Vegetation Management in SBSP's Alviso Unit
seeding high marsh and upland transitional habitats

Report to SCVWD Healthy Creeks and Ecosystems
Environmental Enhancement Grant Final Report (2011-13)

by David Thomson & Aidona Kakouros
San Francisco Bay Bird Observatory – Habitats Program

Table of Contents

Executive Summary

The Santa Clara Valley Water District's (SCVWD) Healthy Creeks and Ecosystems' Environmental Enhancement Grant Program funded the planning and implementation of tidal marsh-upland transitional plant community restoration at former salt pond A6 (Figure 1 below). Pond A6 was restored to tidal action by the South Bay Salt Pond Restoration Project in December 2010, and in the fall of 2011 we seeded approximately 13 acres of the remaining levees modified during construction. We seeded 28 species of native plants historically found at the Bay's margin (Table 1 below). Aerial hydroseeding was used due to a lack of ground access, and NASA-Moffett Field donated the use of their airfield.

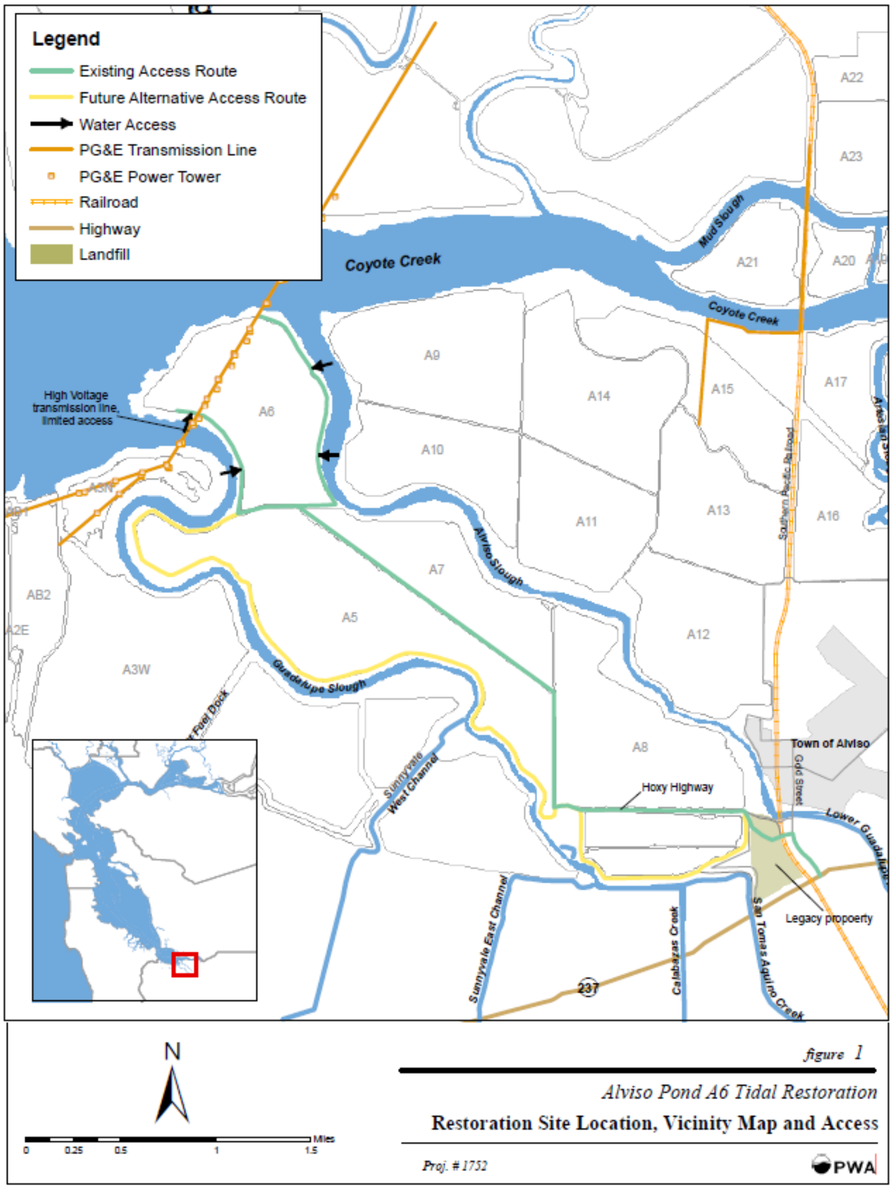
Drought conditions prevailed during the rainy season of 2011-12, and after some rain in late October it did not rain again until mid-January of 2012. The drought was so severe that even the hardiest non-native weeds had very little success that year. There was very little recruitment from the seed mix as well; thus we modified our project goal to identify how the restoration methods would perform in the second year after a drought. This is valuable information because climate change models predict more weather variability, and droughts may occur more often. Since we cannot predict in which year droughts will occur, and we continue restoring plant communities, we must address this issue in our methods.

Although rainfall in year 2 (2012-13) started off well, seemingly adequate for other seeding projects implemented last fall (see Conclusions), rainfall since the beginning of the calendar year has been poor (the driest on record since 1874) so we cannot say if the results this year are indicative of a second year after a drought. Our monitoring this year (2012-13) showed some recruitment from seed, but not enough to meet our revised project goal, perhaps due to this year's drought. So we focused on characterizing the conditions where recruitment occurred to inform the restoration methods and improve their performance.

Background

The South Bay Salt Pond Restoration Project (SBSPRP) restored the 330 acre former salt pond A6 to tidal action in 2010 (Figure 1). Their work did not include active management of the vegetation above the zone of strong tidal influence, so SFBBO proposed to create tidal marsh-upland transitional plant communities on the levee remnants, a critical action to create needed habitats. Tidal marsh-upland transitional plant communities (or "transition zones") create high tide refugia as well as nesting and hiding places for endangered species that non-native plant species do not provide. Our work on methods for restoring large tracts of the estuary's transition began in late 2007, working with the National Wildlife Refuges in San Francisco Bay to create these habitats more efficiently. Almost all of the habitats surrounding the bay, and in particular those immediately adjacent to it, are dominated by nonnative species. These habitats are disturbed enough to make once common native species difficult to find. Therefore when restoration projects create bare ground, these areas are colonized predominantly by non-native plants that do not provide needed habitat values.

Figure 1. Pond A6 Vicinity Map (PWA)



At the San Francisco Bay Bird Observatory, our approach has been one of iterative applied research, testing methods feasible to land managers who have limited budgets. Initially we researched historic accounts, species lists, and herbaria records in order to assemble a plant palette, which could develop into a native-dominated plant community that provides ecosystem functions. There are no reference sites to guide us, and these ecosystems have been disturbed for the past two millennia by humans (indigenous fire management until the Spanish explorers ended the practice for cattle foraging, followed by intensive agriculture and finally urban conversion). We then located historic local stands of these species in order to harvest seed, developed and described propagation protocols (as many have never been worked with), and had some amplified to quantities of seed sufficient for large acreages on commercial seed farms. Our results appear very promising after 5 years of monitoring at our primary site, although stabilization (i.e. full development of habitat) in restored herbaceous communities may take up to ten years after disturbance.

Plans & Specifications Development

During the planning grant phase (2010 SCVWD EE Planning Grant), potential methods for seeding the levees around pond A6 were reviewed based on site conditions and access issues. Site conditions include high exposure (i.e. little ground cover or topography), low rainfall (SCVWD estimates an average of 11.5 inches of rainfall are average for this area), and high winds. Therefore the use of a method to secure the materials to the ground surface was necessary, and mulching was warranted to reduce exposure and improve water retention. Hydroseeding was chosen as the most efficient of application methods. Portions of the site are over 1 mile from the nearest ground vehicle access (i.e. truck-mounted hydroseeder), and there is not enough deep water near the site to provide barge-mounted hydroseeder access. Because aerial methods require large sites to be cost-effective we only used this one method.

Aerial hydroseeders specify their own mulch materials due to the nature of the method. The mixture is designed through applied testing to get the slurry to come out of the plane with a moderate droplet size so it spreads evenly. Our contractor AeroTech Inc. (Clovis, NM) utilizes a mixture of recycled wood and paper fibers (60:40 ratio), which are guaranteed to be plastic-free, and a food-grade tackifier (MSDS available upon request). AeroTech offers two hydroseeding rates: 1,000 and 2,000 pounds per acre. Considering both our budget and method feasibility (for agencies) we selected the lower rate, but please note our monitoring findings concerning this below.

We specified the seed palette (Table 1 below), based on previous research. The mixture of 28 species of native grasses and forbs has been (and continues to be) developed through our applied research program. After a population of historic local native species are found, collected, and tested in our nursery, we include them in subsequent seed mixes. Each field seeding trial is monitored and species' performances are used to inform the next species palette. We also test each year's seed mix to help interpret field results; the seed mix's nursery trials are summarized in Appendix A.

Diversity in our seed mix is high for several reasons. The estuary's transition zones contain a strong salinity gradient due to tidal influence, requiring a range of halophytes. There are between two and four distinct seasonal plant communities found in these sites, which requires additional diversity. In addition, we have found that pioneer species (aka early successional) are required to colonize disturbed sites, creating better conditions for later seral species to recruit and establish. Early seral species should create a seedbank during this process, which will help the restored site resist invasion by non-natives in the future.

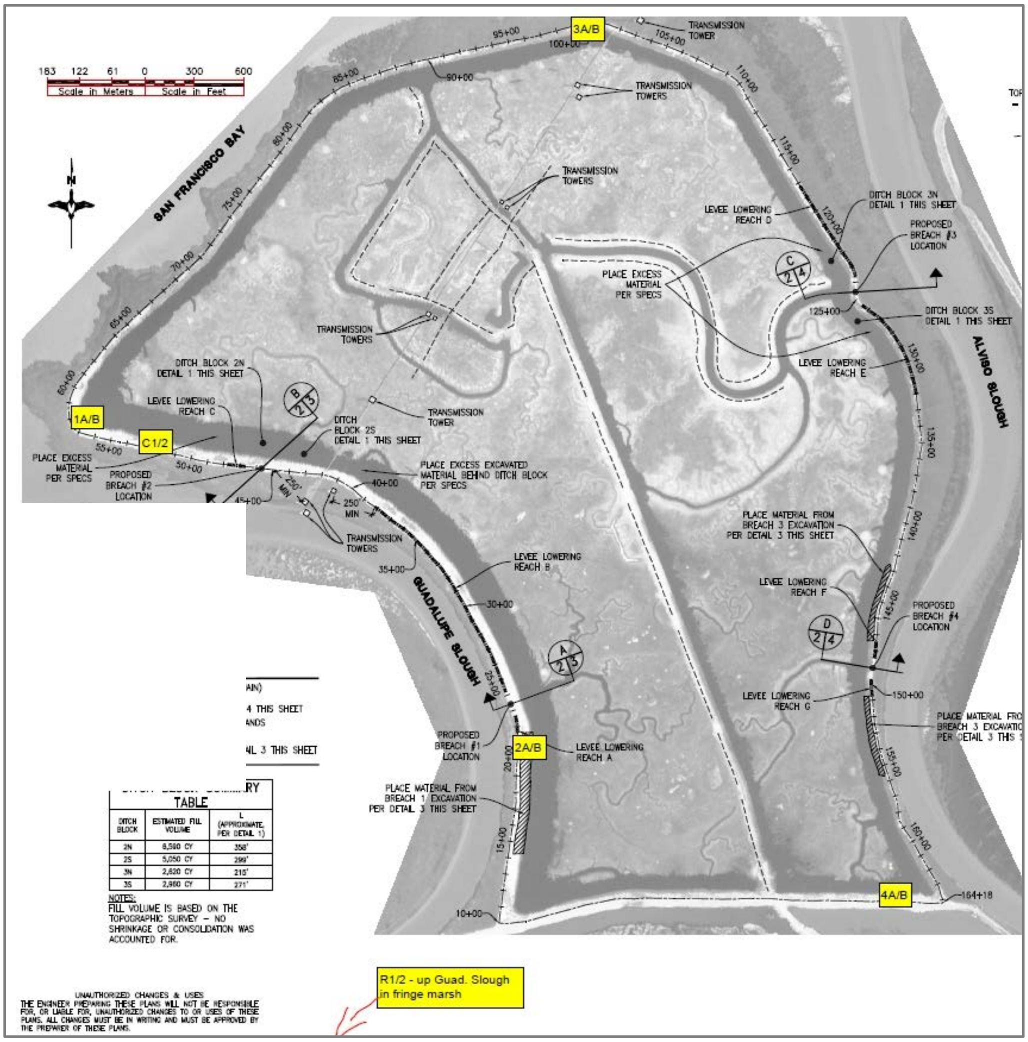
Also during the planning phase, we noted that there was a considerable extent of barren ground onsite, which have persisted since the last time the levee was reworked by the salt production industry (perhaps 10-20 years ago). The barren levees are surrounded by a variety of hearty native and non-native species that should be able to colonize bare ground. In order to determine limitations to plant growth, we collected soil samples from areas that were bare, areas that had vegetation, and a reference sample from a nearby high marsh to help the soils lab interpret the results (sample locations in Figure 2 below). Each sample point had a composite sample from the first foot below ground surface (BGS) and another 1-2' BGS.

Table 1. Species Palette (seed mix)

Species	Name
Achillea millefolium	common yarrow
Ambrosia psilostachya	western ragweed
Amsinckia menziesii	common fiddleneck
Artemisia californica	California sagebrush
Aster chilensis	Pacific aster
Bromus maritimus	seaside brome
Calandrinia ciliata	red maids
Centromadia pungens	common spikeweed
Distichlis spicata	saltgrass
Epilobium brachycarpum	annual willow herb
Eriophyllum confertiflorum	golden yarrow
Escholschzia californica	California poppy
Euthamia occidentalis	Western goldenrod
Frankenia salina	alkali heath
Grindelia stricta	marsh gumplant
Heliotropium currasavicum	seaside heliotrope
Heterotheca grandiflora	telegraph weed
Hordeum depressum	alkali barley
Elymus triticoides	creeping wildrye
Elymus condensatus	giant wildrye
Limonium californicum	California sea lavender
Lotus purshianus	Spanish clover
Lupinus succulentus	arroyo lupine
Malvella leprosa	alkali mallow
Nasella pulchra	purple needlegrass
Phacelia californica	common phacelia
Sarcocornia pacifica	perennial pickleweed
Vulpia microstachys	annual fescue

Laboratory analyses found boron levels exceeded the tolerances of plants in the upper foot of the soil, and recommended that scraping off the first foot to create adequate growing conditions was required. A less strenuous recommendation was to use agricultural lime ($CaCO_3$) to address a calcium-magnesium imbalance, but implementation of this recommendation was not feasible. The scraping recommendation was adopted by project management and wherever possible, scraping was incorporated into the construction design.

Figure 2. Construction as-built map & soil sampling locations (yellow text boxes)



Another significant issue is seeding adjacent to the tidal zone. A general rule for hydroseeding is the tackifier (a glue to hold the materials in place) needs about half a day to dry fully and reach full holding strength. But the tide rises twice each day, one of which usually approaches the lower edge of where we intend to seed (highest reaches of high marsh, generally around 0.5m above MHHW). Although we could not plan the work completely around the tides due to logistical issues (organizing an airplane and pilot, along with two hydroseed mixing crews and a half-dozen support staff) we agreed to not seed during high tides. However, it appeared that seeding too soon after high tide may have interfered with the tackifier drying, presumably because the mud was still wet. Our revised spec for any future work would be to allow seeding a few hours after the higher high tide and only up to 6 hours before.

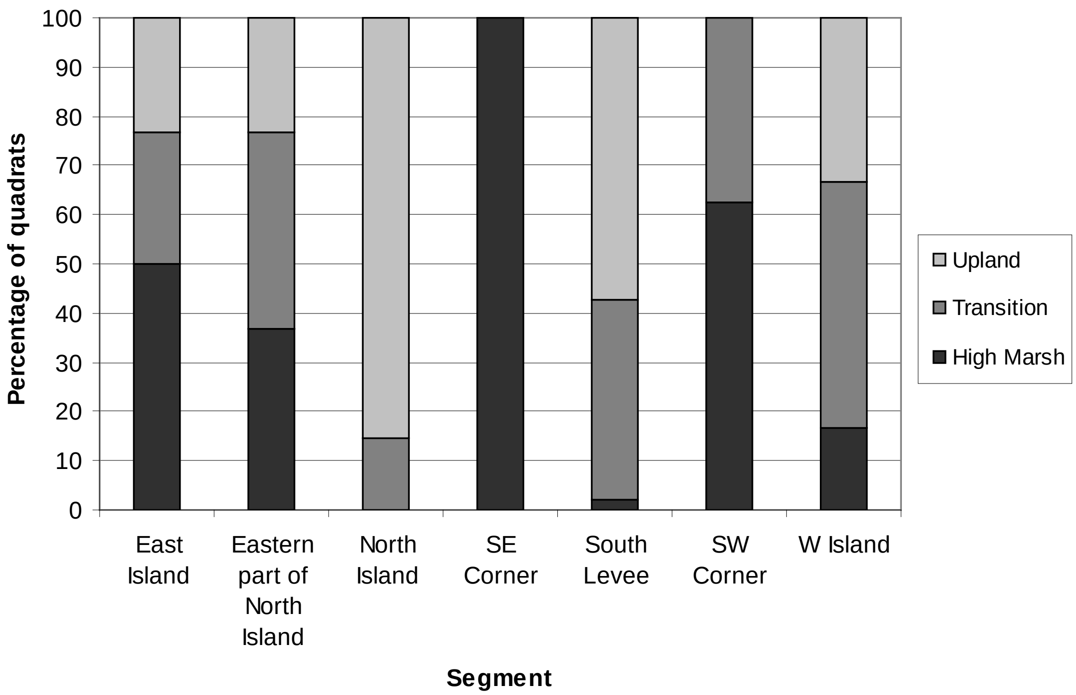
One final significant change: during construction much of the existing levees were lowered to tidal marsh elevation (below MHHW). This was unanticipated as it did not follow the engineering design, and Refuge management halted the lowering once notified, but unfortunately the area suitable for restoration to transitional habitat was significantly reduced. Levee lowering negatively impacted our plant community restoration work, because the fully lowered levees are completely in the tidal zone, and regular tidal action eventually releases the tackifier, allowing the mulch and seed to float away. We should also point out levees that were not cut as low, but still lower than our recommended 1’ scrape to improve soil conditions, were susceptible to significant wrack deposition by extreme tides (i.e. floating materials), which also negatively impacted results. The areas available for seeding are summarized in Table 2 and Figure 3 below.

Table 2. Summary of habitat types in the seeded area created by the construction design

Monitoring Area	high marsh	transitional	upland
Acreage	**6**	**2**	**5**

Please see Appendix C for definitions of these monitoring area terms.

Figure 3. Habitat structure of the hydroseeded area (as recorded during 2012 monitoring)



Implementation

After substantial planning and preparations there still remained a need for staging the aerial hydroseeding firm, AeroTech Inc., at an airport that would best suit their needs. Although they can stage at county airports, their frequent take-offs and landings can cause difficulties. We wanted to optimize this for the owner of AeroTech Inc., Mr. Ted Stallings, because he stood by his quoted price per acre for aerial hydroseeding, even after our initial estimate of the seeding acreage was cut in half, affecting his bottom line by tens of thousands of dollars. Regardless of this, I highly recommend AeroTech Inc. for their technical expertise and professionalism; it was a pleasure working with them.

Pond A6 is very close to Moffett federal airfield, and NASA approved our use. Mr. Stephen Patterson (NASA) handled our request and did not charge any fees for this initial project.

Our calculations of the value of their donation was in the tens of thousands of dollars, based on their takeoff and landing fees, as well as the cost of water used for tank mixes. The fact that AeroTech already works from many federal airfields (including military bases) and has everything in order to meet NASA requirements was likely a strong consideration; NASA lawyers took only one week to draft a use agreement.

Although AeroTech can take care of every detail, our seed mix is too specialized and requires decisions be made right up to the date of delivery. This is due to the nature of grant funding. Native seed suppliers like Pacific Coast Seed Inc. (Livermore, CA), who supplies our seed, request 18-24 months lead-time for large orders that require specialized collections and amplification (growing collected seed on a farm to create a larger stock). We cannot meet that requirement due to grant funding cycles and are forced to negotiate the collection and amplification of some stocks prior to grant awards. This is possible for some species that have a reliable commercial market, but many of the species we work with are not only new to commercial collections but also new to restoration practice.

Therefore, many of the species we use for restoration do not have enough demand in the marketplace for a seed supplier to risk resources collect and amplify them. In order for us to utilize such species we must find collections sites, arrange landowner permissions, and let the seed collectors know when to collect them, all within the year leading up to our specified seeding period (late October – early November). Such late collections cannot be amplified (min. six month lead time for farming) so we have to work with whatever stock can be collected. Finalizing the seed order requires a significant amount of specialized attention that cannot be performed by a contractor.

We created site maps to guide AeroTech's hydroseeding (Figure 4 below) and gave their pilot a site tour so he could better visualize the seeding areas. AeroTech's "swath width", (the width of the hydroseed slurry as applied from the plane) is 27 feet, about the width of the seeding areas along the remnant levees, so the pilot's seeding had to be precise. The site consists of two basic areas: the outer perimeter levee and the marsh mounds or islands created from remnant levees within the pond (Figure 4). The purpose of the mounds was to create high marsh habitat to enhance the restored marshes in the near-term because the natural development of these elevations takes over a century.

Seeding was performed on October 24th and 25th, 2011. We visited the site periodically afterwards to verify that the distribution of the hydroseed matched the GIS files sent by AeroTech, and to observe the behavior of the hydroseed mulch, particularly in tidal areas. The distribution of the hydroseed slurry appeared to correspond to the GIS files. The hydroseed slurry held up somewhat to limited tidal action when it was applied to a dry surface so the tackifier could set up. This is not a recommendation to hydroseed in tidal zones, as all hydroseed tackifiers eventually release when kept wet, and most seed floats, but in our case we were hopeful that some of the high marsh seed might have the opportunity to recruit. Further monitoring results are below.

Figure 4. Primary Seeding Areas (yellow); original levee footprint outlined in red

Monitoring

Initially monitoring was to consist of periodic surveys of hydromulch performance and seed germination through the winter and spring, followed by an intensive quantitative sampling event in the summer of 2012. However, the drought following seeding led us to change the monitoring design and add a second quantitative survey in the Spring 2013. It was readily apparent from our periodic surveys through the winter and spring of 2011-12 that recruitment from seed was exceedingly rare, likely due to an absence of rain from the end of October through the middle of January. Recruitment of common non-native annuals on site, such as slender-leaved iceplant (*Mesembryanthemum nodiflorum*), was likewise exceedingly rare.

Quadrat sampling (1x1 meter frame to standardize sample sizes per point) does not capture rare plants well, so we utilized the quadrat sampling to generally describe the character of the site's vegetation and also to quantify the extent of observable hydromulch persisting on the site, with the expectation that we would monitor the site for recruitment from seed in the second year (2013). AeroTech only expected the hydromulch to persist for 6 months, but it may hold longer in dry conditions. We found that above the tidal zone the hydromulch persisted well into the summer of 2012 (8 months between seeding and sampling). We also collected mulch and put it on potting soil in our nursery to check for persistence of the seed mix's species, which we found did contain viable seed (Appendix B).

Other nursery testing includes seeding the original mix into trays, and irrigating them to check germination of the species included (Appendix A). This helps us to interpret the results on-site, functioning as a performance baseline for the seed mix (in ideal conditions), so that we better understand its performance in site conditions. Although commercially supplied seed usually comes with purity and germination information from a seed lab, some of our seed is collected too close to the seeding event to allow for testing, so it is supplied "as-is" and in bulk quantities instead of as "pure live seed", which utilizes the germination trials data to adjust the bulk weight into a live seed weight (a proportion of the bulk weight, which includes chaff and non-viable seed).

To assess the accuracy of the seeding work we observed almost all of the aerial hydroseeding from a boat, and subsequently walked the site to observe the seeding's extent (Appendix E contains additional photos that show some of this work). These observations were used to qualify the GIS tracks sent by AeroTech. The tracks are simply when the pilot starts the hydroseed equipment, and when he stops it, so there are differences as the slurry does not hit the ground where the line starts and generally stops hitting the ground before the equipment is stopped. Our observations indicated that the GIS tracks were adequately representative of the hydroseeding extent (Figures 5 & 6).

Figure 5. Close-up of hydroseeding tracks to show one double-rate area

Key: blue lines are seeding areas, yellow shows where hydroseeding tracks intersect a seeding area, and red shows where they intersected multiple times

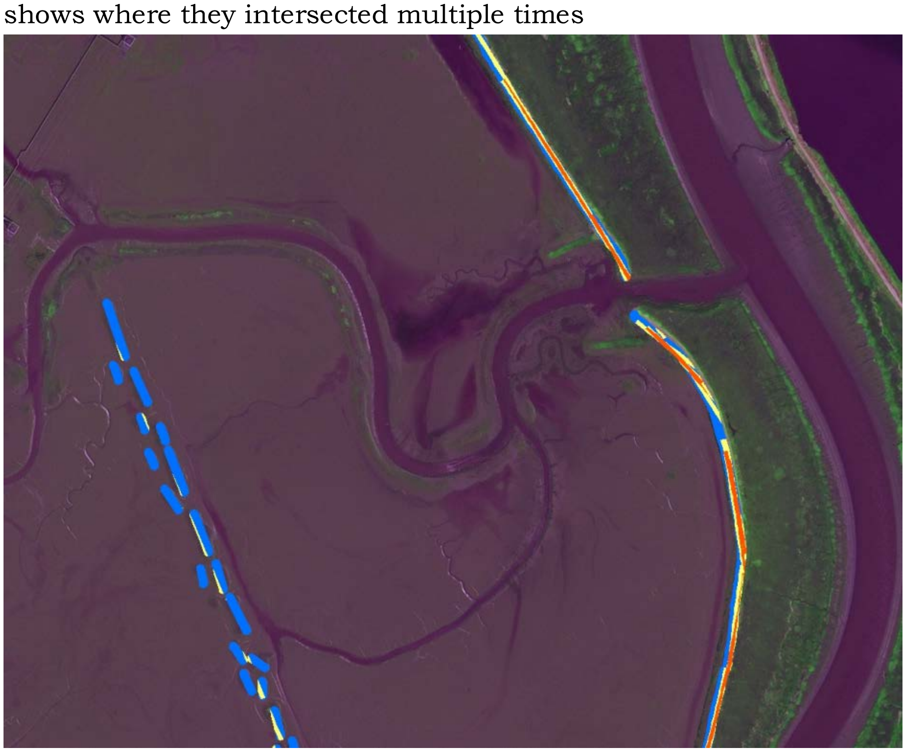
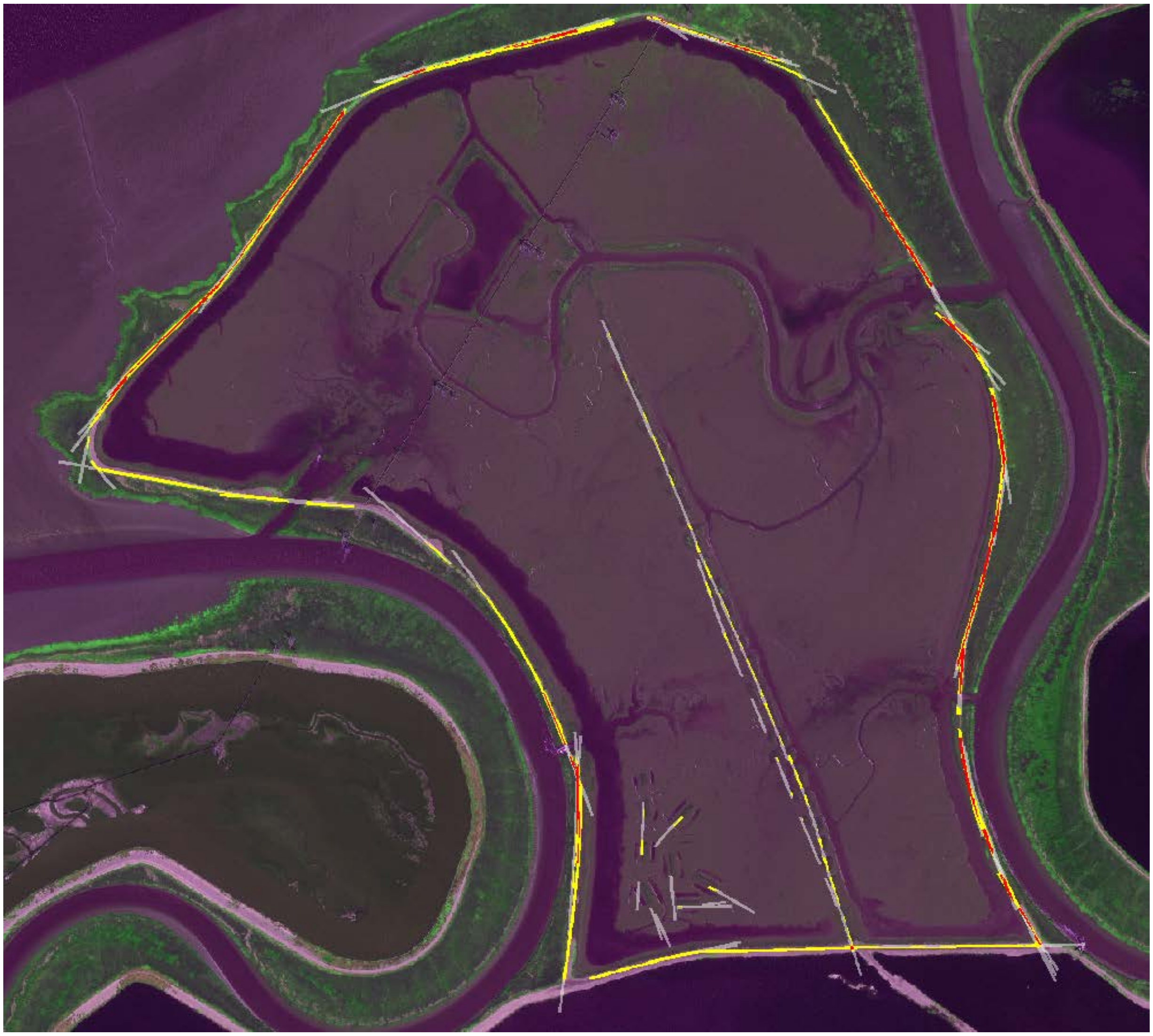


Figure 6. GIS tracks from AeroTech depicting hydroseeding extent
Key: blue lines are seeding areas, yellow shows where hydroseeding tracks intersect a seeding area, and red shows where they intersected multiple times



Upon reviewing the GIS tracks we noted that they overlapped in some cases, which we interpreted as double-rate seeding. An example of these higher rate seeding areas is shown in Figure 5 above. We selected the lower mulching rate (1,000 pounds per acre) offered by Aerotech, but were interested in the higher rate (2,000 lbs per acre), so we decided to count the overlap as the higher seeding rate (2,000 lbs per acre) would provide useful information. A close inspection of the GIS maps shown in Figure 6 above led us to conclude that our original seeding area map may not have covered all levee areas of suitable elevation relative to the tides (Figure 5). So some areas seeded by AeroTech appear to have been unnecessarily excluded from considerations of accuracy. And finally, we must note that due to the PG&E towers' proximity to some levee reaches AeroTech was unable to seed them. They seeded closer than we expected, and we planned on using those unseeded areas as "control" sites for seeding effects.

Considering all of those factors the seeding work may be summarized as follows:

Table 3: seeding accuracy by date (in acres)

Date	Proposed	On-target	Overlap	Sum	Accuracy	Note
10/24/2011	6.5	5.85				
10/25/2011	6.5	5.03	2.8	8.08	62%	not counting overlap
				10.88	84%	counting overlap

One reason that unseeded control areas are needed is some of the seeded species already exist on site, such as the high marsh species in the mix. These areas would allow us to interpret the results better as it is impossible to tell if one of these individuals is from our seed or from the existing stands of this species. That said, due to remaining concerns we have not counted any of the following pre-existing, widespread species as "seeded" in any of our monitoring: perennial pickleweed (*Sarcocornia pacifica*), alkali heath (*Frankenia salina*), or saltgrass (*Distichlis spicata*). We did include some marsh gumplant (*Grindelia stricta*) because there are reaches of Alviso Slough that are devoid of gumplant, so any observed individuals in the seeding areas have a good chance of being from our mix.

Although we expected to consider California sea lavender (*Limonium californica*) in this group we were unable to because it turned out that our seed supplier had mistakenly provided the non-native Algerian sea lavender (*Limonium ramosissimum*). This confusion is one of the issues we have identified with adding new species to seed collectors' work; if there is a morphologically close species in the region it is necessary to point this out to the collectors. We have added this to our protocols: if we request the collection of a new species we will provide the collectors with guidance on any similar species in the region that we do not want collected, in order to proactively address this issue. And currently one of our monitoring duties is to pull Algerian sea lavender whenever we see it onsite.

We have already summarized the salient findings of the periodic germination-period surveys, noting that in Year 1 there was almost no germination of seeded species on the site (almost certainly due to the drought). However, at least some of the hydromulch persisted well into the following summer. Samples of the hydromulch were tested in the nursery for germinating species from the seed mix. Seven of the 28 species from the seed mix germinated in this test, thus at least some of the seed survived for 8 months (Appendix B) so we had some confidence that we could see germination in Year 2.

Year 1 monitoring methods and findings are summarized in Appendix C. Again, presumably due to the drought there was almost no recruitment in the first year (Figure 7), so the modified goals of monitoring were to describe vegetation found within the seeded area and document the persistence of hydromulch. Plant community structure visually corresponded to the height of the levee remnant above the tides, so we stratified the data to correspond with high marsh, transitional, and upland elevations created by the construction design (definitions in Appendix C). The results for Year 1 are presented in Figures 8-10 below.

Figure 7. 1/2012 Photo of an unmodified A6 levee the first year during the drought

The species found within each of the three strata are indicative of the habitat names assigned: salt marsh species in the "high marsh", salt marsh and transitional species in the "transitions", and transitional and upland species in the "uplands". This verifies our habitat stratifications as reasonable approximations as understood by habitat ecologists in the region. Note that the "litter" found in the upland strata was predominantly from last year's *M. nodiflorum*, which did not do well in the drought.

Figure 8. Mean cover values for species found at the lowest seeded elevations in 2012 - Error bars are 2x standard error of the mean, approximating a 95% confidence interval

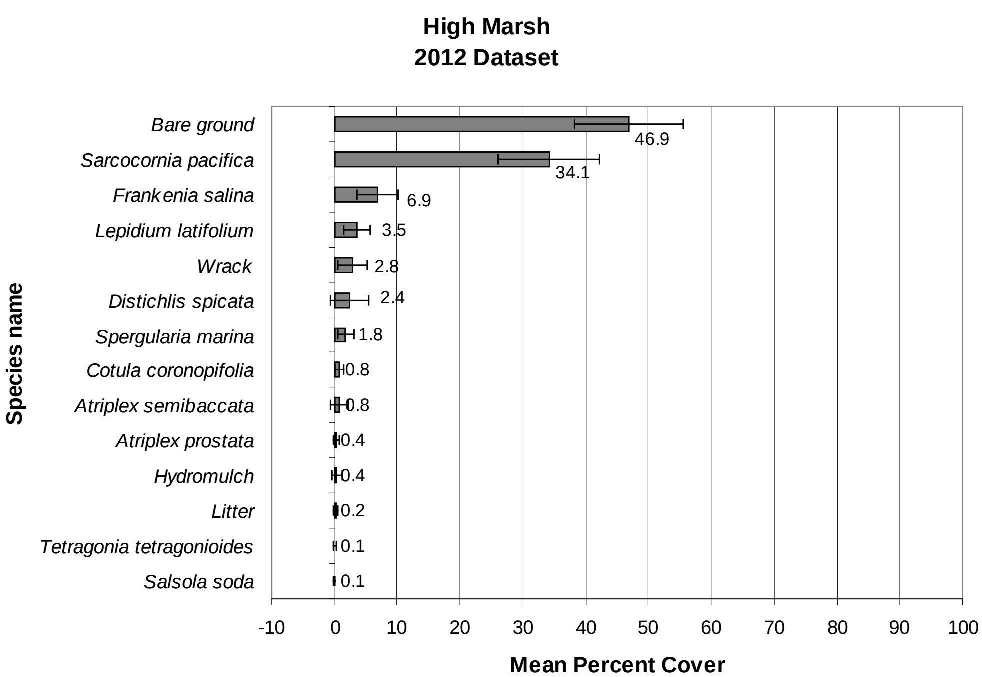


Figure 9. Mean cover values for species found in intermediate seeded elevations in 2012

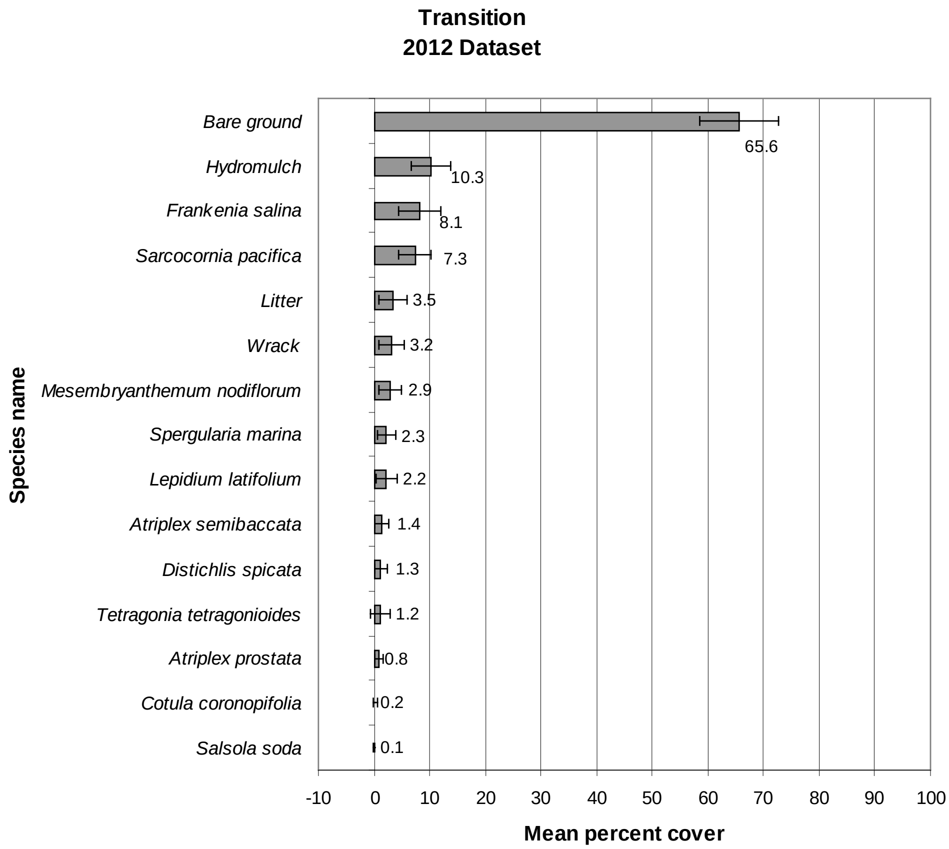
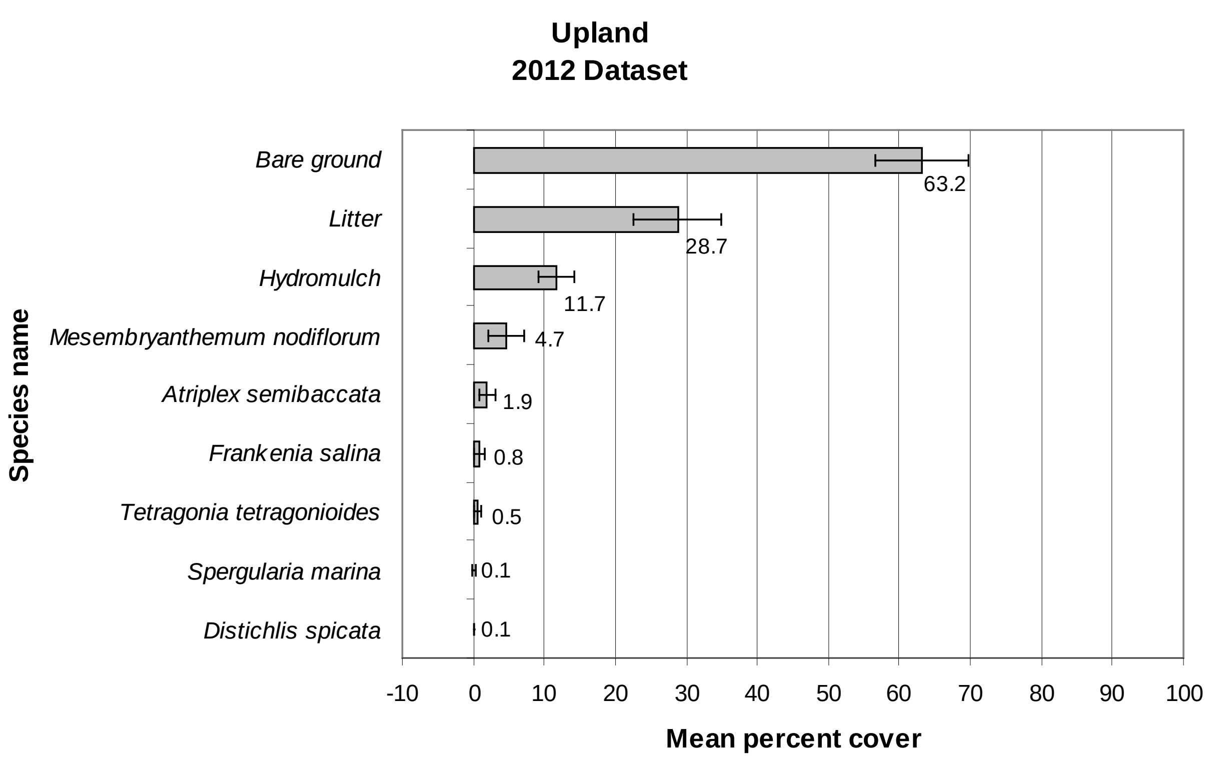


Figure 10. Mean cover values for species found at the highest seeded elevations in 2012



The presence of observable hydromulch was included in our data collection to help us interpret year 2 data. There was likely more hydromulch present as it was easily camouflaged by dust. We do not know what year 1 recruitment may have been with normal rainfall, so we seeded test plots at A6 in 2012. And we cannot predict what percentage of the seed should remain viable through the year, although we did test the hydromulch in the nursery for some indication. But what losses we should expect due to seed browse by animals is an unknown quantity. This data along with data from our testing initiated in 2012 were all to help us interpret year 2 results.

Table 4. Presence of Hydromulch on seeded area segments in summer 2012.

Segment	Mean percentage of hydromulch cover	Standard deviation	N
East Island	13	21.2	30
Eastern part of North Island	3	9.0	30
North Island	10	10.6	95
SE Corner	0	0.0	17
South Levee	14	16.5	47
SW Corner	4	7.3	8
West Island	5	11.4	24

Year 2 monitoring methods and findings are summarized in Appendix D. Although rainfall was also below average this year (9.5 inches as of this report date recorded near the site versus 11.5 inches per year predicted for this region), rain quantities and their temporal distribution have been adequate for fairly good recruitment from seeding at another site nearby (see Conclusions section below for more on this). Recruitment from seed in year 2 was better than year 1, but did not fulfill the funded project's goal of creating native-dominated plant communities, as we did not see adequate recruitment from the seeded species, and significant bare ground remains (Appendix D; Figures 11-13).

A comparison of year 1 and year 2 data shows an increase in salt marsh species cover values in the high marsh strata, which is expected as tidal marsh generally passively revegetates well. The large change in bare ground versus *F. salina* in the transition likely indicates a sample size issue, or some effect of the methodology, but we generally feel the direction of the change is accurate, as it conforms to our casual observations of the site. The most informative data regarding our seeding project's effectiveness (or the impact of the 2011-12 drought) is in the upland strata: bare ground remained relatively constant, showing that nothing was capitalizing on the bare ground, including *M. nodiflorum*, which did rebound this year but not to its extent in 2011 prior to seeding. This discussion continues in the Conclusions section below.

Figure 11. Mean cover values for species found at the lowest seeded elevations in 2013

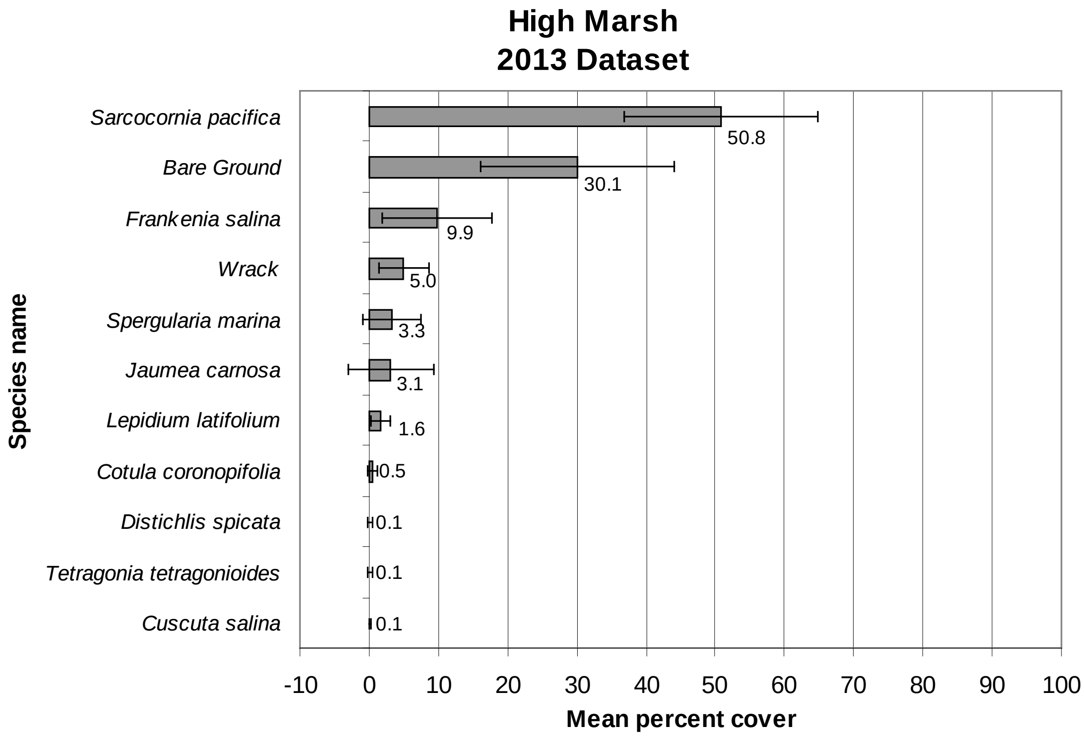


Figure 12. Mean cover values for species found at the highest seeded elevations in 2013

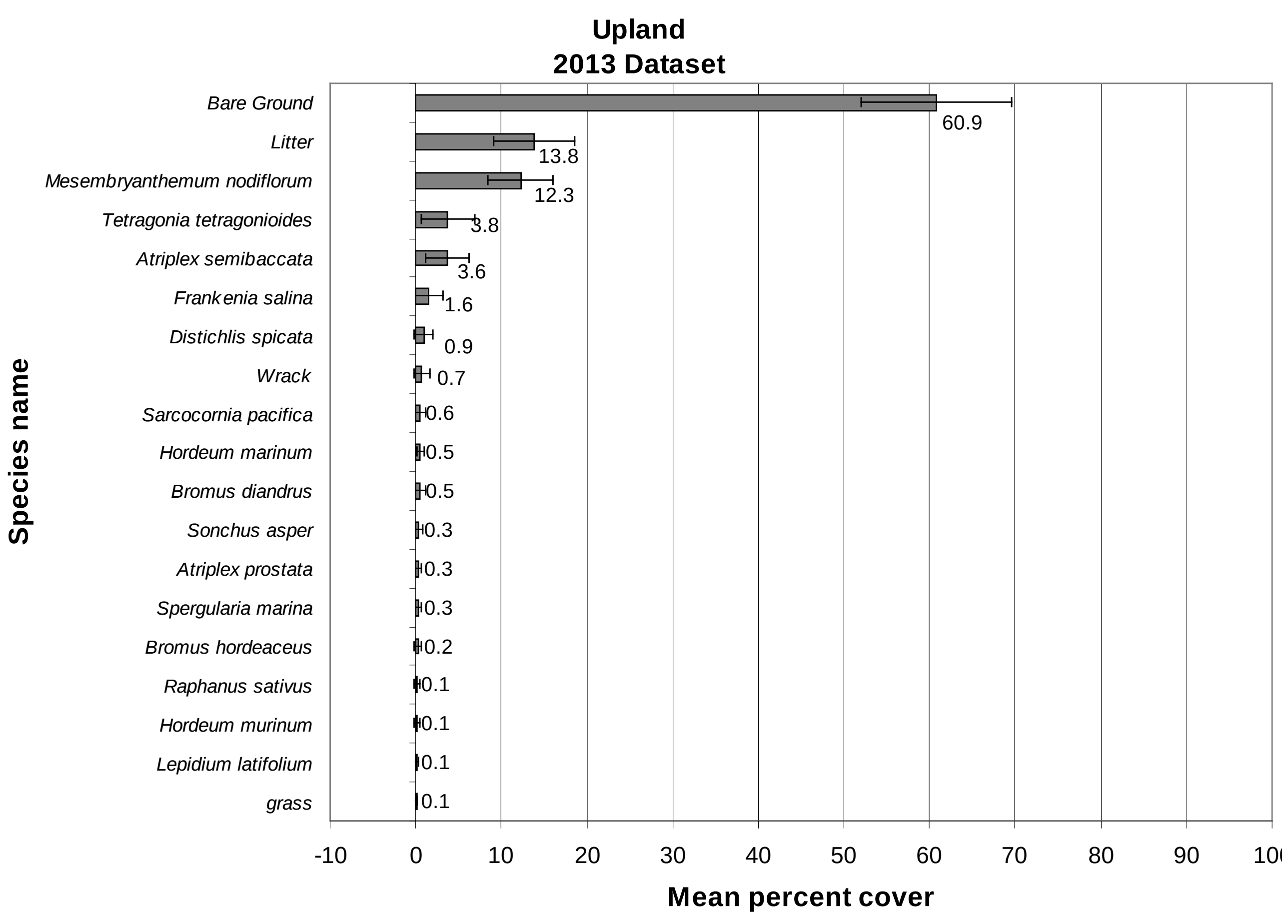
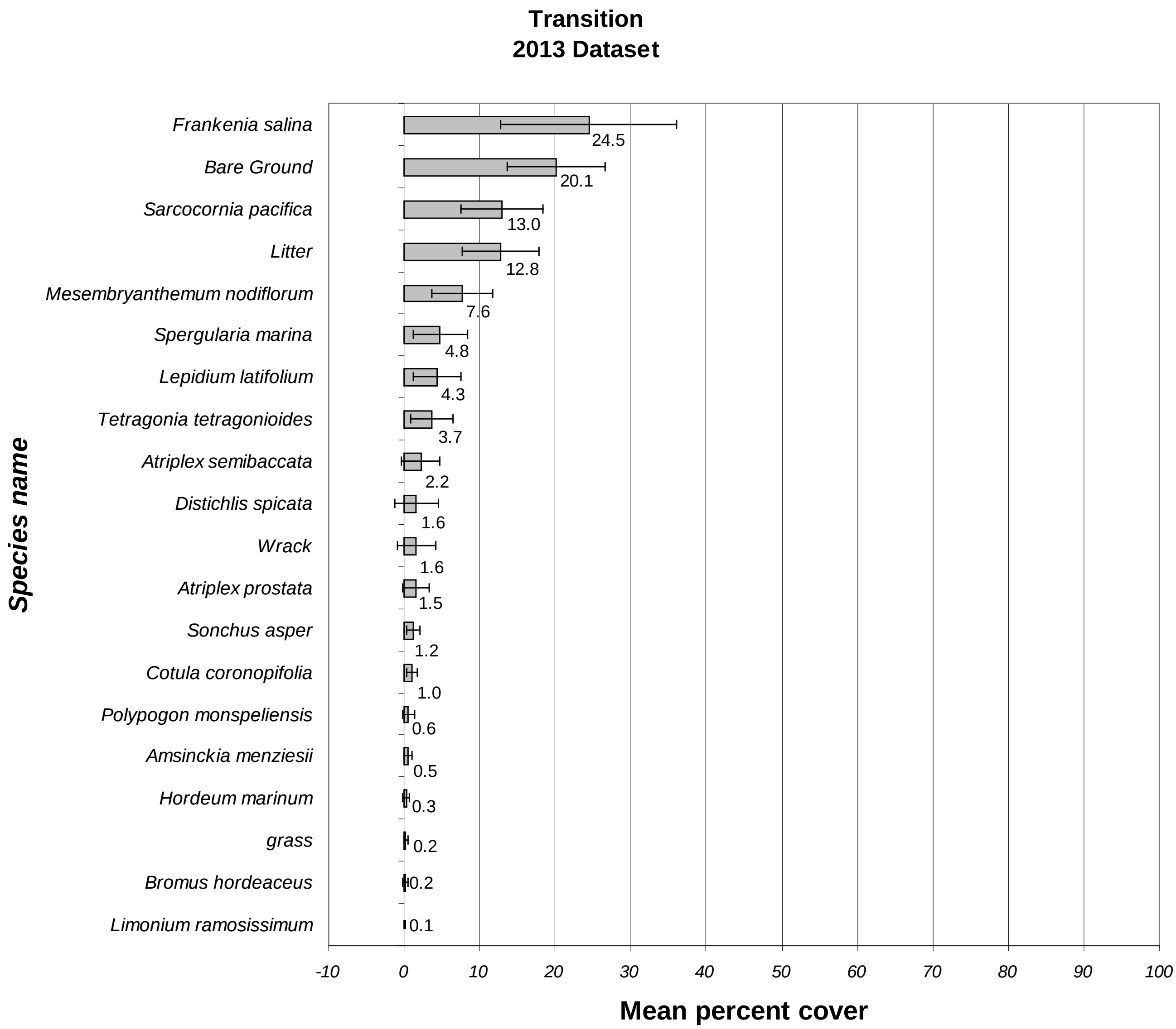
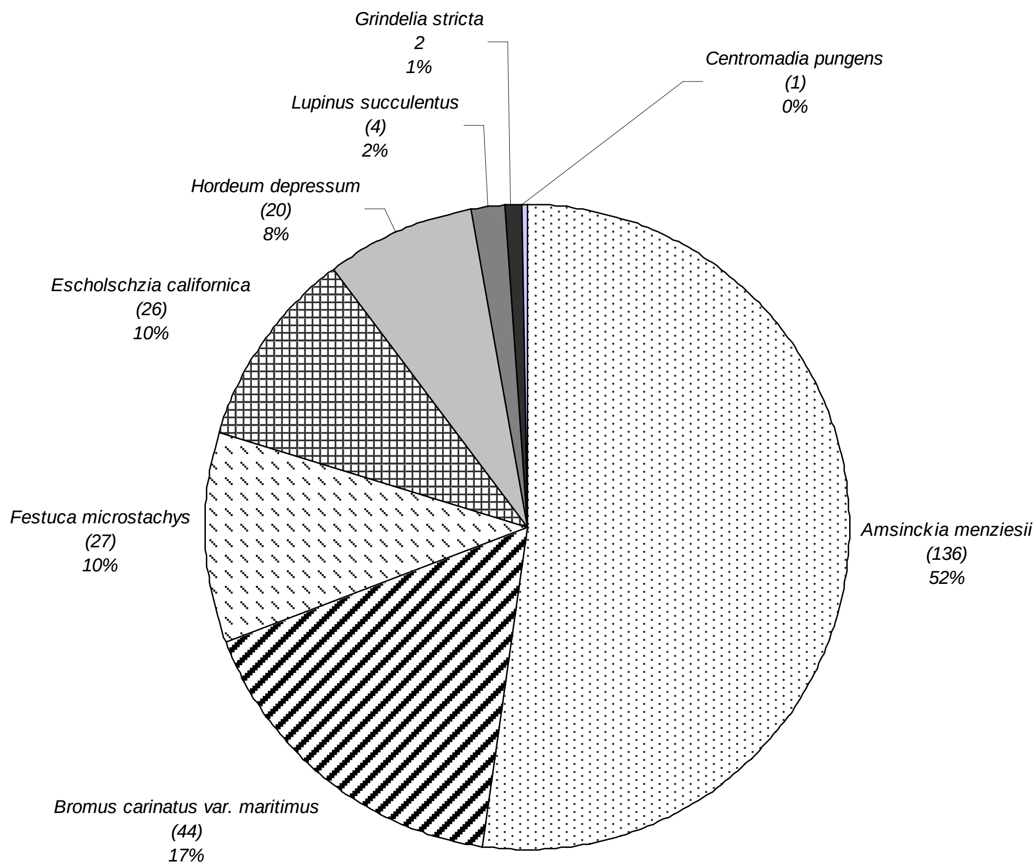


Figure 13. Mean cover values for species found in intermediate seeded elevations in 2013 - Error bars are 2x standard error of the mean, approximating a 95% confidence interval



The majority of our effort in year 2 monitoring was aimed at collecting data on the conditions in which we found obvious recruits from the seed mix. As stated previously, species that already have considerable presence nearby were not recorded to ensure we did not record false-positives. These included the high marsh species noted above. The seeded species we sampled are shown in Figure 14 below. It is important to point out that seasonality almost certainly influences these results, as we were only able to collect data in the spring because the project needed to be completed so the final 10% of held billing could be submitted. As noted above, we seed a high diversity in order to get as much coverage as possible throughout the year. There are distinct wet season (captured here) and dry season communities (not captured well here), and there can also be distinct assemblages in the early and late seasons too (winter vs. spring and summer vs. fall).

Figure 14. Seeding recruits sampled for growing conditions in 2013



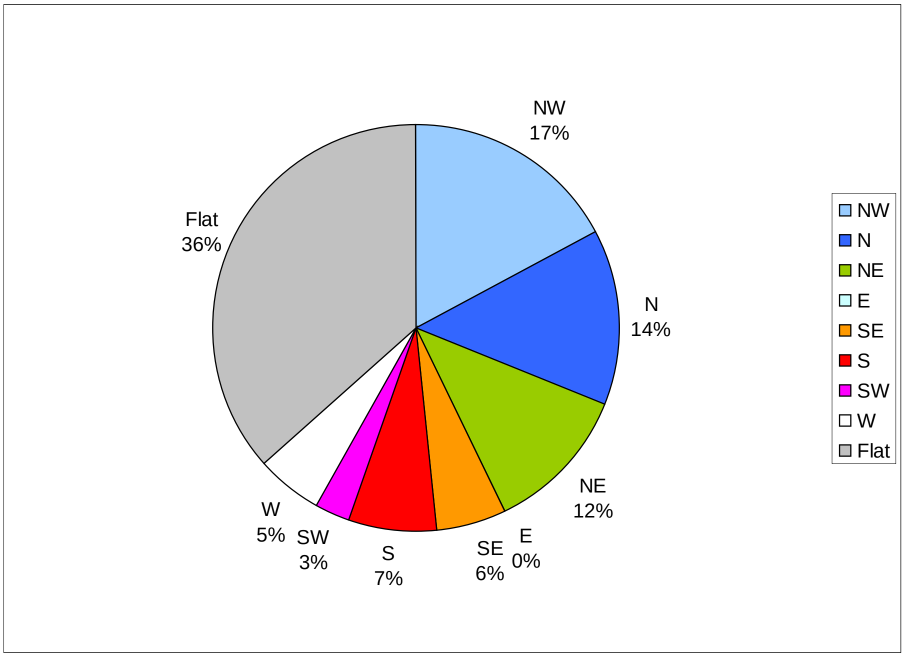
We collected the following growing conditions data by species:

- solar aspect or exposure (8 compass directions),
- soil compaction (uncompacted, light, moderate, or high based on relative effort inserting a hand spade into the soil surrounding the plant),
- microtopography (smooth, rough, or small depressions based on tilling roughness and the small depressions created by seed imprinters, which are ~ 6” wide x 3” deep),
- slope (flat, gradual, or steep),
- and construction treatment (unmodified, scraped, partially lowered, or fully lowered).

The proportions found in each condition are summarized in the figures and discussed below.

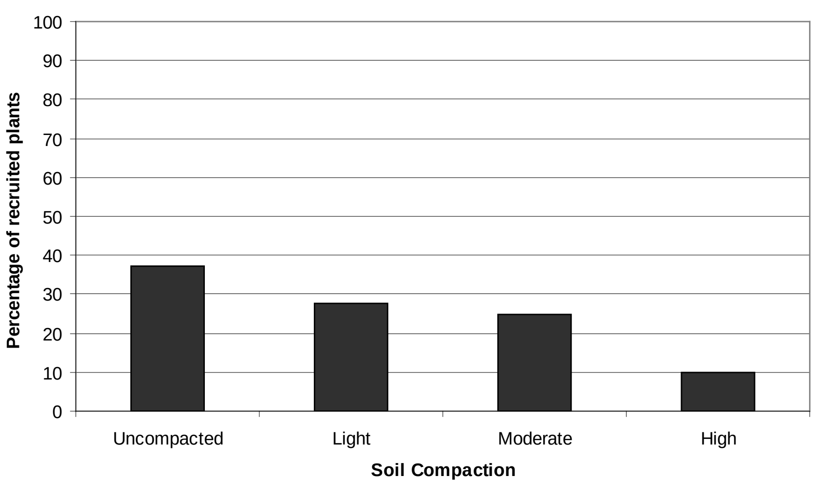
Solar aspect is known to be a significant influence on the distribution of plants, as the sun’s heat alters evapotranspiration, among other things. In our hemisphere, the southern aspect tends to be drier, with the southwest aspect being the driest due to the afternoon sun. But at Pond A6 the northern aspect is subjected to almost daily high afternoon winds, which increases evaporation. That said the northern aspects had more recruitment. You may note the flat (or no) aspect class has substantial recruitment, but this would have to be analyzed with slope in order to control for the interactions between factors.

Figure 15. Proportion of recruits found in each aspect



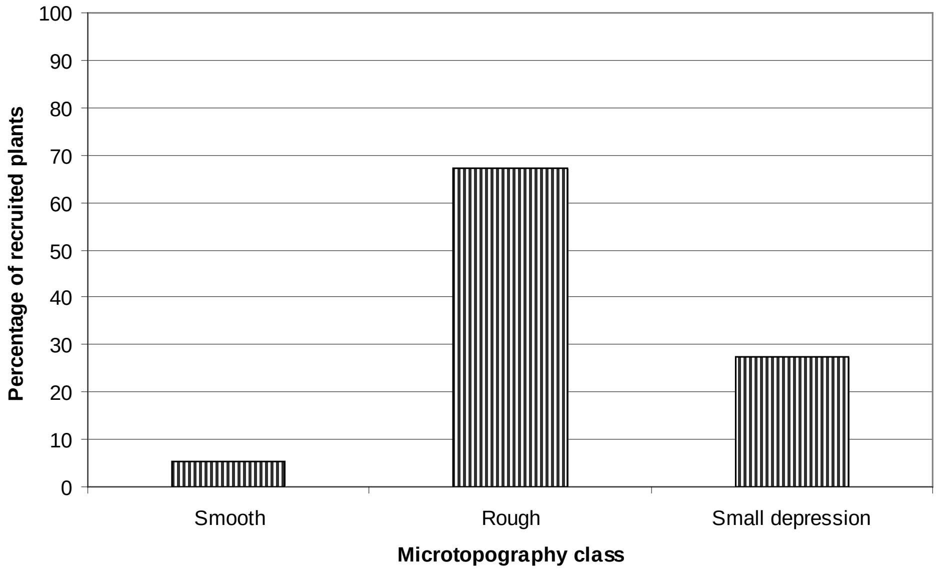
Excessive <u>compaction</u> is known to inhibit establishment of plants, and in this case is likely a contributing factor. Although plants can establish in highly compacted soils their success will be higher in less compacted soils. Our data suggests that soil compaction may be playing a role in the seeding's success.

Figure 16. Proportion of recruits found in each soil compaction class



Soil surface <u>microtopography</u> is also known to influence the success of seed germination and seedling establishment. Surface roughness is known to facilitate the even infiltration of surface water, create shading or microhabitats for better seed germination and/or establishment, and may even reduce evaporative water losses that are likely significant at this site. Our data suggests that microtopography may be playing a role in the seeding's success.

Figure 17. Proportion of recruits found in each microtopography class



Slope alters solar aspect, influences soil moisture through altering infiltration and retention, as well as influence the ability of seeding to stay put until germination. Our data suggests that slope influenced recruitment from our seeding.

Figure 18. Proportion of recruits found in each slope class

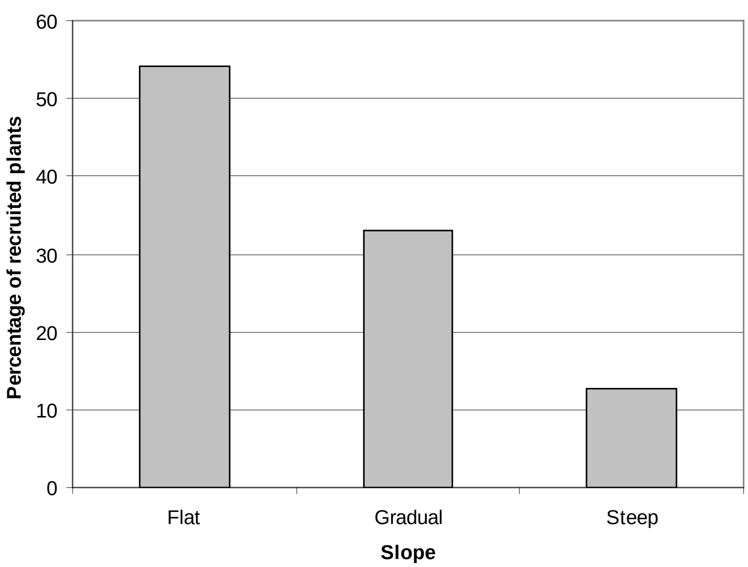
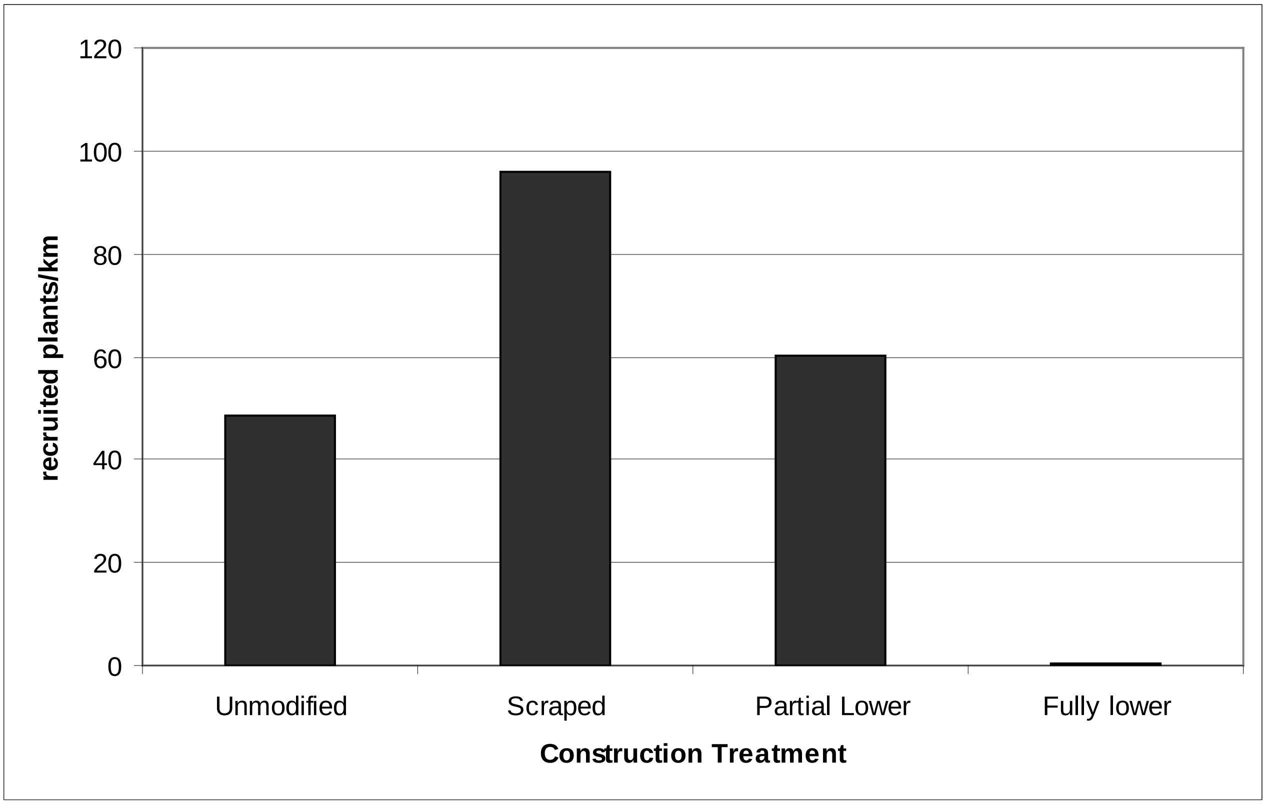


Figure 19 shows a group of factors. Fully lower(ed) is referred to as "high marsh" in other parts of this report, and Partial(ly) lower(ed) is most of the "transitional" strata, although transitions were found on the levee slopes of the Upland strata, which is shown in the "Scraped" and "Unmodified" categories below. As expected, our data suggests elevation influenced recruitment from our seeding.

Figure 19. Proportion of recruits found in each construction treatment



Our data indicate that scraping or some amount of levee lowering was helpful, but further lowering negatively impacted seeding success. It should be noted that additional data collection and analysis would be needed to tease apart the potential interactions among factors to get at the relative importance of each to performance. Slopes should be as gradual as possible, with surface roughness or small depression created or left from construction activities. Any pre-existing compaction or that created by construction activities should be loosened, at least a depth of one to three feet (normal rooting zone). And while there is not a specific recommendation for creating aspects, we feel projects should create as much variability as possible, so that habitat complexity can be greater.

That said, even levees that were scraped, and may have included some type of tilling or soil loosening, did not recruit seed well (Figures 20 and 21 below), which indicates the potential for an uncontrolled factor such as soil chemistry. In most cases the recruits were found on levee flanks, amongst pre-existing vegetation, suggesting that perhaps soil conditions were better and/or microhabitat conditions were created by other vegetation. This is discussed further in the Conclusions below.

Figure 20. 04/2012 Photo of an unmodified section of the A6 levee showing a sample site

Figure 21. 4/2012 Photo of a scraped levee result showing a sample site

Conclusions

The creation of transitional plant communities in the estuary is an ongoing need, but continues to be a technical challenge. Our understanding of these sites, and in particular their soils, contains datagaps that need to be addressed. This project has helped us address these needs, and clarify some of them. Newly drafted recommendations for construction plans and specifications are being refined for future projects and we will continue testing and refining our methods at other sites.

In summary, even considering this year's drought we did not see the quantity of recruitment in Year 2 that was seen at another site seeded in 2012 (Moffett Field, Figures 22 & 23 below). And we did expect to see more than was found based on the data collected (extent of persisting hydromulch, continuing presence of viable seed, and more germination in year 2 than year 1). The lack of recruitment could be due to a year of waiting for precipitation combined with construction design changes, second year of drought, as well as seed viability loses, seed loses due to animal browse, and/or seed loses due to tackifier failures.

In our view, the primary factor that remains uncontrolled is soil chemistry. Soil samples were tested and the lab did identify some factors that are known to inhibit plant growth. However, marine sediments placed supra-tidally (i.e. subjected to oxidation) are complex chemistries. These soils are known to acidify, and their high clay content provides chemical and structural binding sites for elements that, for better or worse, influence soil chemistry with regards to plant life. This remains a potential influence on project success.

Our recommendations to create future plant communities on remnant levees are as follows:

1) Focused research by specialized soil and plant scientists to clarify the chemistries of oxidized dredge spoils and their suitability for plant communities.

2) Construction specifications must include:
    a. not lowering levees below transition zone elevations,
    b. uncompacting the upper 1-3 feet of the soil surface,
    c. creating microtopography (roughness and small depressions) via tilling or other methods,
    d. reducing the slopes as much as possible through creating broad levee flanks,

3) Continued applied research on suitable native species, and an emphasis on the use of diversity in habitat restoration projects, so that appropriate plant species can be found regularly in the commercial seed industry.

Figure 22 and 23. 2012-13 results from a similar seeding project at Moffett Field
Note: The dominant species shown here, goldfields (Lasthenia sp.) were not part of our mix in 2011.

Appendices

Appendix A:

Nursery Trials - Seed Mix Study

Purpose

The goal of the nursery trials was to evaluate the performance of the seed mix, which was purchased from Pacific Coast Seed Inc. (Livermore, CA) and used in the Pond A6 aerial hydroseeding in 2011. The presented study provides information on the germination of seeds per species in a controlled nursery environment which is useful to:

a) evaluate the performance of the seed mix as a whole when combined with results from other sets of experiments under natural and semi-controlled conditions
b) identify seed stratification needs for certain species to improve their germination in future projects, and
c) consider changes in the consistency of the seed mix in the future (e.g. take out species that are consistently performing poorly even in a controlled environment) to improve efficiency.

Methods

Prior to seeding, the seeds were mixed thoroughly in the initial package to ensure uniformity. A 1kg seed mix sample was put in a clean container and from this 9 samples of 0.7 gr each were taken (the seeding rate). A total of nine experimental flats (0.30 x 0.55 m) were filled with three different potting media (three flats per potting media) and seeded with 0.7 gr of the seed mix. Table 1 shows the composition of the three potting media. Seeds were covered with a thin layer of sieved compost. Seeding took place on the 29th of November, 2011. The flats were initially covered with light plastic net to protect from birds and were placed in a random fashion on the germination table, in the large shade house at the EEC nursery at the Don Edwards San Francisco Bay National Wildlife Refuge. They were watered with two minutes of fine spray once a day. In later months, when the conditions were hot and dry, the flats received extra watering. Later the flats were covered with hard wire cages to avoid disturbance from wildlife and entanglement of the seedlings in the net.

The first seedling count took place on Dec 13th. Initially, the number of monocots and dicots were counted for each tray. Species of seedlings were recorded when discernible. Monitoring took place every week for the first two months and then every four weeks until the end of July.

Table a. Description of the three potting media used

Potting media	Description
Clayish	4 prt clay top soil : 1prt redwood compost amendment
Medium	6 part clay : 2 prt compost: 1 prt redwood : 1 prt vermiculite : 1 prt perlite
Light	5 prt vermiculite : 4 prt peat moss : 1 prt perlite

Results

Table b presents the maximum counts of each species on each flat. Because seed germination and time of species identification are asynchronous, maximum counts describe the potential of the seed mix better.

Of the 28 species in the mix, 21 species were identified with great confidence at the species level. For the perennial grass species *Leymous triticoides* (J2 new name *Elymus triticoides*), there was an ambiguous record of presence. Identification of grasses to the species level usually requires the inflorescence. In this case, there were no flowering parts and the seedlings were observed at the first stages of growth which makes identification questionable. The same limitations could apply to *Distichlis* spicata but the very distinctive form of the plant, even in early stages, allows for higher confidence in identification. Of the total seven species of grasses in the mix, only three were identified with 100% confidence, since they flowered during the observation's period. *Festuca microstachys* scored the greatest numbers in all but one flat. *Bromus maritimus* was the second more abundant species.

Table b. Maximum counts of seed mix species on flats of three different potting media. To determine the max values all census dates were considered. Grand max indicates the maximum value found considering all trays and dates and indicates presence or absence of seedling of a particular species based on the tray data.

Potting Media	**Medium**			**Clayish**			**Light**			**All media**
Species/ Tray #	T3 Max	T5 Max	T7 Max	T2 Max	T4 Max	T8 Max	T1 Max	T6 Max	T9 Max	Grand Max
Achillea millefolium	3	3	6	7	6	4	1	6	6	7
Ambrosia psilostachya	1	1	0	0	0	1	0	3	0	3
Amsinckia menziesii	0	2	3	1	6	1	6	3	5	6
Artemisia californica	1	0	0	0	0	1	0	2	0	2
Aster chilensis	0	0	0	0	0	0	0	0	0	0
Calandrinia ciliata	0	0	2	1	0	1	0	0	0	2
Centromadia pungens	1	0	0	0	0	0	2	3	1	3
Epilobium brachycarpum	4	5	5	0	5	5	8	6	6	8
Eriophyllum confertiflorum	6	0	2	0	1	0	1	3	4	6
Escholschzia californica	11	5	27	14	12	11	13	14	16	27
Euthamia occidentalis	0	0	0	0	1	2	1	0	1	2
Frankenia salina	0	0	0	1	0	1	0	5	3	5
Grindelia stricta	0	0	1	0	0	0	0	0	0	1
Heliotropium currasavicum	0	0	0	0	0	0	0	0	0	0
Heterotheca grandiflora	6	7	5	6	8	8	4	6	5	8
*Limonium californicum**	6	5	4	4	6	5	6	7	8	8
Lotus purshianus	3	3	8	3	3	6	5	4	4	8
Lupinus succulentus	2	4	0	0	1	2	3	1	2	4
Malvella leprosa	0	0	0	0	0	0	0	0	0	0
Phacelia californica	0	2	1	1	0	1	2	1	1	2
Sarcocornia pacifica	0	1	2	0	0	3	1	1	1	3
Bromus maritimus	3	4	8	10	2	10	7	1	3	10
Distichlis spicata	1	2	1	0	0	0	0	0	0	2
Hordeum depressum	2	1	2	2	2	4	2	0	1	4
Leymus triticoides	2	0	2	0	0	0	0	0	0	2
Leymus condensatus	0	0	0	0	0	0	0	0	0	0
Nasella pulchra	0	0	0	0	0	0	0	0	0	0
Festuca microstachys	18	6	9	8	8	14	15	14	15	18

Appendix B:

Hydromulch Study

In summer 2012, we collected several small samples of hydromulch from Pond A6's seeded areas. The sample method involved scraping a thin layer of topsoil where the hydromulch was visible. We also collected samples from areas where we considered the hydromulch absent to use as controls.

On the 25th of July , we placed the samples on flats filled with sterilized potting soil and set the flats in the nursery shadehouse where they were watered daily for two minutes. We used wire cages to protect them from browsing. The rationale for conducting this experiment was to identify whether there were viable seeds in the hydromulch more than 8 months after seeding. Since we were collecting hydromulch cover data during the 2012 monitoring survey, we wanted to know their potential for recruitment in year two.

Results

The list of species that germinated in flats with hydromulch and control samples are presented in Table c. Overall, there were 7 species from the seed mix that germinated in the flats with the hydromulch samples. The presence of Seaside heliotrope (*Heliotropium currasavicum)* was surprising since it did not show up at all in the seed mix experiment. However, in a separate stratification study we identified that this species needs moist and very warm conditions to germinate. These conditions were met at the time of starting this study at the end of July. Slenderleaf iceplant (*Mesembryanthemum nodiflorum)* was abundant in all samples. This non-native species is abundant and widespread in the region.

Table c. Hydromulch nursery experiment results. Counts of species germinated for hydromulch and control samples.

Species name	Hydromulch sample plant counts	Control Sample plant counts
Bromus maritimus	2	-
Escholschzia californica	2	-
Festuca microstachys	3	-
Frankenia salina	12	-
Heliotropium currasavicum	1	-
Limonium sp	1	-
Sarcocornia pacifica	3	-
Mesembryanthemum nodiflorum	100	>100

Appendix C:

Year 1 Monitoring Protocols

In the first growing season after hydroseeding our monitoring efforts followed a stratified random sampling design, with stratification based on the general region and breaks created by levee breaches. The seven segments monitored are listed in Table 1. On each segment the researchers used two-digit random numbers to locate random sampling points along the length of the segment. For each sampling point the researchers would identify the type of tidal marsh gradient zones included in the seeded area (e.g. the 8.23 meters wide seeding swath width). The three gradient zones were High Marsh, Transition and Upland (Table e), which are perpendicular to the seeding swath long axis due to the topography of the levee remnants. In each gradient zone present at a sampling point, a 1 m^2 quadrat was randomly placed and vegetation cover data were recorded based on visual estimation. The visual estimation was done by the same two researchers at all times to minimize bias. The percent cover of bare ground, litter, wrack and hydromulch were also recorded. The presence of hydromulch was mostly defined by the visibility of fibers used in the hydromulch.

Table d. List of Segments monitored in Year 1.

Segment description	Length in meters
East island	709
Eastern part of North Island	770
North Island	1612
SE Corner	376
South Levee	974
SW Corner	323
W island	650

Table e. Definition of the three gradient zones present in the hydroseeded area.

Gradient Zone	Description
High Marsh	Frequently influenced by tidal action. The lower limit of the zone towards the marsh is adjacent to the marsh plain or tidal flat and the upper limit is around the backshore. We define the backshore elevational contour somewhat higher than the Mean Higher High Water datum. Wrack line usually present.
Transition	The zone above High Marsh. Minimally influenced by tidal water during extreme events (i.e storms, king tides). This zone is always higher than the backshore. May be strongly affected by salts deposited by strong onshore winds. It may contain a mixture of salt marsh and upland salt tolerant species. Wrack deposition is common when the zone includes a flat area.
Upland	The zone extending above transition zone. This zone is not reached by regular tidal action and is characterized by upland conditions. Wrack deposition is rare.

Floristic composition

Table f. Mean percent cover and standard deviation of the mean of all recorded species in the three tidal salt marsh gradient zones. Data are presented from the 2012 monitoring survey.

		High Marsh		Transition		Uplands	
Scientific name	**common name**	Mean	SD	Mean	SD	Mean	SD
Atriplex prostata	Fat hen	0.40	1.656	0.81	3.302	0.04	0.439
Atriplex semibaccata	Australian saltbush	0.76	4.843	1.41	5.097	1.92	6.481
Cotula coronopifolia	Brass buttons	0.76	2.209	0.21	1.241	0.00	0.000
Distichlis spicata	Saltgrass	2.42	11.05	1.25	4.897	0.06	0.510
Frankenia salina	Alkali heath	6.87	12.01	8.09	15.62	0.85	4.136
Hydromulch	Hydromulch	0.40	2.748	10.29	14.39	11.68	14.610
Jaumea carnosa	Marsh jaumea	0.02	0.137	0.00	0.000	0.00	0.000
Lepidium latifolium	Pepperweed	3.53	7.544	2.22	7.523	0.00	0.000
Mesembryanthemum nodiflorum	Slenderleaf iceplant	0.00	0.000	2.88	8.205	4.68	14.501
Salsola soda	Alkali Russian thistle	0.06	0.412	0.06	0.382	0.00	0.000
Sarcocornia pacifica	Pickleweed	34.13	29.52	7.34	12.00	0.00	0.000
Spergularia marina	Salt Marsh Sand Spurry	1.81	4.579	2.25	6.634	0.08	0.877
Tetragonia tetragonioides	New Zealand spinach	0.09	0.687	1.18	7.310	0.54	2.659
Wrack	Wrack	2.83	8.744	3.24	9.295	0.00	0.000
Litter	Litter	0.19	1.374	3.46	10.58 9	28.73	35.098
Bare ground	Bare ground	46.87	31.27	65.62	29.02	63.18	37.780

Year 2 Monitoring Protocols

The major goals of the 2013 monitoring survey were to:

a) Describe the plant community the second year after hydroseeding took place, and
b) Investigate potential patterns in the recruitment of seeds from the hydroseeded mix related to environmental conditions on the site.

Monitoring followed a stratified random sampling method. Stratification was based on the different treatments applied during construction and the prevalent aspect of the segment (Figure a). Table g shows the list of strata used for this survey and the number of random points per strata. The number of sampling points was defined based on vegetation variability for each strata. Vegetation variability was assessed by inspecting the site visually during February and March and from the vegetation and gradient zone data collected in 2012. To ensure that the whole stretch of each stratum would be sampled, each stratum was divided into equal-length segments and the point was randomly selected within each part (i.e. tessellation).

Figure a. Sampling stratification based on the construction design

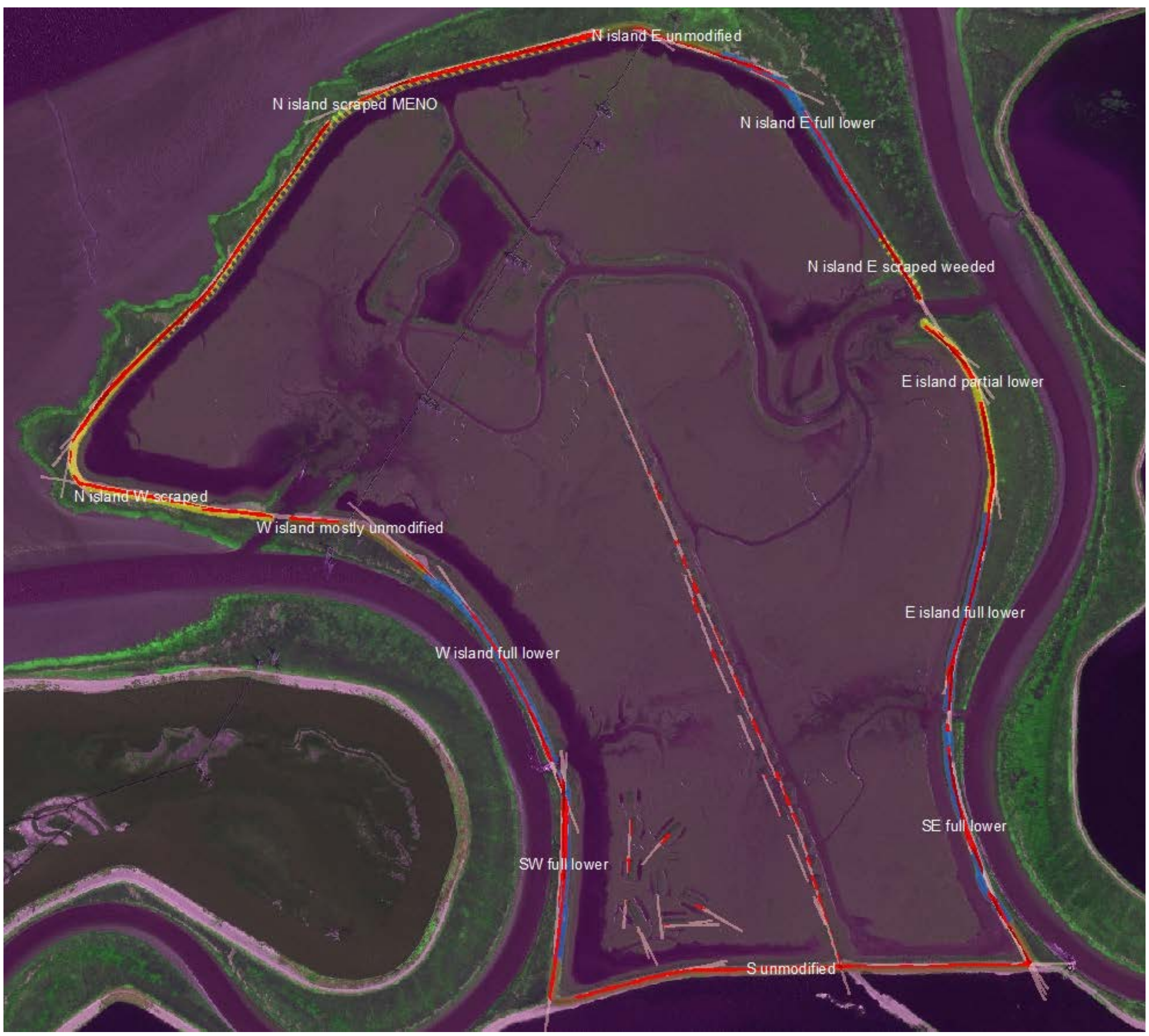


Table g. List of strata and corresponding number of sampling points in Year 2

Monitoring Area Sratum	length (m)	Number of points	Segments' length
E island partial lower	366	11	33
N island scraped MENO	987	25	39
W island full lower	396	5	79
S unmodified	974	25	39
SW full lower	323	5	65
SE full lower	376	5	75
E island full lower	343	5	69
W island mostly unmodified	254	5	51
N island W scraped	625	10	62
N island E scraped weeded	126	5	25
N island E full lower	431	6	72
N island E unmodified	213	6	36

For each sampling point we randomly located a 1 m^2 quadrat and recorded the gradient zone (Table h), and the vegetation percent cover per species. We also recorded bare ground, litter and wrack cover. Finally, we recorded microtopography, slope, aspect, and soil compaction data (Table h) for the point at the center of the quadrat.

In addition to the quadrat data, we collected data on the recruitment of species from the hydroseeded mix. We randomly selected plants that likely recruited from the hydromulch and recorded data on the microtopography, slope, presence of plant community, and aspect. In addition, we measured the height of the target plant. Table h lists the variables used to address recruitment and their states.

Table h. Description of variables used to assess conditions of recruitment.

Variable	Description
Species	Name
Height	Plant height in cm
Community	Presence or absence of other plants immediately adjacent
Aspect	Cardinal
Slope	• Flat • Gradual • Steep
Microtopography	• Smooth • Some roughness • Small depression(s) • Tilled or chunky • Large depression
Compaction	• High • Moderate • Light • Uncompacted

Floristic composition

Table i. Mean percent cover, and standard deviation of the mean, of all recorded species in the three tidal salt marsh gradient zones. Data were collected in the 2013 monitoring survey.

		High Marsh		Transition		Uplands	
Scientific name	**common name**	Mean	SD	Mean	SD	Mean	SD
Amsinckia menziesii	Fiddleneck	-	-	0.54	1.319	0.04	0.270
Atriplex prostata	Fat hen	-	-	1.50	4.615	0.32	1.387
Atriplex semibaccata	Australian saltbush	-	-	2.18	6.912	3.65	10.566
Bromus diandrus	Ribcut brome	-	-	-	-	0.52	2.465
Bromus hordeaceus	Soft chess brome	-	-	0.21	0.957	0.24	1.821
Cuscuta salina	Saltmarsh dodder	0.06	0.250	-	-	-	-
Cotula coronopifolia	Brass buttons	0.50	1.317	1.00	1.846	0.02	0.121
Distichlis spicata	Saltgrass	0.13	0.500	1.64	7.539	0.93	4.406
Festuca microstachys	Small fescue	-	-	-	-	0.04	0.270
Frankenia salina	Alkali heath	9.88	15.86	24.46	30.89	1.57	6.647
Hordeum depressum	Alkali barley	-	-	-	-	0.02	0.121
Hordeum marinum	Seaside barley	-	-	0.29	1.084	0.53	1.832
Hordeum murinum	Foxtail barley	-	-	-	-	0.15	1.213
Jaumea carnosa	Marsh jaumea	3.13	12.50	0.04	0.189	-	-
Lepidium nudum	Pepperweed	1.63	2.895	4.32	8.433	0.09	0.617
Limonium ramosissimum	Algerian	-	-	0.07	0.378	-	-
Mesembryanthemum nodiflorum	slenderleaf iceplant	-	-	7.64	10.584	12.27	15.647
Parapholis incurva	Curved sicklegrass	-	-	0.00	0.000	0.03	0.243
Polypogon monspeliensis	Rabbitsfoot grass	-	-	0.57	2.080	0.04	0.364
Raphanus sativus	Wild radish	-	-	-	-	0.15	1.213
Salsola soda	Alkali Russian	-	-	0.04	0.189	-	-
Sarcocornia pacifica	Pickleweed	50.81	28.12	12.96	14.34	0.56	2.766
Sonchus asper	Spiny sowthistle	-	-	1.21	2.500	0.32	1.714
Spergularia marina	Salt Marsh Sand	3.25	8.371	4.79	9.558	0.32	1.569
Tetragonia tetragonioides	New Zealand spinach	0.13	0.500	3.68	7.394	3.75	12.673
Bare Ground	Bare Ground	30.06	28.08	20.14	17.10	60.87	36.240
Litter	Litter	-	-	12.79	13.45	13.79	19.568
Wrack	Wrack	5.00	7.303	1.61	6.811	0.66	3.854
Grass	Grass	-	-	0.21	0.833	0.06	0.382

Appendix D: Additional Photos

Photo A. A high diversity of species recruited from seed in 2013, including common fiddleneck, California poppy, alkali barley, small fescue, and California brome; also present are New Zealand spinach, perennial pickleweed, and alkali heath, among others.

Photo B. Hydromulch still obvious in the early spring of 2012

Photos C & D. Hydromulch comparison between the spring of 2012 and fall of 2011; light beige color shows mulch presence in the lower area in 2012, which was green in 2011.

Photo E. Hydromulch in fully lowered section during the fall of 2011 shortly after seeding

Photos F - H. Aerial Hydroseeding in action

Photos I and J. Aerial Hydroseeding equipment (please note: pilot standing outside of the plane)

Photos K and L. Post-construction conditions (winter of 2010), showing tilled higher elevations and somewhat smoothed lower elevations