marsh, and avoid disturbing all potential *Rallus longirostris obsoletus* (California Ridgway rail) (CRR) habitat from February 1 - September 30, with the exception of assisted entry with a permitted approved rail biologist for a small spray crew in years when no CRR were observed. Mike Forbert has provided technical insight into herbicide application techniques and options with regards to site specific conditions and challenges in the marsh, as well as feedback regarding secondary invaders and other species threats observed in the field, which are integrated into the adaptive management discussion each year. Mike is a highly valued contractor to DPR given that he works to retain a high level of conscientiousness among his field crew regarding species identification, avoidance measures and specialized treatment requirements.

Dr. Grewell has provided DPR with an unprecedented amount of data and insight into the management of this tidal marsh community over several decades; her participation in this project as the USDA-ARS team lead has provided invaluable guidance to DPR the project manager and is highly integral to project success. The focus of the USDA-ARS team has been to provide scientific data and results to DPR that contribute to a better understanding of the ecology of marsh, the responses of the system to management, and the effectiveness of management decision-making. Specifically, the role of the USDA research support team has been to assess the magnitude of pepperweed and secondary invader infestations and the distribution and evaluate the abundance and demographic status of the *Chloropyron molle* subsp. *molle* population. During the annual meetings, and consistently throughout the year, the USDA team contributed data, analyses and results from study of the response of the weed, endangered plant population, and the native plant community to treatment for integration into management decision-making. This project participation was partially made possible by an agreement USDA-ARS team entered into with the USFWS Sacramento Field Office Endangered Species Division, Recovery Branch, in 2009. The USDA team established monitoring protocols, designed field experiments, and collected baseline data prior to DPR's initiation of weed control actions in the Preserve. Project tasks, methods, and preliminary results of project activities completed in years 2009 – 2012 were summarized in a publication titled 'Ecologically based adaptive management of invasive pepperweed for endangered species and tidal marsh recovery at Southampton Bay Wetland Natural Preserve in the San Francisco Estuary' (Grewell, B.J., C.J. Futrell and M.J. Skaer. 2013). The USDA-ARS fulfilled their agreement terms with USFWS in 2013.

Field Work

The project methodology was determined by the project team as follows:

1. Given that annual avian surveys to date resulted in a negative for CRR presence but indicated a high density CBR population, CRR habitat would be avoided through September 30th, with the exception of several days of entry into the habitat for a small spray crew directly following behind an approved avian biologist who would clear the area(s) within the habitat daily for avian species. CBR habitat was avoided year round. If annual survey results were to vary, different conservation measures were drawn up and proposed for agency review.
2. All personnel accessing the marsh received endangered species training prior to marsh entry. In addition, project kick off meetings included summations of project goals, conservation measures, chain of communication, team member roles and responsibilities. The 2015 environmental training is attached in Appendix A.
3. While working in the tidal marsh environment, 'Walking in the Marsh' protocol was to be implemented by all personnel during project activities.

4. Rare plant protection zones were established and mapped by the USDA team based on the GPS data they collected the previous year. For all weeds to be treated within 1 meter of a *Chloropyron molle* subsp. *molle* individual or sub-population, the leaves of the weed were hand-wiped or hand-wicked with herbicide solution using a sponge attachment to the spray wand, and a drizzle application (very low pressure, <3lbs at the nozzle tip) down the stem.
5. Rare plant data collection occurred to the extent dictated by permits and responsibilities held by Dr. Grewell for the purposes of research continuity and to provide DPR with both tidal marsh resource management recommendations and project guidance for rare plant impact avoidance.
6. Marshwide pepperweed distribution, abundance, and community response tracking would occur throughout the year. Data would be stratified by three geographic study areas within the marsh corresponding to the tidal inundation gradient from Southampton Bay to the northern (inland) preserve boundary (bay, mid, north). Data would also be stratified by occupied microhabitat type (marsh-terrestrial ecotone and tidal slough/creek channel levees). The USDA team would quantify weed abundance by assigning four cover classes that included trace (<1-10%), low (11-30%), medium (31-60%), and high (61-100%).
7. Distribution of high priority secondary invaders was mapped annually by the USDA team. Based on the increase in distribution of *Apium graveolens* (wild celery) documented by the researchers, DPR added wild celery to the weed treatment program in 2014.

Results

Given the closing date of this grant cycle, project activities and results which occurred between March 2013 and May 2015 are included in this report; 2015 rare plant data and weed treatment results from the 2015 treatment season could not be included, as that data collection occurs into the late summer and fall months and will not be completed by the grant cycle closing date.

Herbicide Treatment

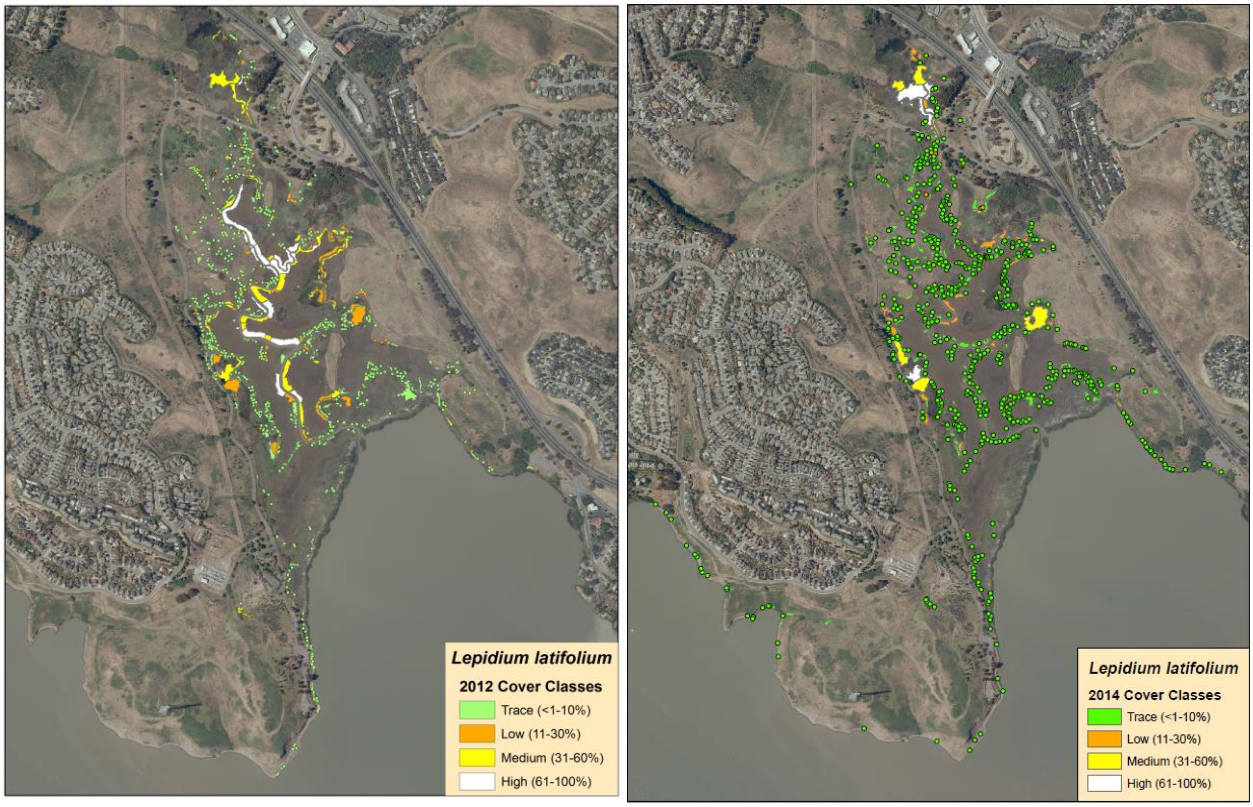
Herbicide treatment of pepperweed has led to a steady reduction in the infestation in the Preserve. Total area of pepperweed in the marsh in 2012 (prior to grant initiation) was 63,369 m^2 (15.79 acres); in 2014, total area was reduced to 44,834 m^2 (11.08 acres). Treatments were most effective in the marsh-terrestrial ecotone microhabitat where pepperweed received herbicide treatment each spring. Pepperweed in the marsh-terrestrial ecotone exhibited only minimal resprouting in several areas, especially along the marsh perimeter. This was determined to be a significant, positive result of the project because the area where tidally-drained high marsh plains transition into the terrestrial ecotone (approximately mean higher high water to extreme high water) is where the highest biological diversity of native plant and animal species in the Suisun region are found, including several endangered species. Along the marsh-terrestrial ecotone, patch visibility was high and there was easy access to the patches invaded by the weed and herbicide applications were highly effective. Herbicide application to pepperweed along tidal sloughs and creeks and the bayshore in this marsh is an inherently more challenging task. The height of pepperweed is somewhat reduced in the more stressful conditions of the bayshore. The visibility of more diffuse stands of pepperweed in this area is often poor when the weed is growing among tall, dense bulrushes and cattails. In cases where pepperweed was not affected by herbicide, the individual plants or patches had been missed by applicators, rather than by potential ineffectiveness of the chemical. A major portion of pepperweed along channel edge habitat fell within the CBR conservation zone, so substantial areas of the weeds in this microhabitat were not treated for two of the three years covered in this report.

Table 1. Infested area (m^2) and percentage of total infested area of pepperweed at the marsh by cover classes the year before grant initiation (2012), and following each year of treatment (adapted from Grewell et al. 2013).

Pepperweed Cover Class	2012		2013		2014	
	m^2	%	m^2	%	m^2	%
Trace	12,784	8	20,296	44	12,616	27
Low	15,860	10	13,044	28	11,528	25
Medium	18,749	12	7,306	16	12,317	27
High	15,976	10	5,398	12	8,372	18

Data results indicate the pepperweed within the mid marsh study area has a high amount of response to the treatment, reduced from 38,051 m^2 in 2012 to 22,214 m^2 in 2014, a positive benefit to the CCR habitat existing within this area. The Bay study area showed a large decrease as well, from 13,386 m^2 in 2012 to 5,180 m^2 in 2014. This is likely due to the weakening effects of inundation on the pepperweed. The North study area actually showed an increase in area occupied by pepperweed, from 12,456 m^2 in 2012 to 17,439 m^2 in 2014, which was due to the exclusion of a majority of this area from access due to the resident CBR population. Considering the increase in the high density of the pepperweed in these patches, which compounded from 3,722 m^2 to 6,718 m^2 between 2012 and 2014, the project team re-assessed this area and methodology during the 2015 annual meeting. It was determined that the risk to the CBR due to habitat loss from conversion was higher than the risk of a two person crew accessing these areas peripherally to attempt the control of pepperweed. Cautious treatment of the edges of this area was initiated in spring 2015.

Figure 1. Geographic distribution of pepperweed presence and cover class in the Preserve 2012 (prior to grant initiation) and 2014.



The aboveground biomass and stem density of pepperweed, and the below ground reserves of non-structural carbohydrates that fuel plant resprouting were greatly reduced by backpack-spay applications of glyphosate herbicide (Grewell et al. 2013). The USDA-ARS team calculated treatment effect sizes to illustrate the practical outcome of the herbicide treatments (variation in effectiveness) by marsh study areas and invaded microhabitats. Their study results indicated the efficacy of treatment was most variable and least effective in mid-marsh areas along tidal sloughs. Hand-wick applications of glyphosate to pepperweed within 1-m of any rare plant were highly effective in killing the weed, with no observed mortality to rare plants.

In 2014, the area occupied by wild celery in the Preserve was 1,209 m^2, representing 2% of the total area infested by weeds in the marsh. It was added to the weed treatment program in 2014 and 2015.

Project Impacts on Native Plant Habitat

It was found that the cover of native species increased steadily each year. Short-term observations are reported here; community succession should to be evaluated over a longer time period. Positive responses by non-target native plant species were recorded. For example, native marsh butterweed (*Senecio hydrophilus)* grows channel-side with pepperweed. Following treatment of pepperweed, marsh butterweed

has increased in abundance and showed no herbicide damage. In the pretreatment year, a single plant of the special status plant species Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*) was observed. Two years after herbicide treatments, the research team observed a marked increase of Delta tule pea, to the point where it is now common along tidal sloughs. Other native plant species were observed to respond positively to pepperweed suppression, particularly in plants that track slough channels. Notable were increases in stands of native salt marsh fleabane (*Pluchea odorata),* yarrow (*Achillea millefolium*), marsh gumplant (*Grindelia stricta* var. *angustifolia*), western goldenrod (*Euthamia occidentalis*), and slender aster (*Symphyotrichum subulatum* var. *parviflorum*).

Figure 2. Geographic distribution of wild celery in the Preserve in 2014.

Careful and precise applications of herbicides have resulted in minimal effects on non-target native plant species (Grewell et al. 2013). For example, native *Senecio hydrophilus* (marsh butterweed) is closely associated with pepperweed, and was present and blooming during herbicide applications. Following treatment, the *S. hydrophilus* stands were apparent with their spectacular blooms and showed no herbicide damage. Other native plant species were observed to respond positively to pepperweed suppression, particularly in plants that track slough channels, emerge late, and bloom in late summer or fall. Notable were increases in stands of native *Pluchea odorata* (salt marsh fleabane*), Achillea millefolium* (yarrow), *Grindelia stricta* var. *angustifolia* (marsh gumplant), *Euthamia occidentalis* (western goldenrod), and *Symphyotrichum subulatum* var. *parviflorum* (annual aster/slender aster) that were present in greater abundance at BSRA than has been observed since before *pepperweed* invaded and became dominant in this marsh.

Project Impacts on Soft Bird's Beak Population

USDA-ARS research team scientists used GPS-based technology to annually assess the marshwide distribution and abundance of perennial pepperweed and endangered soft bird's-beak to prioritize weed treatments, provide information for adaptive management decisions, and to establish and annually update rare plant protection zones for stratified management approaches.

The distribution of *Chloropyron molle* subsp. *molle* decreased from an occupied area of 15,185 m^2 in 2012 to 11,311 m^2 in 2014. The recent decline in soft bird's beak was observed primarily in the upland edge habitat sections of the marsh and the drier sections of the marsh plain. There were more unoccupied patches than observed in previous years; most 2014 unoccupied patches were individual points that were previously

composed of < ten individual plants each. In addition, several polygons that had merged in previous years contracted in 2014 back into separate smaller polygons. Even with this decrease, the 2014 occupied area was still greater than observed in 2009 or 2010, and the population size observed in spring 2013 is the largest population of *C. m.* subsp. *molle* ever recorded at this location, 16,696 m^2.

With adjustments to the rare plant protection zones ('red' zones) each year, DPR was able to apply herbicide to pepperweed in close proximity to *C. m.* subsp. *molle* with no visible herbicide damage to the rare plants. Throughout the project the research team has carefully monitored these rare plant protection zones, and have not detected any mortality of the endangered plants relative to the weed management actions, but several invasive weeds were found growing with the soft bird's beak that may need future control actions, including fathen (*Atriplex prostrata*), Rabbitsfoot grass (*Polypogon monspeliensis*), *and* Black rush (*Juncus gerardii); Lepidium latifolium* was initially the most frequent invasive species that co-occurred with soft bird's-beak (Grewell et al. 2013).

Figure 3. Geographic distribution of endangered soft bird's-beak (*Chloropyron molle* subsp. *molle*) based on (A) presence and (B) size (log abundance) classes in 2012 and 2014.

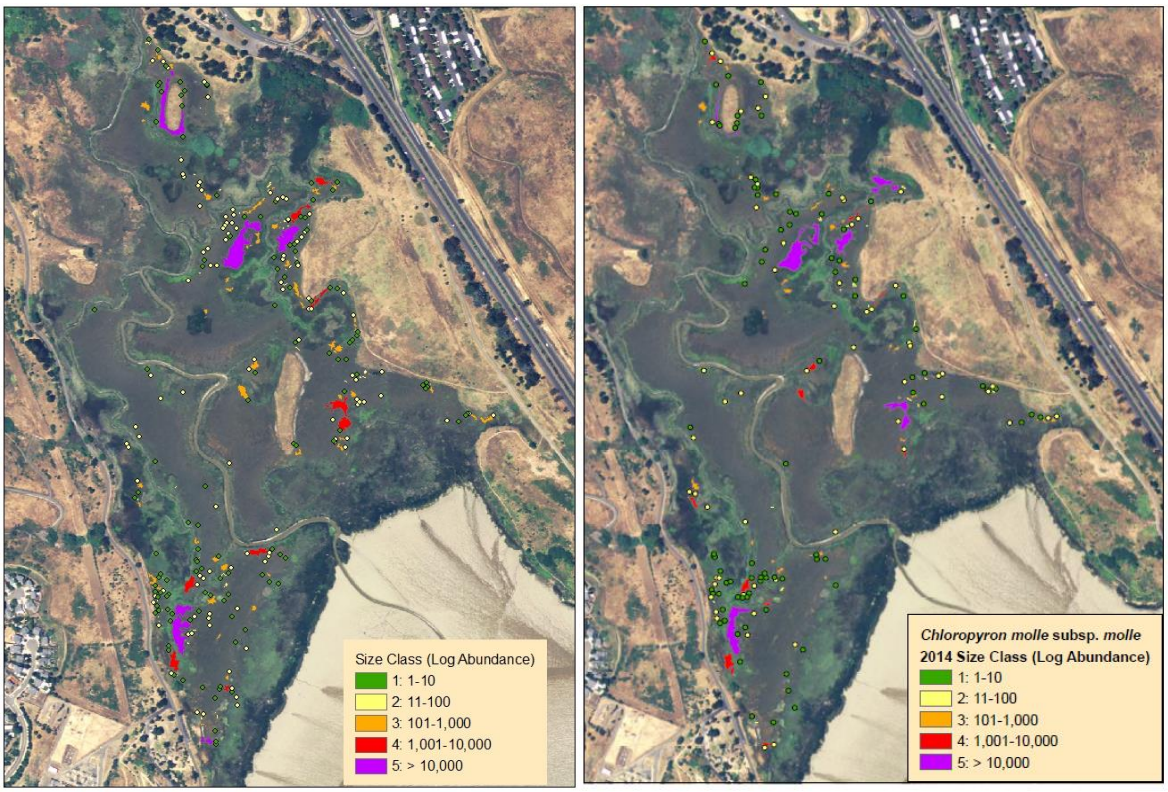


Table 2. Summary of the number of sub-population patches of *Chloropyron molle* ssp. *molle* that were occupied in year prior to grant initiation, newly colonized (new) or no longer present (unoccupied) in subsequent survey years, patches that grew together and merged into one (included), and the total number of patches (total) and total occupied area each year since grant initiation (2012-2014) (from Grewell et al. 2013, and Grewell pers. comm. 2014, 2015).

Year	Occupied	New	Unoccupied	Included	Total	Total Area (m^2)
2012	344	73	27	175	546	15,185
2013	283	26	77	212	572	16,696
2014	259	16	196	133	588	11,311

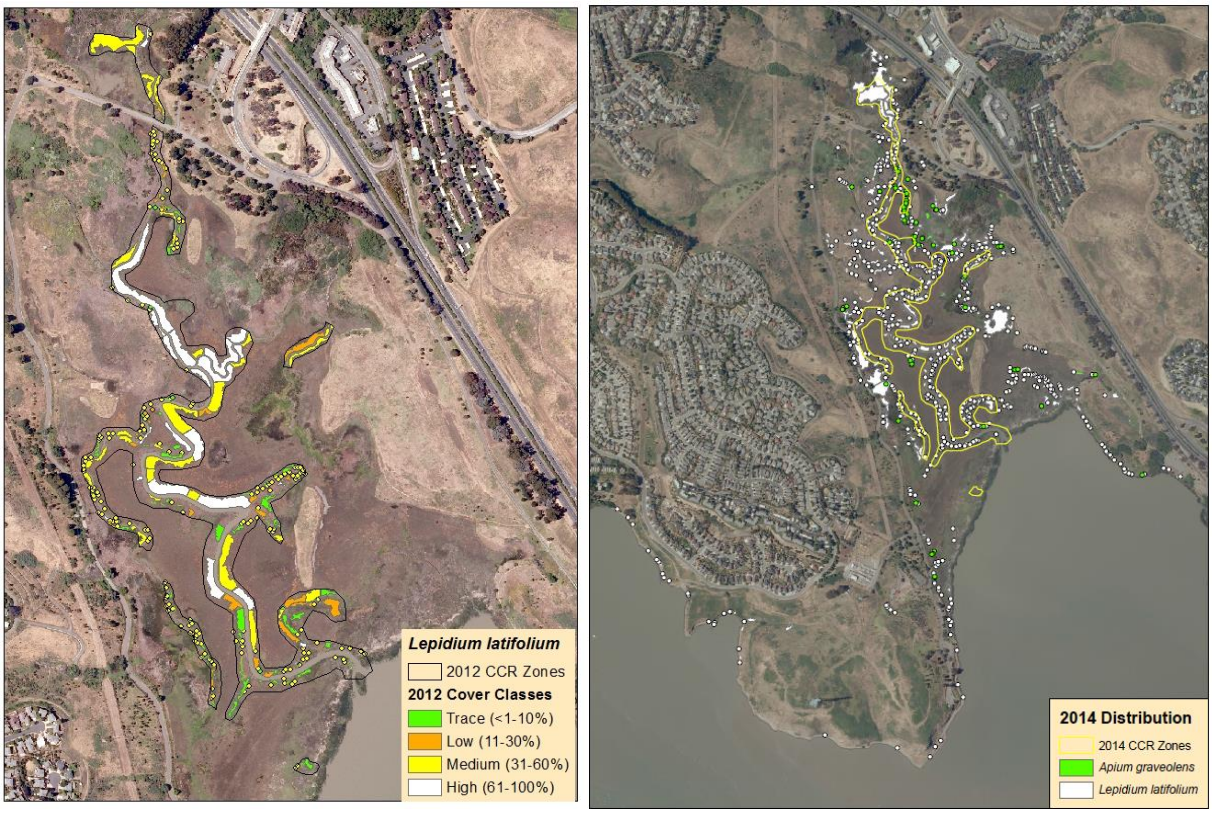
During a portion of this grant cycle, but NOT funded by this grant, to improve weed management success, the USDA researchers tracked the phenology and growth of pepperweed relative to the timing of herbicide applications, evaluated the efficacy of backpack-spray herbicide applications, resprouting capacity of the weed, efficacy of hand-wick herbicide application methods within 1-m of endangered plants, non-target plant community responses, and the efficacy of hand-weeding for pepperweed control in sensitive black rail (marsh bird) nesting habitat. It is important to note that this work was not funded by this agreement, but was conducted under the USDA-ARS agreement with USFWS, which was completed in 2013. For a full discussion of the phenology, efficacy and community response data, please see the Grewell et al. 2013 report.

The researchers found that hand-wick applications of glyphosate to pepperweed within 1-m of any rare plant were highly effective in killing the weed, with no observed mortality to rare plants (Grewell et al. 2013). There was an average decrease of pepperweed biomass in response to manual removal in the sensitive black rail habitat areas after rail breeding season, though the overall cover of pepperweed did not change markedly in these areas and an increase in overall spread of the weed was observed (Grewell et al. 2013).

Project Impacts on Rare Avian Species Habitat

Inside the CCR zone, it was observed that areas of high cover class of pepperweed was reduced from 25% of the total CCR zone area in 2012 to 15% of the area in 2014. Inside the CBR zone, it was observed that areas of high cover class of pepperweed increased reduced from 0% of the total CCR zone area in 2012 to 19% of the area in 2014.

Figure 4. Infested area and percentage of total infested area of pepperweed at the marsh by cover classes [trace (<1-10%), low (11-30%), medium (31%-60%), high (61-100%)] within and outside of the California Ridgway Rail conservation zone for years 2012-2014.



Non-Target Impacts

Localized non-target damage has not been reported onsite since 2012.

Secondary Invaders

The extensive research provided by the USDA team has allowed DPR to begin fine tuning an approach to integrate the treatment of secondary invaders in the marsh. USDA began mapping the distribution of all primary secondary invaders in the marsh in 2013 to provide background for a comprehensive weed management approach. DPR has learned that these secondary invaders need to be continually tracked and evaluated for treatment based on degree of risk to the rare plant and animal species and associated native communities on site.

High risk invaders observed in the Preserve have included *Spartina patens* (salt-meadow cordgrass), *Juncus gerardii*, *Polypogon monspeliensis, Phragmites australis* subsp. *australis (*non-native form of common reed*),* and *Apium graveolens* (wild celery*).* DPR and the Invasive Spartina Project began a new control program for the *S. patens* in the marsh. In addition, in 2014 DPR began treating wild celery in the marsh as part of the annual weed management program.

Weed Management Program Improvements

DPR's weed management program in the marsh has greatly improved during the course of this project, due to continued increases in understanding regarding the utility of a select specialized and engaged project management team. DPR has learned that effective herbicide treatment can be accomplished in a conservation zone when there is a coordinated effort between project managers, avian experts, and the weed management team to time the clearance and treatment actions to move efficiently through the conservation zone. Through this interactive management model, DPR was prompted to change how the project has been implemented over time to maximize the effectiveness of the control efforts. The recommendations to stratify the marsh by endangered species protection zones, treat the weed populations in various zones based on leaf area/weed phenology, and vary application methods as needed to avoid impacts to endangered species were direct products of the work done by the USDA-ARS team and insights from project team specialists on a daily basis. In addition, DPR learned that treatment approaches may evolve year to year in response to the changing character of the infestations and key species distributions, or to incorporate new methods that improve efficacy and efficiency.

DPR is confident that the project approach and results shown to date would not have been remotely possible without the knowledge, data, and experienced guidance provided by the project team members. Costs have been reduced each year by fine tuning field activities. Although there has been a large reduction in pepperweed density, herbicide applicators are still required to go through the entire infestation area of the marsh, so the increase in productivity is less related to weed population reduction than an increase in electronic data guiding treatment activities and focused project planning regarding access, sensitive species avoidance directives, and scheduling guidelines, such as the inclusion of consecutive days of treatment, consistent field presence by the West Coast Wildlands field manager, and consistent engagement and presence by DPR staff, the importance of which has been overlooked in the past.

Weed Management Program - Lessons Learned

The project process has become more streamlined year by year, but the DPR staffing levels make it near impossible to provide constant project manager oversight of all activities and decisions. Therefore, the chain of communication, project restrictions and expectations, and team member roles and responsibilities must be clearly communicated to allow for the conservation measures to be consistently enforced during marsh access.

Weed management efforts need to prioritize the treatment of black rush. This invasive species is spreading beyond BSRA; it has invaded the Martinez regional shoreline marsh, Point Pinole, in the tidal wetland in Benicia by the marina. The distribution increased by 5% from 2013 to 2014, occupying an area of 8,541 square meters in the marsh. DPR needs to act on controlling this species in the Preserve to ensure that State Parks property is not acting as a propagule source for offsite invasion in San Francisco Estuary, and was remiss in omitting this target weed from the 2014 and 2015 program.

Conclusion

Overall, this project has continued to reduce the presence of numerous invasive plants in the tidal wetland within the Preserve, increasing habitat availability and biodiversity in the marsh. The project is set to become a regional model demonstrating the benefits of integrating expert guided adaptive management with careful, precise strategizing and implementation to tackle invasive plants in highly sensitive ecosystems.

References

Grewell, B.J., C.J. Futrell and M.J. Skaer. 2013. Ecologically based adaptive management of invasive *Lepidium latifolium* for endangered species and tidal marsh recovery at Southampton Bay Wetland Natural Preserve in the San Francisco Estuary. USDA-ARS Exotic & Invasive Weeds Research Unit, University of California-Davis report to: U.S. Fish and Wildlife Service Endangered Species Division, Recovery Branch, Sacramento, CA; California Department of Parks & Recreation, Diablo Vista District, Petaluma, CA; and California Department of Fish & Wildlife Habitat Conservation Planning Branch, Sacramento, CA.

APPENDIX A

ENVIRONMENTAL TRAINING – BENICIA SRA TIDAL MARSH RECOVERY PROJECT 2015

Overview

- This park unit contains a 210 acre Preserve which supports a highly sensitive tidal marsh community.
- The preserve is not open to public access.
- State Parks tightly manages all restoration and academic access. Only two projects and one ongoing avian study are allowed access to the marsh.
- Anytime anyone enters the marsh there is an impact.
- Project goals include tidal marsh species protection/enhancement through weed suppression (perennial pepperweed, spartina patens, and wild celery). See Figure 1 for weed locations from 2014. Shapefiles of these 2014 weed locations have been provided to guide fieldwork – ensure all of the updated files are loaded on the mappers prior to work initiation in the marsh!

Marsh ecology

- The Preserve contains many microhabitats which differ according to elevation, inundation, salinity, vegetative structure.
  - Marsh plains are lower elevation areas under high tidal flux inundation which support pickleweed, saltgrass, and other low to medium height saline vegetation.
  - Tidal slough edges are mid elevation areas on the banks of permanent, tidally influenced sloughs and channels which support grindelia and Delta tule pea
  - Upland edge areas are mid to higher elevation areas which tend towards drier conditions.
- Endangered plant and animal species occur in all microhabitats. When present in the marsh, always assess what type of microhabitat is present around you and be highly focused on the protection measures for species located within these habitat types.

Project Biological Concerns and Species Protection Measures

- The project area contains federal and State listed avian and rare plant species. See photos sheet for species images.
- Endangered Species Act compliance agreements require impact avoidance to all associated nesting/refuge/host community habitat, directed by endangered species protection zones established by tidal marsh ecology and species experts.
- Compliance will be achieved by restricting access paths by vegetation type/structure, using specialized herbicide applications while in close proximity to rare plants, obtaining daily avian clearance surveys ahead of herbicide work done in certain habitat zones, and requiring complete access exclusion in others.
- Shapefiles of the protection zones and understanding of the habitat surrounding you will guide fieldwork – ensure all of the updated files are loaded on the mappers prior to work initiation in the marsh!
- Strict care should be taken to avoid the creating new trails which could be used by predators, such as the common raven, to access these fragile species and their nests

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- In all areas of the marsh, this project requires attention to habitat type in the field and careful evaluation of plant species targeted by herbicide prior to application. When in doubt, stop work activities and ask your field supervisor for assistance with species.

Avian species

- CA Ridgeway Rail (CRR)
    - Risks are abandonment due to noise disturbance and predation
    - Generally prefer tidal slough edge habitat type. Habitat areas depicted in Figure 2 and in shapefiles. Locations where target weeds occur within CRR habitat are depicted in Figure3.
    - Access into these areas is allowed only immediately following a survey by avian experts clearing the area for CRR presence. Once an area is cleared, spray crew personnel may enter the habitat zone to treat. Clearances are good for 24 hours only.
    - Small teams only to reduce trail creation for predators
    - If a RR is observed, exit the marsh immediately
- Ca Black Rail (CBR)
    - Risks are abandonment due to noise disturbance and trampling
    - CBR can utilize all habitat types – they are found within areas containing a certain vegetative STRUCTURE - tall pickleweed stands, three-square, tule, or bulrush patches. See photo sheet for examples.
    - Approximate habitat areas depicted in shapefiles, but actual boundaries vary annually based on environmental conditions (e.g. climate, precipitation, etc). Both shapefiles AND diligence in the field is required to protect this species.
    - CBR habitat shall be avoided during treatment and access to the utmost extent possible; access to the marsh should occur through open areas with low growing vegetation, with the exception of:
        - Pepperweed and celery treatment in CBR habitat will occur in the patches north of Dillon Point Road, in the northwest marsh area, and
        - Spartina patens treatment in the CBR habitat will occur within the pre-approved locations depicted in Figure 4.
    - If a CBR is observed, leave the area immediately
    - Other bird species “of special concern" that nest in them marsh include Suisun Song Sparrow and Common Yellowthroat

Salt Marsh harvest Mouse

- Risk is death or injury due to trampling
- Mouse utilizes marsh plain/pickleweed habitat type
- Protection measures include abiding by the Walking in the Marsh protocol (attached) and being careful where steps are placed in this habitat type.

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Rare Plant Species - Soft Birds Beak (SBB)

- Risks are trampling and accidental herbicide application
- SBB is a hemiparastitic plant which survives on host plants. Occurs throughout the marsh, in tidally drained marsh plain habitats and along lower edge natural levees adjacent to tidal sloughs.
- Known SBB distribution depicted in Figure 5 and in shapefiles.
- Target weeds within 3 feet (1 meter) of SBB patches will be hand wicked – these areas are called red zones, depicted in Figure 6.
- If a SBB is observed, completely avoid
- Tread with care!

Walk in open marsh plain locations when possible, look carefully at application target, follow protection zones, and BE SAFE ☺