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

STATUS REPORT
SPARTINA ERADICATION, HUMBOLDT BAY NATIONAL WILDLIFE REFUGE
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SUMMARY

Invasive dense-flowered cordgrass (*Spartina densiflora*) has had a major impact on Humboldt Bay, where it has come to dominate the salt marsh since its introduction in the 1800s. Although acknowledged as a serious ecological threat since the 1980s, managers have been unable to initiate meaningful control because the only method presumed to be effective for a rhizomatous perennial—chemical control—has been highly controversial and vociferously opposed by the community. However, between 2004 and 2006, with funding from the State Coastal Conservancy, staff at Humboldt Bay National Wildlife Refuge developed a successful manual/mechanical method of control. In a pilot project on a 4-acre salt marsh island on the Mad River Slough, we used a combination of repeated mowing (corded weed eaters, mowing to base of plant) in dense areas and digging (to remove short rhizomes) in sparse areas, and attained virtually 100% eradication, with high levels of unassisted native species recovery and no recruitment of new seedlings. Based on this success, the U.S. Fish and Wildlife Service and the Coastal Conservancy jointly funded a larger-scale pilot project on the mainland salt marsh at the Lanphere dunes beginning in January 2007.

During the course of this 2-year project, an adaptive approach led to the development of a more efficient methodology using metal-bladed weed-eaters and cutting below the root crown, which required fewer treatments. We also learned that the mainland salt marsh responded differently than the island salt marsh, with repeated flushes of new seedling recruitment. Methods were developed to eradicate seedlings, using propane torches or weedeaters depending on seedling size and density. We also experimented with revegetation using plugs of native plants. We expected revegetation to be a necessary step, given the larger scale of the project and the large openings created in areas of very dense *Spartina*. Although revegetation was highly successful, preliminary results indicate that it may not be a necessary step in the restoration process except for the purpose of increasing species diversity.

The project demonstrates that *Spartina densiflora* can be eradicated using mechanical methods, and that the salt marsh is able to advance substantially along a trajectory of recovery by native plants in only 2 years. The project also demonstrates that restoration will require ongoing removal of new seedling recruits over time. For this reason, a major conclusion of the study is that regional eradication of *S. densiflora* is needed in order to achieve sustained eradication. Although a relatively small area such as the 15-acre area restored through this study could conceivably be maintained through ongoing seedling treatments, the size of the restored area would restrict full ecosystem functioning. Large scale restoration is needed to restore estuarine ecosystem services, but may not be feasible unless seedling recruitment is eliminated through regional eradication of the species.

METHODS

Mapping. The project was initiated in August 2006 with FWS Challenge Cost Share funding, and continued through August 2008, with matching SCC funding. All work was carried out on the Lanphere and Ma-le'l Units of Humboldt Bay NWR. Mapping was carried out initially to facilitate control efforts and serve as a baseline (Fig. 1). All salt marshes within the two units were surveyed and mapped with the exception of the island salt marsh previously subject to control during the 2004-2006 project, and the large island in the Mad River Slough, of which FWS owns only a portion. Control on this island was not deemed feasible due to the influence of *Spartina* from adjoining uncontrolled areas not under our ownership. Occurrences of *Spartina* were mapped on the ground using a Trimble GeoXT. Mapping relied on a combination of polygons for continuous occurrences, lines for linear occurrences, and points for isolated occurrences. All polygon boundaries and linear occurrences were walked. All mapped features were attributed with cover/abundance data consisting of 3 cover classes: stunted plants (generally occurring on high elevation islands), patches of less than 60% cover, and dense patches of greater than 60% cover. The cover classes were linked to the expectation (based on the pilot project) that digging treatments would be applied to stunted plants, while mowing would be applied to all other occurrences. The distinction between greater and less than 60% cover was used to facilitate estimation of labor needs. Mapped *Spartina* by cover class and type of occurrence is shown in Table 1. Approximately 30 acres of *Spartina* occur within the mapped portions of the unit.

Table 1. Number of isolated occurrences, and acreage of linear and continuous occurrences of *Spartina* within the Lanphere and Ma-le'l units (*acreage of linear occurrences assumes an average width of 3 ft.; see map for excluded areas)

Type of occurrence	*Cover Class*	*No. of occurrences*	***Acres***
Isolated	Stunted	3	
	<60%	36	
	>60%	87	
	SUBTOTAL	**126**	
Linear	Stunted		.01
	<60%		.05
	>60%		.12
	SUBTOTAL		**0.2***
Continuous	Stunted		0.4
	<60%		25.2
	>60%		3.2
	SUBTOTAL		**28.8**
TOTAL			**30.0**

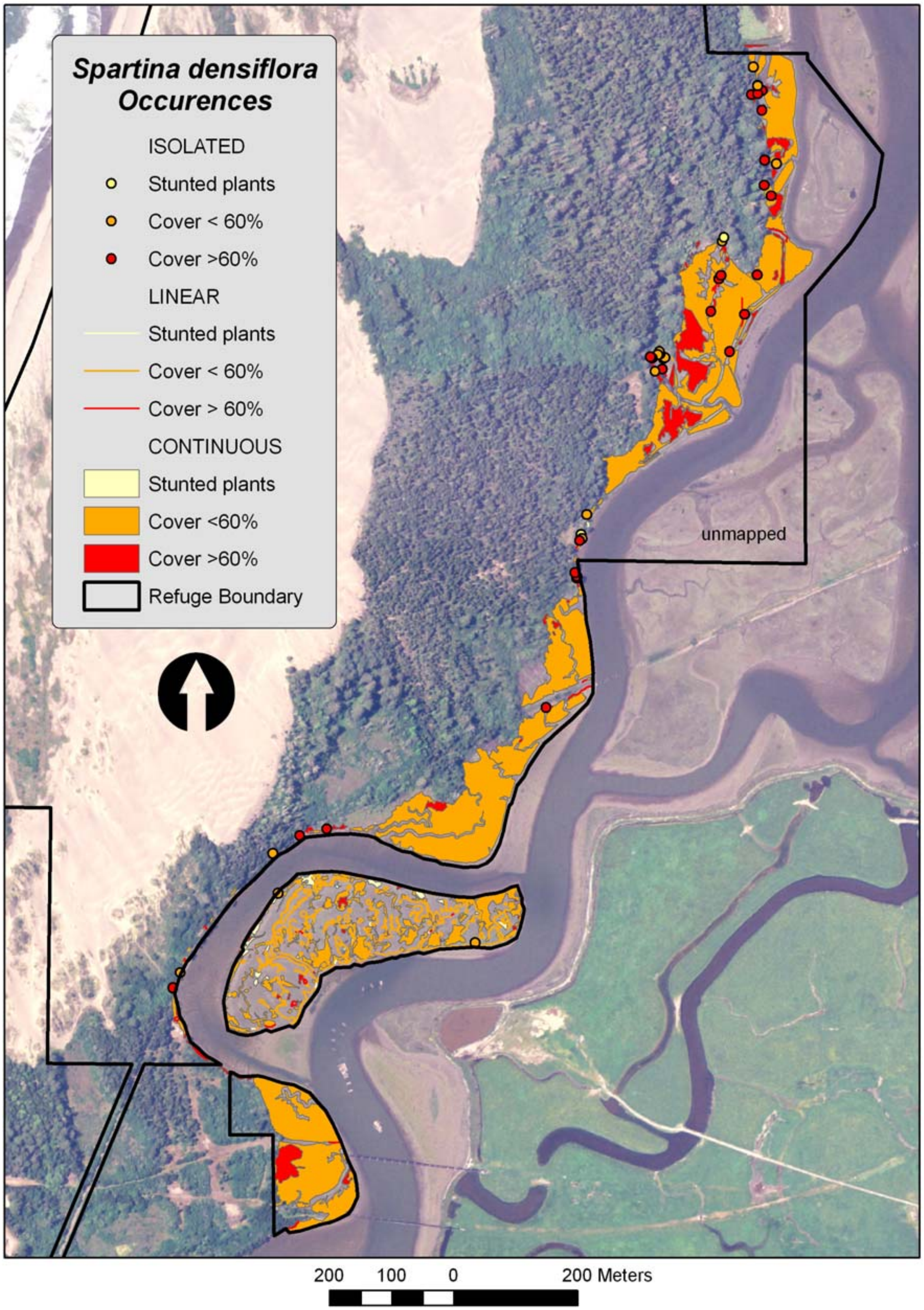

Figure 1. Results of mapping.

Figure 2. Mower with two-stroke metal-bladed weedeater.

Mowing. Initially mowing methods were based on those used on the smaller island site, and consisted of a corded weed eater, with plants severed at the base. The field crew quickly found that the cords were inadequate for the size and amount of mowing done in the larger areas, and switched to a metal-bladed weed eater. After experimenting with this method, the crew found that actually cutting into the mud at an angle slightly below the base of the plant resulted in faster mortality, and this method was used over most of the project area after the first few weeks (Fig. 2). After initial mowing, dead material is raked into haystacks and burned. Following initial mowing in very dense areas of *Spartina*, a bare mud stage occurred over the first winter and in some places persisted into the second growing season. Algal mats quickly colonized the bare mud (Fig. 3). Our monitoring measured the extent of algal colonization but did not identify algal species or functional groups. A new study is examining the succession and role of algae and diatoms in a newly mowed area.

Figure 3. Algal mats covering a mowed area of previously dense *Spartina*.

Between August 2006 and September 2008, a total of 15 acres of salt marsh covered by *Spartina* of varying densities was mowed multiple times. At the end of this time resprouts were reduced to very low numbers (quantitative monitoring results have not yet been analyzed). In our previous pilot study, 4 acres were restored on an adjacent island. An additional 5 acres have received a complete first mowing treatment, and the first treatment is in progress over 5 remaining acres (Fig. 4).

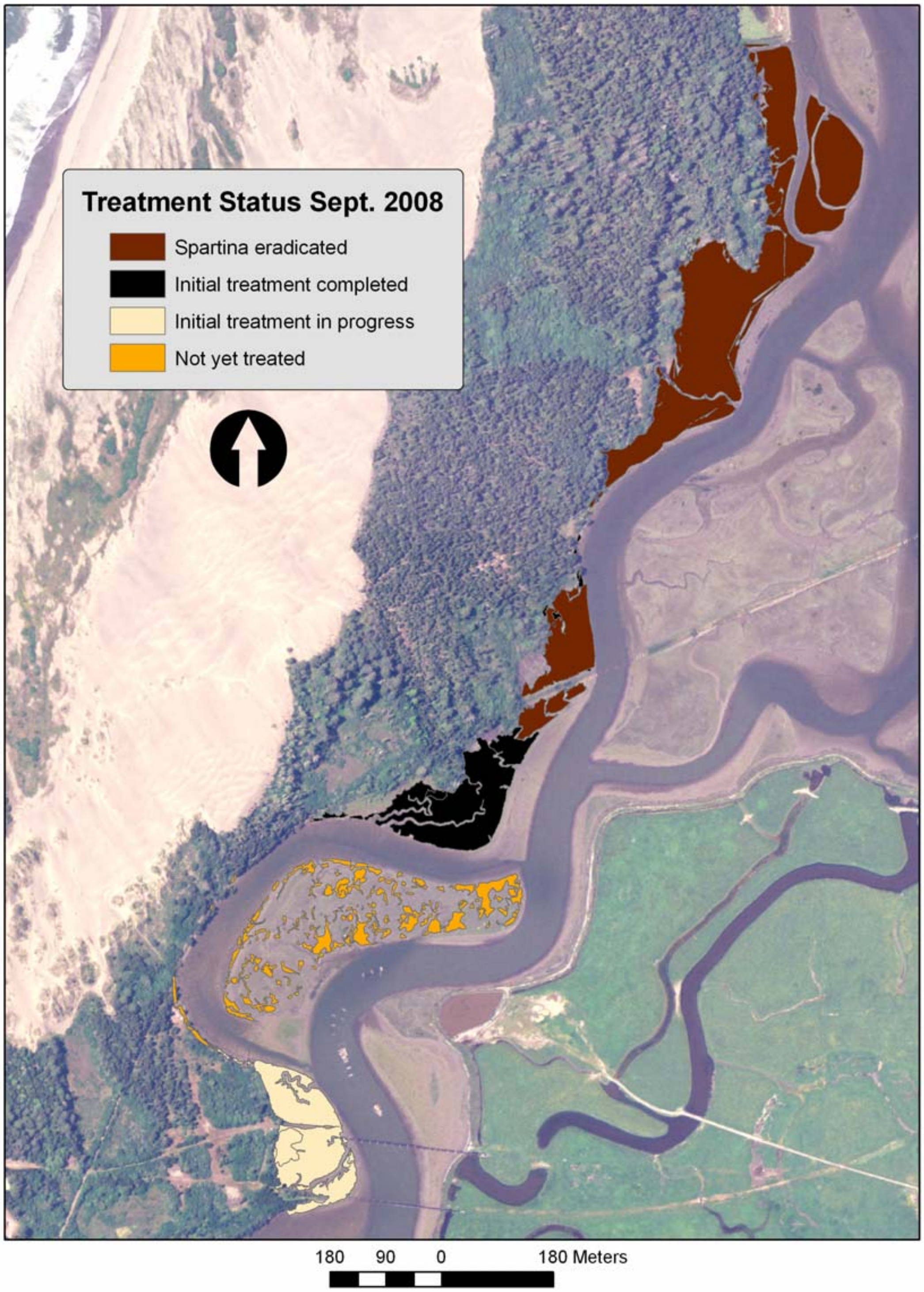

Figure 4. Status of treatment as of September 2008.

Seedling Treatment. The emergence of seedlings after treatment was unexpected based on the smaller island pilot project. Possibly, the fresh water input on the mainland compared with the island marshes resulted in more seedling emergence. Alternatively or in combination, the greater elevation of the island caused more prolonged exposure and suppressed seedling emergence. Seedlings first appeared in March 2007, covering large expanses of algal-covered mud resulting from mowing. Monitoring revealed that seedling emergence was correlated positively with algal cover (r^2=.70), and bare mud (.20) and negatively correlated with native plant cover including *Distichlis spicata* (-.60), *Sarcocornia pacifica* (-.20) and *Jaumea carnosa* (-.20) ($p<.05$). Although no causative relationship can be concluded, it is possible that algal cover ameliorated conditions for seedlings while native plants suppressed emergence through shading or resource competition.

The first seedling flush occurred in relatively bare areas and was treated using propane torches (Fig. 5). Seedlings were easily desiccated and killed, and where native plants couldn't be avoided it was observed that they were not always killed by the

Figure 5. Members of High Rock conservation camp flaming *Spartina* seedlings in Spring 2007..

treatment (especially the succulent *Sarcocornia*). At the time of the seedling emergence in March, a total of 8 acres of salt marsh had been treated, and removal of seedlings took up significant resources, although the availability of California Department of Forestry and Fire Protection crews reduced the cost considerably.

Seedlings again emerged in the fall of 2007. At this point, there was much native recovery in areas affected by seedlings, so rather than flaming, seedlings were removed with weedeaters. This resulted in a set-back in the recovery of native plants and added to the cost of the project.

Surprisingly, there were no seedlings in the Spring of 2008 despite abundant rains (nor had any emerged in the beginning of the study in Fall 2006). In September 2008 seedlings again appeared following late summer rains. However, with native vegetation recovery far advanced, seedlings were far less numerous and the labor required to mow them was much less significant than in the past, even through the time required to search out individual seedlings increased.

The pattern of seedling emergence was difficult to interpret. Furthermore, it isn't known whether the species has a persistent seed bank and whether seeds were dispersing onto the site from adjacent populations, emerging from a seedbank, or both. Further research is planned in this area.

Revegetation. Although the pilot project did not indicate a need for revegetation, we expected that the larger areas affected in this project would result in persistent bare areas requiring revegetation. In Dec. 2007 we began experimenting with revegetation methods. Plugs of native *Distichlis spicata* and *Sarcocornia pacifica* were collected from a site on the Salmon Creek Unit of HBNWR where restoration of Salmon Creek flows were expected to create unsuitable conditions of elevation and salinity for existing salt marsh vegetation that had formed in a subsided area previously behind leaking dikes. Various collection methods were tried, with the most efficient being the removal of large blocks of salt marsh vegetation with an excavator (Fig. 6). These blocks were then loaded into a pickup and transported to the parking area at Ma-le'l, where they were carried in a trailer pulled by an ATV along existing trails to a clearing adjacent to the salt marsh. At this staging area, blocks were cut into small plugs (approximately 4-6" on a side) and covered

Figure 6. Blocks of *Distichlis* stockpiled before loading into truck.

with a tarp one to several days prior to planting. All planting was accomplished using volunteers. Refuge staff and contractors readied the planting areas by flagging out a grid marked with color coded pin flags to indicate species. Volunteers then carried plugs to the sites in buckets, and dug holes using narrow bladed shovels to plant plugs. At later planting dates the plugs were pre-placed to make planting easier for volunteers (Fig. 7). Revegetation was very labor intensive due to the distances from the staging area to the experimental sites. However, survivorship was over 90% for all planting dates (ranging from December to April) by September 2008.

Figure 7. Volunteers planting plugs according to color coded flags.

Native Plant Recovery. Although quantitative monitoring data have not yet been analyzed, it is qualitatively evident that most of the areas mowed were able to recolonize naturally within two years. Initially in the first spring following mowing, there was a flush of *Triglochin maritima* colonization in all areas receiving some freshwater input. Since then, *Triglochin* appears to have declined as other species, especially *Sarcocornia*, increased in cover. From the pre-restoration baseline conditions, species composition in native areas appears to have shifted in general from more *Distichlis*-dominated vegetation to *Sarcocornia*. The ability of *Sarcocornia* to rapidly colonize bare areas in restoration projects has been noted in other areas. In our revegetation plots, although both species survived, planted *Sarcocornia* now appears much more robust and/or has spread farther. In addition, new *Sarcocornia* volunteered around the plantings and has covered much of the area around the plugs. (Fig. 8). Interestingly, the planted *Sarcocornia* exhibits a much different habit from the first year plants that have volunteered. Plugs of this perennial emerged from dormancy and assumed an erect habit, while those growing from seed were more prostrate and spreading.

The shift in species composition may be beneficial, given that *Distichlis* is more prevalent than *Sarcocornia* in the native areas of Humboldt Bay's marshes. The restored area now represents an early successional stage. While we expect species composition to shift over time back to *Distichlis* in suitable elevations, we plan to introduce additional species in order to increase species richness. In the freshest areas close to springs near the edge of the marsh, species diversity is currently highest, with many brackish species present including *Triglochin, Spergularia marina, Scirpus cernuus, Lilaeopsis*

Figure 8. Erect planted *Sarcocornia* surrounded by prostrate volunteers in an experimental revegetation area.

occidentalis, and *Juncus lesueurii*. In the first and second spring seasons following treatment, we saw very high numbers of the rare salt marsh hemiparasitic annuals *Castilleja ambigua* ssp. *humboldtiensis* and *Corydlanthus maritmus* ssp. *palustris*. Monitoring and mapping carried out for these species will allow us to correlate their success with treatment, and we plan future studies that will more directly address impacts of *Spartina* removal on these species.

We have collected soil samples and elevation data from revegetated as well as unplanted control areas. These data will allow us to elucidate patterns in recovery of native species and will help to guide future revegetation efforts. Although much of the area has revegetated naturally, there are relatively small, localized areas of apparently highly anoxic conditions which consist of bare mud covered with at thick algal layer.

Analysis of existing data along with future research should help to determine limiting conditions and suggest strategies for recovering these areas.

CONCLUSIONS

The project demonstrated the feasibility of using mechanical methods to eradicate mature Spartina on a scale of 20 acres. Revegetation may be needed in some areas, especially to promote species diversity. Recurring seedlings can be controlled at an initially high but decreasing cost over time. However, on a regional scale of hundreds of acres, the elimination of the seed source will be necessary to make restoration economically feasible. Additional analysis of monitoring results will allow us to refine conclusions and to estimate labor needs for the different methods involved in the project. The results of this study will be integrated with new studies now underway to refine techniques and analyze impacts of *Spartina* invasion and its removal, with the ultimate goal of regional eradication of *Spartina densiflora* from the Mad River, Eel River, and Humboldt Bay estuaries.

Rare Humboldt Bay owl’s clover in the restored marsh of the 2004-6 pilot project.