OBSERVATIONS ON THE SPREAD AND CONTROL OF *SPARTINA ALTERNIFLORA* IN WILLAPA BAY

Summary report of the San Francisco Bay Invasive Spartina Control Project
Field Trip to Willapa Bay, 16-18 July 2003

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Staff of the San Francisco Estuary Invasive *Spartina* Project (ISP) visited Willapa Bay, Washington in July 2003 to observe that area's non-native *Spartina* infestation and the treatment methods being used there[1]. The purpose of this report is to summarize staff's observations, and to present insights, conclusions, and recommendations for the (ISP) based on that visit.

I. Environmental Setting

The marsh and mudflat setting of Willapa Bay differs from San Francisco Bay in some significant aspects.

Willapa Bay's **western shore** is the back of a very large, old, multiple-ridge barrier beach (sand spit). It slopes gently, and normally has very low incident wave energy dissipated over very wide intertidal flats. Drainage patterns and tidal channels are only slightly developed. Most *Spartina alterniflora* salt marsh is a narrow and irregular fringe along the shore, formed over silty flats on a sandy foundation. Native salt/brackish marsh is scarce

[1] The trip was hosted by hosted by Kim Patten, Washington State University, Long Beach Research and Extension Unit.

and very narrow, consisting of high marsh dominated variably by hairgrass (*Deschampsia cespitosa*), silverweed (*Potentilla anserina*), jaumea (*Jaumea carnosa*), saltgrass (*Distichlis spicata*), gumplant (*Grindelia stricta* ssp. *stricta*, prostrate) and pickleweed (*Salicornia virginica*), with many herbs and rushes present at low abundance. The vegetation of these native marshes is *more similar to the vegetation of California's north coast stream mouth estuaries, or eastern Suisun Marsh, than San Francisco Bay*. *No sensitive plant species* appear to be associated with native marsh here. Most of the flats are hummocky (irregular microrelief), and have enough shear strength to support our walking on them. This west shore condition contrasts with the prevalence of clay-silt bay mud with very low shear strength, well-developed tidal channels, and frequently higher wave energy of central and south San Francisco Bay. We visited tidal flats and marshes at Ledbetter Point State Park, and areas near Oysterville.

The **eastern and southern shores** of Willapa Bay include numerous large river mouths that deposit significant silt loads, and support deeper, extensive *S. alterniflora* marshes. Native marsh, however, is generally limited to narrow fringes of high, peaty brackish marsh, often with relict wave-scarped edges above the cordgrass zone. Its composition is similar to the west shore, but appears to support even a higher diversity of brackish marsh species (*Aster* sp., *Carex lyngbyei, Achillea, Angelica* spp.), corresponding to the major freshwater discharges of the mainland shore. Marshes we saw on the south shore tend to form wide plains with minimal topographic relief and slope, and small, sparsely branched, sinuous channels. On the eastern shore, we observed larger, sinuous sloughs in young cordgrass marsh, but few branch sloughs, and no true pans. *All these marshes were topographically more uniform than those of San Francisco Bay*. The sediments here are fine silt or silt-clay, more like those of SF Bay than the west (barrier back) shore of Willapa Bay. We visited numerous sites from the North Bay to the Naselle River, and viewed others from the car.

Cordgrass marsh in Willapa Bay is often pure *Spartina alterniflora*. Where *S. alterniflora* marsh has undergone significant accretion, such as in southern Willapa Bay on the U.S. Fish and Wildlife Service's Willapa Bay National Wildlife Refuge, it remains in pure stands where it is intact. Where accreted *S. alterniflora* marsh has been disturbed or killed by herbicide, it undergoes colonization by some pioneer native marsh species, such as *Jaumea carnosa, Spergularia* sp., and *Salicornia virginica*, in addition to its own abundant seedlings (see below).

We observed what was possibly a single Virginia rail (*Rallus limicola*) in *S. alterniflora* marsh at one northeastern Willapa Bay site, flushed by the operation of the MarshMaster. Since *S. alterniflora* marsh is a new habitat in Washington, this may represent a habitat expansion for the species.

II. Herbicide Treatments

Treatment Efficacy Versus "Control" at a Population Level

Most of the experimental research (K. Patten) and field trials (multiple resource agencies) of herbicide treatments along the western and south shores of Willapa Bay experienced very rapid and vigorous recolonization by seedlings of *Spartina* control work. Regardless

of the efficacy of treatment (% mortality of standing vegetation), most plots were extensively recolonized within less than a year, apparently by seedlings in most cases. It appeared likely that within one to two growing seasons after treatments, live shoot density and cover could approach pre-treatment levels, even with 100% mortality (completely effective treatments). In terms of experimental results, these would be reported as "complete control", but in terms of population management at a larger spatial scale, it would be misleading to refer to high treatment efficacy as "control". We learned that there is no population modeling or demographic analysis of *S. alterniflora* populations in relation to any treatments, or post-treatment conditions. At a regional (metapopulation) scale, there is currently no scientific guidance to estimate the rates of treatment (acreage/year) needed to achieve net regional population decline of *S. alterniflora*. We discussed the possibility of finite annual treatments in a "seed saturation" scenario that could result in the equivalent of "cropping" *S. alterniflora*, rather than population control. There are no plans to cover this scientific gap.

Prof. Patten and we observed differences in seedling recruitment in plots with residual roughness from standing dead stems, versus bare plots. There are no data yet available on the effect of varying densities of standing dead shoots on *S. alterniflora* seedling microhabitat or recruitment rates. This would be very relevant for San Francisco Bay. One of the principal contrasts we observed between herbicide treatment and mechanical treatments (such as rolling/crushing) is the residual degree of surface roughness.

Efficiency and Advantages of Imazapyr

Prof. Patten pointed out striking differences in imazapyr results compared with glyphosate. Although high mortality could be achieved rapidly with very high concentrations of glyphosate, glyphosate effects were most sensitive to "dry time" (post-spray time before tidal immersion, duration and % leaf canopy left emergent in tidal cycle following treatment) and to a lesser degree, to sediment films. Many glyphosate treatments left uneven results at small spatial scales, relative to the annual growth rate of cordgrass rhizomes. In many treatments, the survivors of glyphosate treatments would have the opportunity to recolonize herbicide-killed gaps within a single growing season, unless retreated. In comparison, imazapyr treatments were generally highly effective (100% mortality or nearly so in the entire plot) even with brief drying times and limited spray contact with foliage (coverage). Imazapyr is slow-acting in comparison with glyphosate (delayed symptoms, often not apparent until late in the growing season or following growing season), but more effective under a wide range of circumstances and concentrations.

Pure imazapyr, like glyphosate, is reported to have extremely low toxicity to wildlife. It is, however, not stabilized by contact with sediment, and is mobile in soil and groundwater. It is also relatively persistent and physiologically active after contact with plants and soil, so drift effects or non-target effects may be greater than glyphosate. There are no sensitive plant species in or adjacent to cordgrass in Willapa Bay, at least not to our knowledge or Prof. Patten's. We believe imazapyr use may be most applicable to San Francisco Bay treatment sites in the low marsh or mudflat, where drying times (favorable tides) and sediment films on foliage are major limiting factors for treatment efficacy. No other plant genera are present in the low marsh zone in San Francisco Bay, so nontarget plant injury would be avoided. It may be most constrained in the high marsh (*S. patens*, *S. densiflora*), where plant diversity and sensitive plant species and wildlife habitats may be more vulnerable to effects of drift or mobility.

We learned that EPA approval of imazapyr use for estuarine use in Washington was pending, and imminent. The approval process involved NEPA (EIS) and equivalent state environmental quality laws. We discussed the possibility of "coat-tailing" or adopting a similar approval process for California estuarine use, because the basic ecotoxicity analysis has already been accomplished. The surrogate test organisms for the Pacific Northwest estuaries would generally be applicable to San Francisco Bay, since we used these in our own Program EIS/R covering glyphosate effects. We recommend investigation of possible California registration of imazapyr for use in San Francisco Bay.

III. Mechanical Treatment Methods and Equipment

Environmental Setting and Treatment Effects

The effects of crushing or disking were difficult to compare among subregions of Willapa Bay, because variable amounts of time had elapsed between treatment and our visit. The following interpretation, therefore, is tentative.

We observed that on the relatively well-drained, gently sloping, irregular topography of the (sand subsurface) west shore marshes, that mechanical treatments were rapidly recolonized by *S. alterniflora*, as were most herbicide-treated plots. Seedling growth was generally rapid and vigorous, and soil conditions were usually favorable for growth and

germination (gray-brown, aerobic sediment surface layer 1 – 3 cm in depth). We observed that in areas of poor drainage (seeps or surface sheetflow, indicated by black, sulfidic, anoxic sediment less than 1 mm below the aerated surface), seedling densities and seedling sizes were reduced, or seedlings were absent. Most of the gently sloping flats here were surface-drained, and seeps and waterlogged drainages were a small percent of the total surface.

In contrast, the northeastern marshes we visited (active MarshMaster crushing in progress), were essentially planar, lacking a gradient, and traversed by sinuous sloughs. Their substrate was uniformly fine-grained silt and clay. The equipment operator reported that within three days of crushing above-ground cordgrass canopy, the surface muds shift from gray-brown to deep black. This reported observation would be consistent with elimination of gas transport through stems to roots in aerenchyma (spongy air channels of stems). The surface of MarshMaster-treated sites on the planar marshes became pan-like, subject to shallow puddling and surface anoxia. Erik was able to walk ankle-deep in the puddled mud surface, so the substrate was well-consolidated. The equipment operator reported visible leaf necrosis (burn) due to contact of black mud splashed on live leaves, and enhanced mortality where black mud covered flattened shoots. This observed phenomenon would be consistent with toxic levels of hydrogen sulfide in the black mud.

Based on these observations, we hypothesize that sustained high to extreme waterlogged sediment (high sulfide levels) following crushing of cordgrass vegetation may be an important component the treatment effect. It may also be a significant factor in the sustained suppression of regeneration from rhizomes, and sustained inhibition of cordgrass seedling germination and establishment. We recommend that this particular mechanism of crushing be investigated further, because it may be dependent more on the environmental setting than the type of equipment or technique used. If marsh drainage conditions may affect the efficacy of this method (especially effects on regeneration and recolonization) in invaded San Francisco Bay salt marshes, we may expect more limited application for this method in San Francisco Bay, especially in areas of relatively high drainage density (creek density). If severe soil anoxia is essential to the most effective application of this method, then the few types of San Francisco Bay wetland environments likely to be able to physically support the equipment used (mature, well-drained marsh, sandy tidal flats) may be least conducive to development of toxic, waterlogged soil conditions following crushing.

The equipment operator described in detail past observations of what he believed to be Virginia rail behavior in cordgrass marsh undergoing crushing treatment. Rails fled the path of the MarshMaster, seeking refuge (flying, running) in remaining adjacent stands of cordgrass. Concentrations of fugitive rails occur in isolated stands during crushing, with multiple rails dispersing from the last stand as equipment approaches. The extent to which the Virginia rail in Willapa Bay may be used as a surrogate for conceptual models of clapper rail behavior in treatment marshes is unknown, but it should be investigated.

Equipment Cost and Efficiency

We observed two types of tracked vehicles used for various eradication operations. They differed significantly in procurement costs, maintenance costs and 'down time' for repair.

The Washington State Department of Agriculture was using a **Marsh Master** tracked vehicle on the eastern shores of Willapa Bay to crush the wide *Spartina* meadows there. These vehicles are relatively small and lightweight (5100 lbs.; ground pressure: <1 psi), and the operators there tow a cylindrical drum with welded angle iron behind the vehicle to crush the plants between the tracks. The Marsh Master in use here was equipped with a 95 hp turbo diesel engine that was described by the operator as "more than adequate" for the work being done. Maintenance costs on the Marsh Master were described as very low, requiring one major overhaul in the 2+ years the vehicle has been in operation there. Consequently, this vehicle was able to operate throughout the year, treating that much more *Spartina* during that time.

The US Fish & Wildlife Service uses the **Quality Machine** to do both mowing and crushing work on the Spartina-infested marshes within their jurisdiction. We were unable to see the Quality Machine in operation during our visit due to mechanical difficulties. The Quality Machine in use by the USFWS was specifically designed in coordination with the manufacturer for *Spartina* control work there, and is significantly heavier than the Marsh Master (11 tons). We were told by WSDA representatives that the Quality Machine requires 're-treading' of the articulated tracks after every 300 hours of use. This regular replacement of the tracks comes at significant cost both in maintenance time and materials, as well as time absent from working in the marshes

As described above in the Environmental Setting section, the substrates upon which these two crushing operations are undertaken differ significantly enough to render direct comparisons problematic. Also, the Quality Machine used by the USFWS serves in a dual capacity as mower and crushing machine at need. The Marsh Master has the attractive quality of being easier to transport and cheaper to maintain. We were left with a general impression of the Marsh Master as being more appropriate for limited use in selected SF Estuary marshes, were crushing operations adopted as a control method by the ISP or its partners.

Ripping and Fragment Dispersal

Ripping appears to generate cohesive fragments of cordgrass sods, consisting of a mesh of rhizomes, roots, and soil. Prof. Patten showed us drift-lines of cordgrass sod jetsam near the high tide line near Oysterville (west shore), near former sites of discontinued ripping treatment tests. In later discussions with two oyster farmers with many years experience in cordgrass eradication efforts and volunteer monitoring (Dick Sheldon and son), we heard reports that cordgrass sod fragments had anchored themselves at low intertidal elevations, and established far below the lower limit of observed cordgrass seedlings and colonies. We were presented with a (recently killed) rooted, regenerated sod fragment collected by the oystermen, as an example. They reported numerous observations of rafted sod fragments as agents of pioneer colonization beyond the typical seedling zone, and they stated that they have uprooted as many. As we would expect from reports in the scientific literature covering *S. alterniflora* marsh of the Atlantic and Gulf of Mexico coasts (and *S. maritima* in s. Europe), sod and rhizome fragments of *S. alterniflora* may cause effective dispersal if they are generated. Sod fragment dispersal has been observable below the crumbling, eroding marsh peat scarps of the Hayward shoreline in San Francisco Bay (P. Baye, pers. observ.).

Topography, Spatial Scale, and Habitat Sensitivity:
Comparison with San Francisco Bay

Willapa Bay's exotic cordgrass marshes are extensive and relatively homogeneous compared with the invasion of *S. alterniflora* hybrids in San Francisco Bay. Willapa cordgrass stands are well-segregated and demarcated from native tidal marsh plant communities, and they do not occur near rare or endangered wildlife or plants. Although large, continuous stands of *S. alterniflora* and hybrids do occur at some marsh localities in San Francisco Bay, mosaics of invasive colonies within native marsh communities is more typical. Many of the operations and techniques we observed in Willapa Bay were based on efficient marsh access, treatment of large homogeneous blocks of marsh, relatively cohesive substrate capable of supporting amphibious tracked vehicles, and minimal avoidance of non-target organisms or communities. Valid estimates for rates of treatment (acres/year), and costs (acres/unit cost) in San Francisco Bay probably cannot not be made from Willapa Bay unless they are substantially modified for site-specific conditions.

IV. Interagency Coordination

We were impressed by a very low level of interagency cooperation in Willapa Bay regarding regional population control of cordgrass. We found instead appearances of rivalry among various jurisdictions, and identification between particular institutions and preferred methods or equipment. There exists also competition for funding, with the U.S. Fish and Wildlife Refuge leading in funding. The distribution of scientific and research and monitoring appears to be skewed to the west shore (Prof. Patten's research) and south shore (Refuge).

V. Recommendations for Follow-up Actions

1. Population Dynamics and Regional Control

Willapa Bay managers emphasize treatment (methods and rates of control) over population dynamics for regional eradication of *S. alterniflora*. There appear to be few or no data on seed production, or rates or vectors of seed or vegetative propagule dispersal. To minimize the risk of ineffective population control for *S. alterniflora* hybrids in San Francisco Bay, we recommend close coordinate population studies (modeling and field studies, including demographic analysis of regeneration and recruitment following treatments) with regional treatment methods in San Francisco Bay. This is needed to minimize the risk of inadvertent "cropping" rather than eradication of smooth cordgrass hybrids. We need to develop spatially explicit population models to estimate patterns and rates of eradication in specific population settings, aiming at thresholds of treated areas to escape cycles of rapid recolonization and need for perpetual re-treatment.

2. Imazapyr Registration for Estuarine use in California

We should investigate the possibility of collaborating with EPA Region 9 in pursuit of an EIR/S for registering imazapyr for estuarine use in San Francisco Bay, exploiting the existing FEIS developed for Washington State.

3. MarshMaster Field Trials

We should investigate the efficacy of the MarshMaster (tracked vehicle) in crushing trials of smooth cordgrass on variably drained wetland types in San Francisco Bay (sandy flats [San Lorenzo Creek delta area]; fringing marsh [Alameda FCC]; and mudflats.

4. Ripping and Fragmentation

We recommend caution regarding the risks of sod fragment and rhizome fragment dispersal and establishment resulting from disking or ripping, based on accounts from Willapa Bay.

5. Rail Surrogate Model

We should consult with Jules Evens and U.S. Fish and Wildlife Service regarding the potential validity or utility for investigation of Virginia rail impacts as a surrogate model for clapper rail impacts of invasive cordgrass treatment in SF Bay.

6. Cordgrass Stubble-generated Surface Roughness and Cordgrass Seedling Recruitment

We should investigate the effect of residual stubble of herbicide-killed cordgrass on rates of invasive cordgrass seedling recruitment, compared with crushed or bare substrate. If stubble improves seedling habitat significantly, it may require removal or crushing.