Tracking Soil Dynamics to Understand Plant Community Development in Restored Tidal Wetlands

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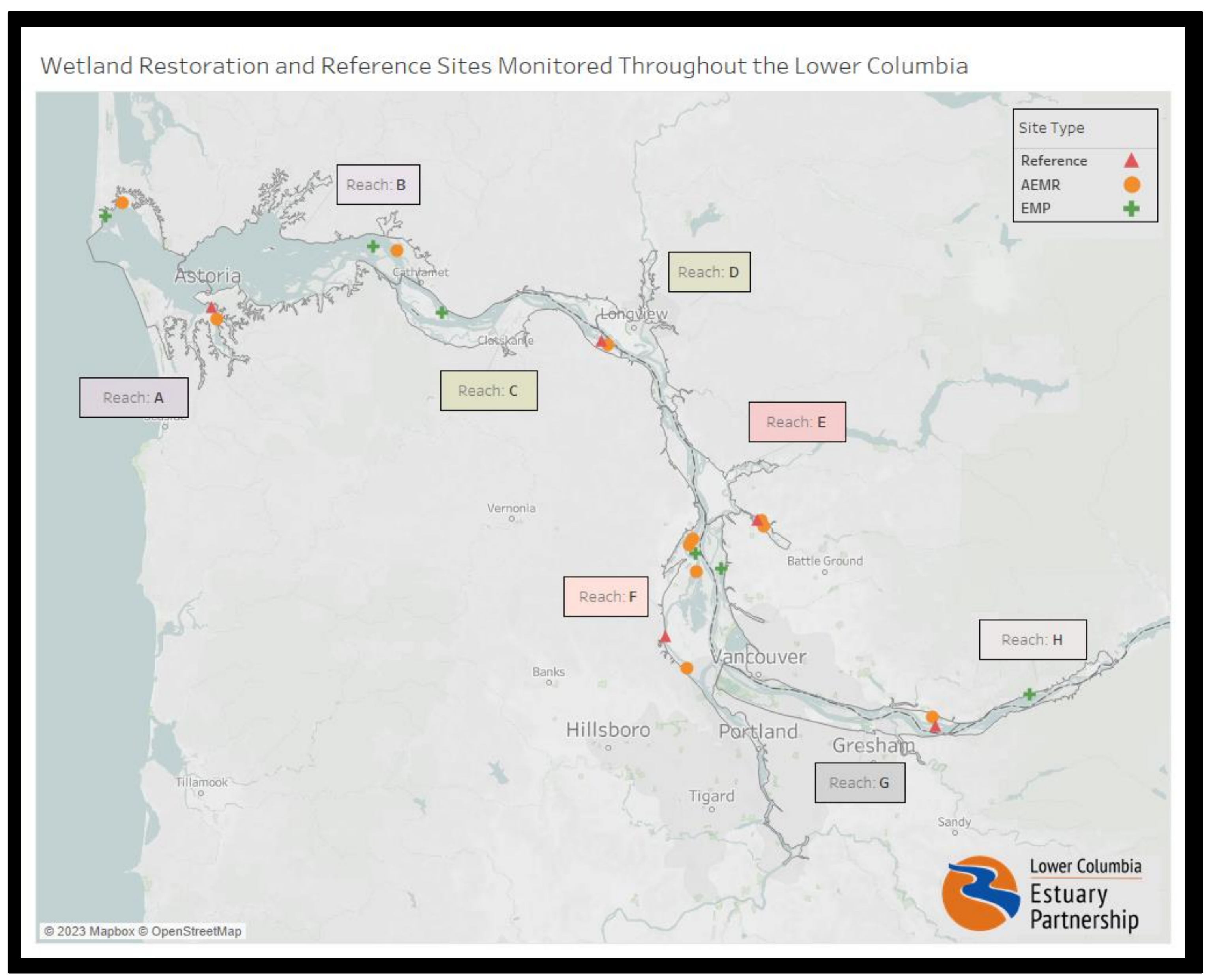
Abstract

Through monitoring soil conditions, this research aims to help us better understand the ecological mechanisms driving plant community development within tidally restored wetlands. Pre-restoration agricultural sites typically consist of well-drained soils with high oxygen concentrations. Reintroducing tidal flooding saturates the soil, creating an anaerobic wetland environment. In more saline sections of the estuary, this shift in soil oxygen levels is also accompanied by a shift in salinity. The restoration of these tidal wetland dynamics causes a cascade of biogeochemical and microbial reactions in the soil—ultimately affecting plant community establishment. In this study, we monitor these biogeochemical changes using in-situ soil ORP (oxygen reduction potential), pH, and salinity probes across multiple restoration and reference sites throughout the Lower Columbia River Estuary. These data provide insight into factors that drive the continued dominance and spread of Reed canarygrass (*Phalaris arundinacea*). In contrast to successful native plant communities, Reed canarygrass (*Phalaris arundinacea*) was found to thrive primarily in soil with lower pH and salinity values, and higher ORP levels. The results and methods developed from these soil monitoring efforts can be used to guide continued native plant community restoration and adaptive management efforts throughout the estuary.

Why Monitor Soil?

- Soil is a fundamental component of ecosystem structure and function. In wetlands, it drives essential functions such as nutrient retention, seed germination, and plant growth.
- Wetland restoration, including reintroducing or shifting flooding regimes, dramatically alters soil conditions.
- These soil changes form a new template for wetland plant community development.
- Monitoring these soil transitions allows us to better understand and manage this plant community development.
- This understanding guides more effective and resilient wetland restoration efforts.



Methods

Materials: *The study requires various probes for ORP, pH, salinity, conductivity, and temperature measurements. Other necessary tools include a regular fork, squirt bottle, and calibration solutions.*

Sites: Map of sites with concurrent soil data and vegetation data used in these analyses. There are 21 sites and 2000 soil data points used for this analysis – soil data collection began in 2017 and these data go through 2022. See 2022 AEMR report for more details

Methods: *All probes must be calibrated after each field day and verified each time. In the field, probes are inserted about 5cm deep into the soil and readings are recorded for each metric. If the soil is too hard, a fork is used to soften it, or a slurry is created with water. Readings are taken in standing water if it's >10cm deep.*

Data Management and Analysis: *The data collected will be used to inform the expected plant communities and the overall health of the ecosystem. All data was analyzed using Tableau.*

ExTech Soil Probes and Deployment at John R Palensky Restoration Site, 2021

Note: All data are provisionary and still under review.

Soil Parameters Measured

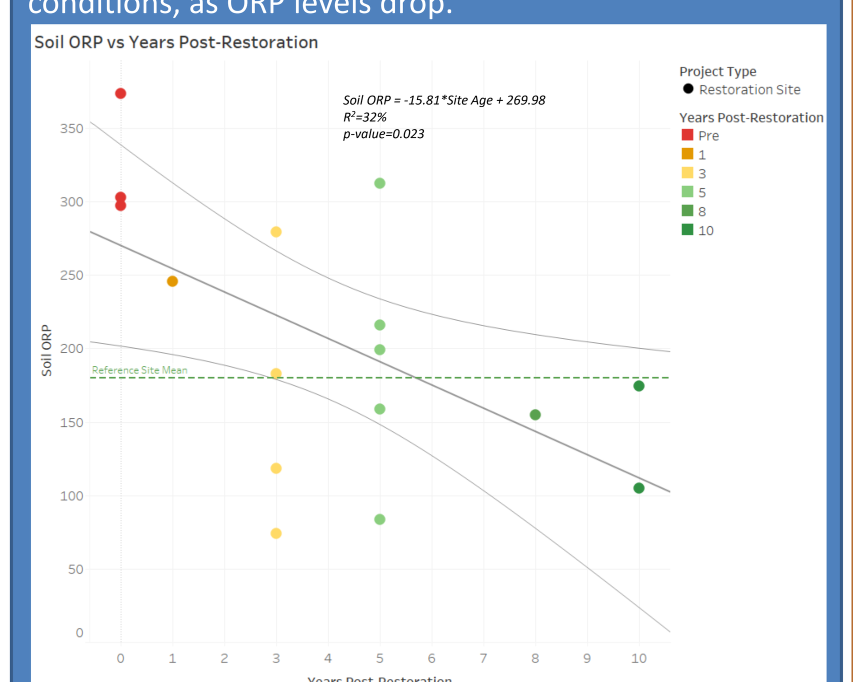
Oxygen Reduction Potential (ORP): Indicates the shift from oxygen-rich, well-drained pre-restoration soil to anaerobic, waterlogged post-restoration soil.

pH: Influences nutrient availability and microbial activity, impacting plant growth and community composition. Reed canarygrass thrives in lower pH soils.

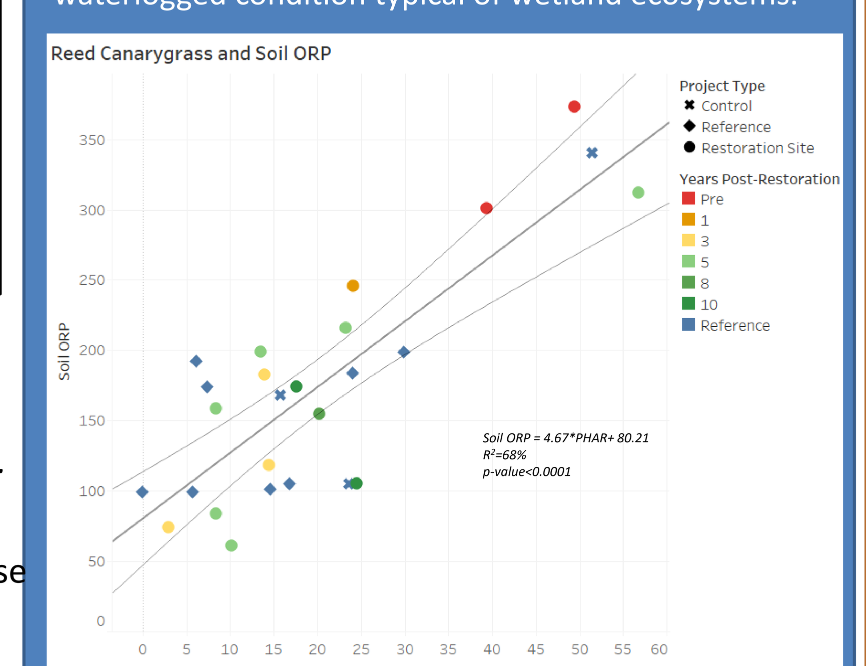
Salinity: Critical in estuary environments as it directly affects plant growth, species composition, and diversity. Shifts in salinity influence plant community responses and adaptations.

Reed canarygrass at Steigerwald 2020

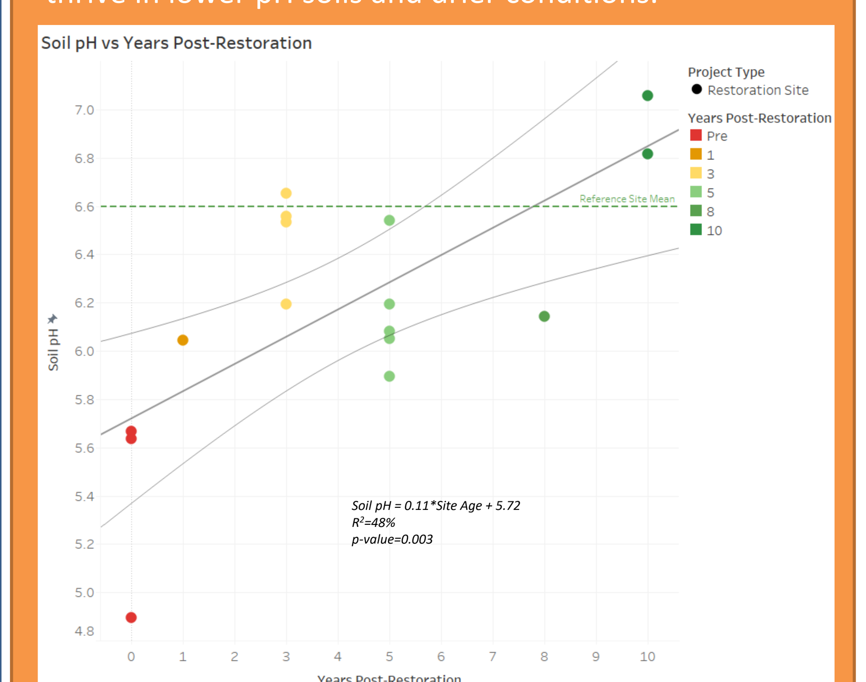
Hypothesis 1: The Oxygen Reduction Potential (ORP) in the soil is expected to decrease significantly after the reintroduction of tidal flooding. This shift from a high to low ORP will mark the transition from an oxygen-rich, well-drained soil environment to an anaerobic, waterlogged condition typical of wetland ecosystems. Consequently, we anticipate a corresponding decrease in the prevalence of Reed canarygrass (*Phalaris arundinacea*), a species known to thrive in higher ORP conditions, as ORP levels drop.



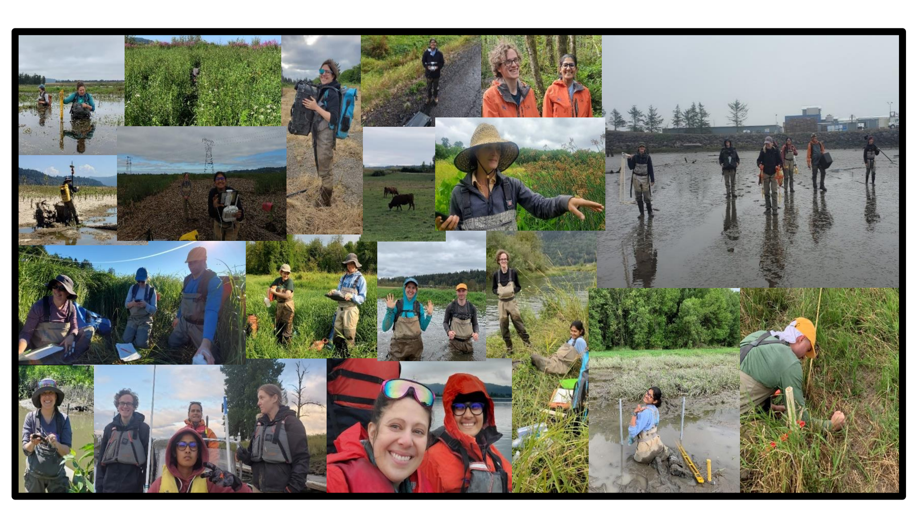
The findings of our study confirm the hypothesis that the Oxygen Reduction Potential (ORP) in the soil significantly decreases after the reintroduction of tidal flooding (P = 0.023), above, and below are significantly Correlated with a drop in Reed canarygrass abundance (p<0.001). This marked shift from high to low ORP underscores the successful transition from an oxygen-rich, well-drained soil environment to an anaerobic, waterlogged condition typical of wetland ecosystems.



Hypothesis 2: The pH of the soil may increase, especially in areas exposed to prolonged flooding, after tidal flooding is reintroduced. This shift, potentially driven by changes in biogeochemical processes and microbial activity in a waterlogged, anaerobic environment, may be influenced by site-specific conditions such as initial soil properties and the type of vegetation present. An increase in soil pH is expected to negatively correlate with the cover of Reed canarygrass (*Phalaris arundinacea*), an invasive species found to thrive in lower pH soils and drier conditions.



Our research results substantiate the hypothesis that soil pH increases after the reintroduction of tidal flooding, particularly in areas exposed to prolonged flooding [P < 0.003]. Importantly, we observed a negative correlation between increased soil pH and Reed canarygrass (*Phalaris arundinacea*) cover, supporting the assertion that this invasive species thrives in lower pH soils and drier conditions.



Acknowledgements

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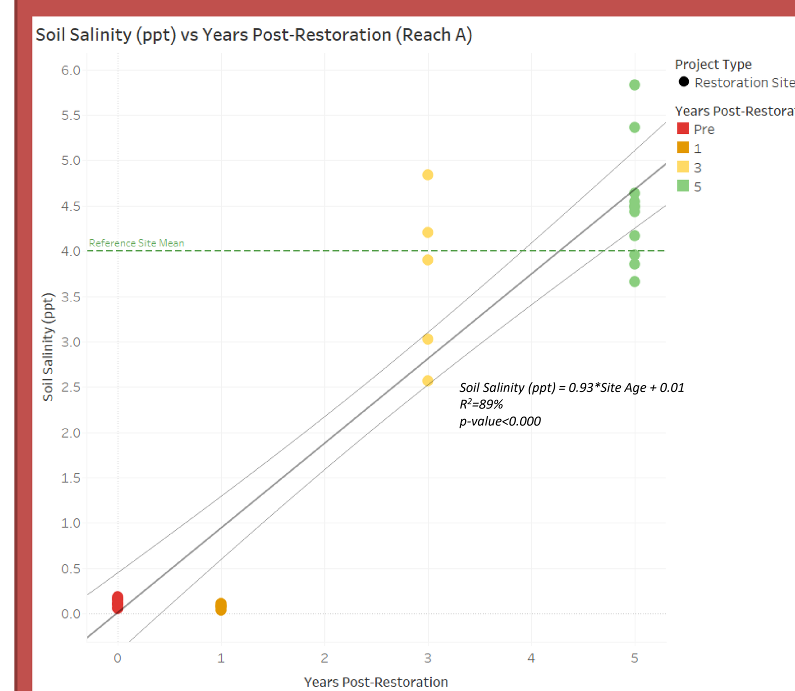
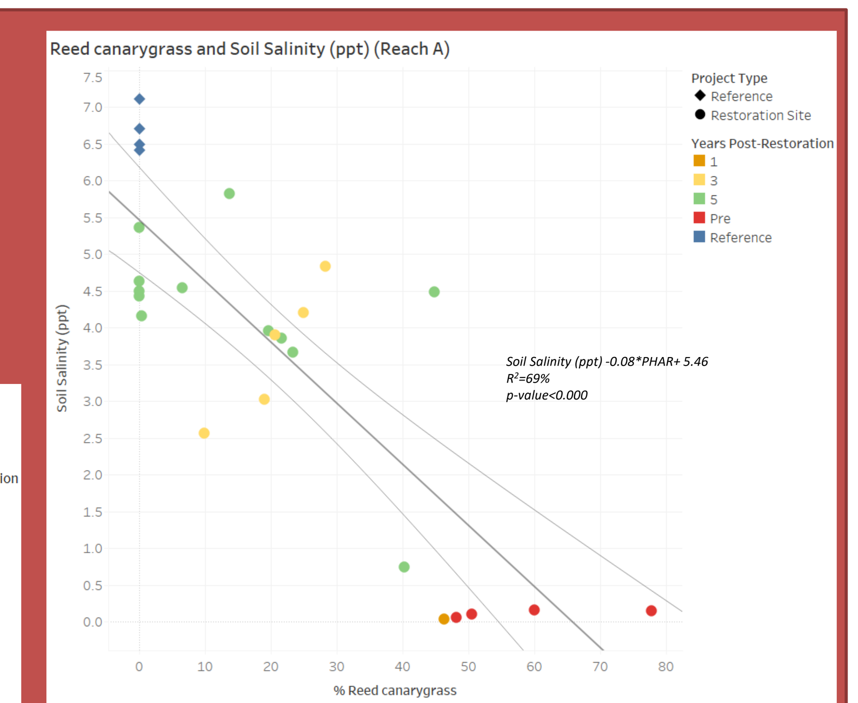
Hypothesis 3: In Reach A, as salinity increases due to the reintroduction of tidal flooding, we anticipate a shift in plant communities. Reed canarygrass (*Phalaris arundinacea*), a species favoring lower salinity conditions, may decline. Conversely, native wetland species, which are adapted to higher salinity conditions, may become more dominant.

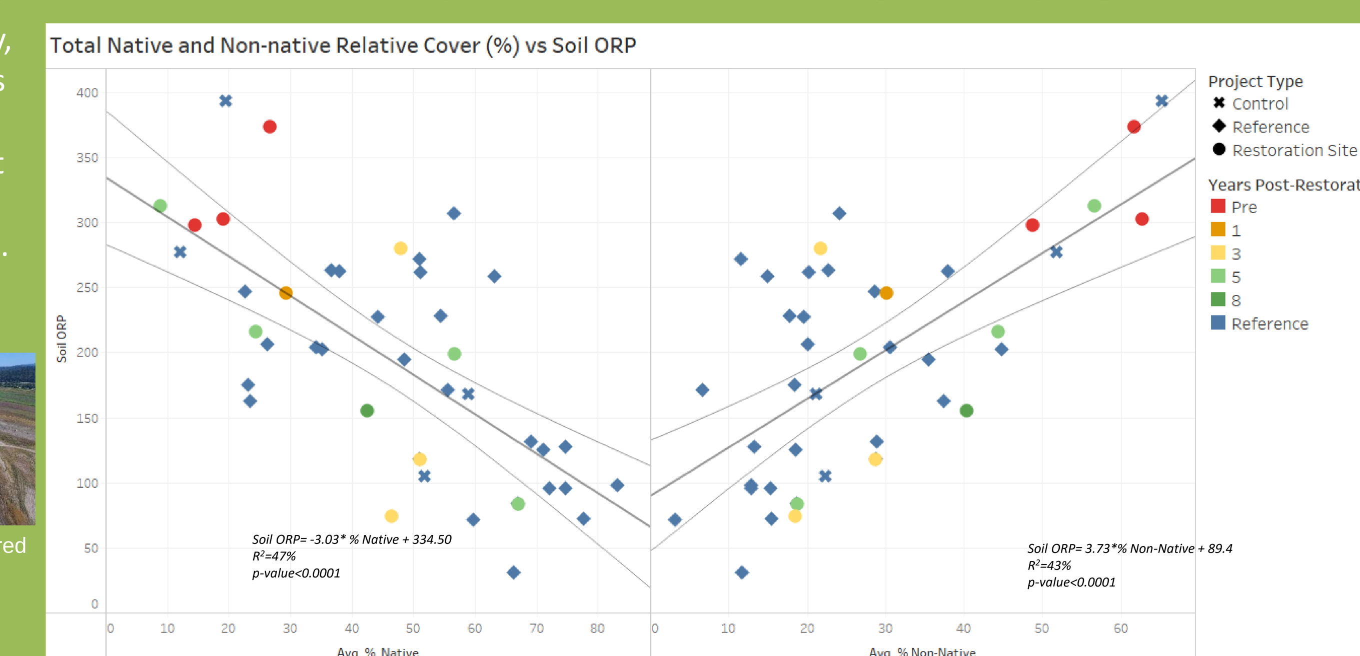




The data from our study robustly support the hypothesis that an increase in salinity triggers a shift in plant communities [P < 0.01]. We observed a noticeable decline in Reed canarygrass (*Phalaris arundinacea*), which prefers lower salinity conditions. Concurrently, native wetland species, adapted to higher salinity conditions, showed increased dominance, highlighting the critical role of salinity in influencing plant community composition in restored tidal wetlands.

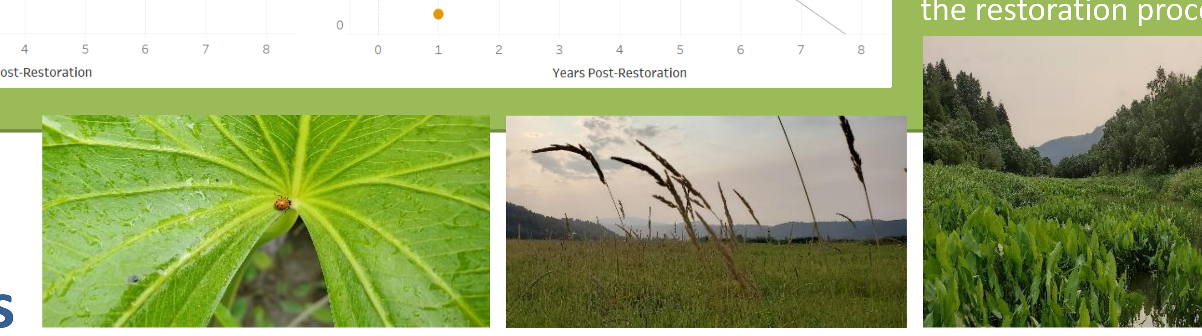
Hypothesis 4: Changes in soil parameters, including oxygen availability (as indicated by ORP), pH, and salinity, are expected to impact plant community composition in the restored wetland. As these soil conditions shift, it can lead to changes in microbial community composition and activity, influencing nutrient cycling processes, and consequently, the dynamics and development of plant communities.

Steigerwald, Restored 2022



Our research supports the hypothesis that wetland restoration significantly alters soil conditions, which in turn impact plant community dynamics. soil conditions in the restoration process.

Notably, non-native species such as Reed canarygrass (*Phalaris arundinacea*) decline, while native emergent wetland species like Wapato (*Sagittaria latifolia*) increase post-restoration. The provided figures collectively underscore these findings, highlighting the importance of understanding site-specific soil conditions in the restoration process.



Conclusions

The study's conclusions highlight the pivotal role of soil parameters in wetland restoration. The reintroduction of tidal flooding significantly decreased the Oxygen Reduction Potential (ORP) in the soil, marking a successful transition from an oxygen-rich, well-drained environment to an anaerobic, waterlogged condition typical of wetland ecosystems. Concurrently, a slight decrease in soil pH was observed, likely due to an increase in decomposition and subsequent release of organic acids in this new anaerobic environment. The magnitude of this pH shift was found to be influenced by site-specific factors such as initial soil properties and vegetation type. The shift in salinity triggered a significant change in plant communities: Reed canarygrass (*Phalaris arundinacea*), which prefers lower salinity, declined, while native wetland species adapted to higher salinity and lower ORP conditions became more dominant. Moreover, these changes in soil parameters significantly affected the microbial community composition and activity, thereby influencing nutrient cycling processes and plant community dynamics in the restored wetland. These conclusions underscore the critical importance of monitoring soil parameters in guiding successful wetland restoration efforts.