Vegetation Colonization Thresholds and Marsh Platform Expansion at a Tidal Freshwater Restoration Site in the Sacramento-San Joaquin Delta, California

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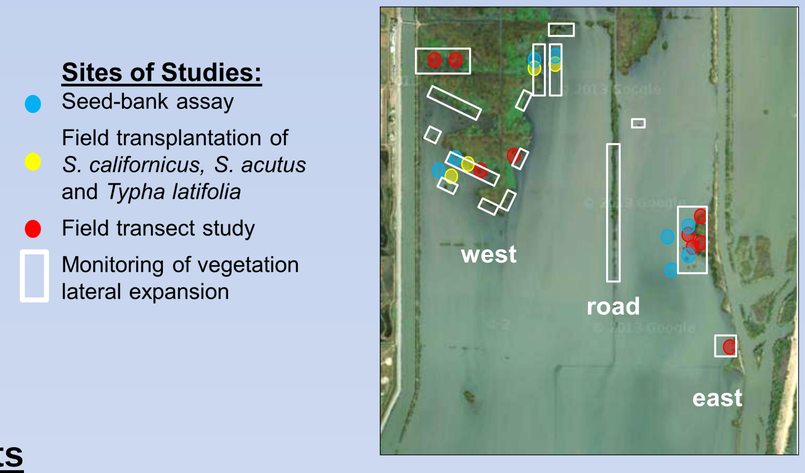
The Sacramento-San Joaquin Bay Delta has undergone substantial anthropogenic alterations and is in need of effective wetland restoration. Successful and sustainable restoration is best accomplished when there is a thorough understanding of the tolerances of desired wetland plant species to environmental conditions at the selected restoration site. We employed a combination of manipulative and observational studies to elucidate key factors controlling vegetation colonization and expansion dynamics in a tidal freshwater *Schoenoplectus* spp.(tule) marsh restoration site at Liberty Island, CA. The insights gained from this research are broadly applicable to the restoration of altered tidal freshwater wetland habitats in the region.

Methods

We assessed seed-bank dynamics by collecting 5-cm deep cores from intertidal and subtidal mudflats in several areas of Liberty Island in September 2010 and June 2011. We evaluated the potential of utilizing transplants to enhance the establishment and expansion of key species. This was done with rhizome only or intact adult transplants of *S. californicus, S. acutus* and *T. latifolia* starting in June 2010. Transplants were monitored for survival, growth and expansion for two years.

In May of 2010, a transect study was initiated to assess relationships between plant and soil characteristics in *S. californicus* marshes. 1-m^2 plots were established in four zones (marsh interior, marsh fringe (edge), adjacent mudflat, open mudflat) on both the east and west sides of Liberty Island. Transect plots were monitored for stem density and height, as well as soil elevation and physicochemical properties for two years. Real Time Kinematic (RTK) surveys were conducted at transect, transplant, and natural marsh edges in September 2010, 2011, and 2012. Survey points were reoccupied each year to determine change in elevation and lateral expansion of marsh edge.

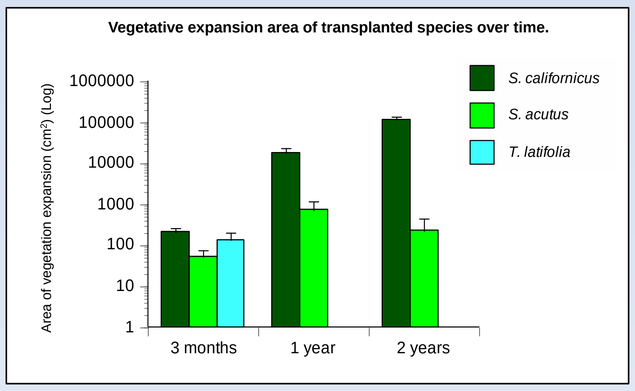
Liberty Island CA Restoration Site

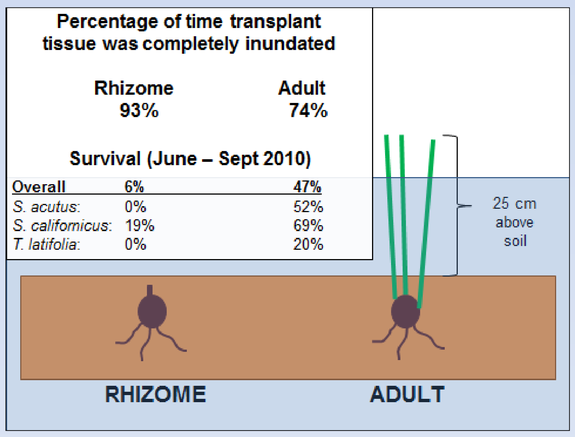


Results

The seed-bank assay revealed the occurrence of viable seeds for a greater number of species than is visually present in the emergent wetland plant community, suggesting that environmental conditions limit the successful germination (likely excessive flooding) and persistence of many species present in the seed-bank.

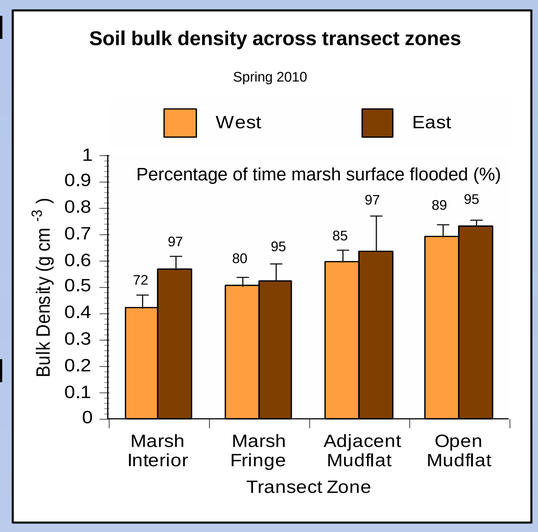
Adult transplants far out-performed rhizome transplants likely due to less percentage of time the adult transplants were completely inundated. We believe the transport of oxygen from the atmosphere down the cut stems to the belowground tissues was crucial to survival and establishment.

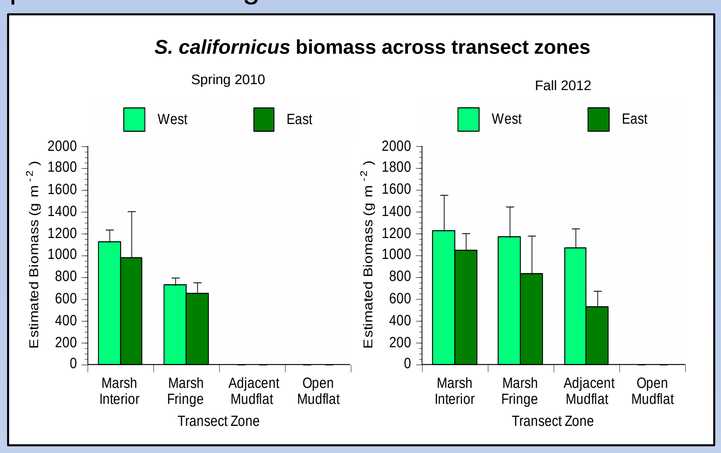




S. californicus transplants exhibited significantly higher survivorship and vegetative expansion compared to *S. acutus* and *T. latifolia.*

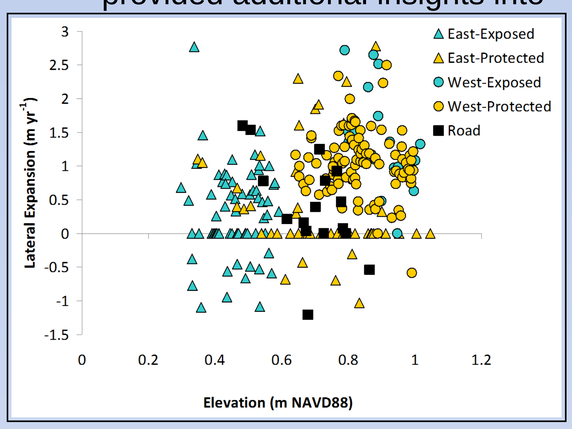
The east side of Liberty Island is characterized by lower elevations and consequently a greater percentage of time the marsh platform is flooded than the west side. Further, the east side exhibited greater depth to soil penetration resistance, lower soil organic matter and lower aboveground biomass. Marsh platform development appears to be modulating soil development. This is particularly evident on the west side where soil organic matter generally increased from the mudflat to the interior marsh, and lower soil bulk density tended to correspond with the prevalence of vegetation.





The RTK survey of marsh edge lateral expansion also indicated a general positive relationship between elevation and rate of lateral expansion, with eastern exposed edges tending to have the lowest elevations and lowest rates of lateral expansion (see below).

Principal Components Analysis provided additional insights into relationships between variables. Lateral expansion loaded equally on both Principal Components, whereas aboveground biomass had a strong positive loading on Principal Component 2 that was associated with a negative loading of soil bulk density. Principal Component 1 was characterized by high loadings of soil organic matter, soil penetration depth and elevation, which as expected was negatively associated with percentage of time flooded.



Variable	Principle Component 1	Principle Component 2
Soil Bulk Density	-0.472	**-0.646**
Soil Organic Matter	**0.580**	-0.497
Depth to Soil Penetration Resistance	**0.730**	0.294
Lateral Expansion	**0.426**	**0.405**
Aboveground Biomass	0.103	**0.857**
Percentage of Time Flooded	**-0.885**	0.256
Elevation	**0.890**	-0.297

Conclusions

The combination of field observations and experiments emphasize the importance of species and life-history stage selection in wetland restoration planning and planting. Elevation and hydrologic regime are key factors regulating plant survival, growth and expansion. Our findings also illustrate the importance of multiple environmental factors, including wind and wave energy, that may exert influence on marsh development and persistence. In summary, recognizing the dynamic interactions between the plant community and the abiotic environment is essential when determining restoration goals and ecosystem thresholds.

Acknowledgments

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