St. Louis River Wild Rice Restoration Substrate Sampling and Mapping Report

Prepared for
Minnesota Land Trust

December 7, 2017

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Acronyms

Acronym	Description
AOC	Area of Concern
ASTM	American Society for Testing and Materials
BUI	Beneficial Use Impairment
CL	clay (lean clay)
DIVER	Data Integration Visualization Exploration and Reporting
FdLNR	Fond du Lac Band of Lake Superior Chippewa Natural Resources
GIS	Geographic Information System
GLIFWC	Great Lakes Indian Fish and Wildlife Commission
GPS	Global Positioning System
IDW	Inverse Distance Weighting
MDNR	Minnesota Department of Natural Resources
ML	silt
MPCA	Minnesota Pollution Control Agency
MLT	Minnesota Land Trust
msl	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NAD83	North American Datum, 1983
OL/OH	organic silts and clays
PT	peat
SM	silty sand
SP	poorly graded sand
SP/SM	poorly graded sand with silt
SW	well graded sand
TSF	Tons per Square Foot
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WDNR	Wisconsin Department of Natural Resources

1.0 Introduction

In 1987, the St. Louis River estuary was designated as a Great Lakes Area of Concern (AOC) due to water resource impairments resulting from a history of pollution, unregulated land use, and degraded habitat (Minnesota Pollution Control Agency (MPCA) and Wisconsin Department of Natural Resources (WDNR), 1992). Efforts to delist the St. Louis River AOC are underway through partnerships involving the states of Minnesota and Wisconsin and tribal partners. As a part of this effort to delist the St. Louis River AOC, development of a plan for wild rice restoration in the estuary was identified as an action item in the most recent version of the St. Louis River AOC Remedial Action Plan (MPCA 2013). A critical component of this plan is restoring wild rice beds, which will support the removal of the Beneficial Use Impairment (BUI) 9 – Loss of Fish and Wildlife habitat.

In 2014, Minnesota Department of Natural Resources (MDNR), MPCA, WDNR, Fond du Lac Band of Lake Superior Chippewa - Natural Resources (FdLNR), 1854 Treaty Authority, Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and Minnesota Land Trust (MLT) identified areas to focus restoration efforts for wild rice within the St. Louis River estuary. The Wild Rice Restoration Implementation Plan for the St. Louis River Estuary (Implementation Plan) (MDNR, 2014) outlines the specific implementation strategies to be employed over the next 10 years to restore at least 275 acres of wild rice in the estuary. Within the Implementation Plan, there is a generalized wild rice restoration site selection model based on water depth, energy environment (exposure to wind fetch), and substrate, that assists with choosing areas where the restoration will be focused. This model was developed using existing data sets and from field work conducted in the summer of 2014. Using this model, wild rice restoration work was implemented in 2015 and 2016, with seeding occurring in 10 restoration areas (1854 Treaty Authority, 2016).

In August 2017, Barr Engineering Co. was hired by MLT to complete a substrate sampling study within selected portions of the St. Louis River Estuary to map and quantify substrate parameters for “good” or ”poor” prediction of wild rice establishment success. The initial 2014 Implementation Plan models of the estuary identified numerous sites suitable for wild rice restoration based on water depth and exposure (Figure 1). However, incomplete data on riverbed substrate materials, composition, texture and hardness limited the precision with which the model could predict suitable wild rice establishment areas. Barr quantified and mapped substrate conditions and wild rice performance in seven of 10 previously seeded reference sites, and at four future restoration sites. The parameters used to refine the 2014 Implementation Plan model included soil texture, organic content, substrate penetration force, and localized vegetation type and volume. The reference sites were sampled to provide data to refine the wild rice model and guide future site selection; although it was understood that the reference sites were recently seeded and that rice may not have fully established in all suitable locations within those sites. The intent of the model is not to predict everywhere wild rice could occur, but to identify best conditions to optimize restoration actions.

2.0 Methods

2.1 Sample Design

Seven reference and four restoration sites identified by MLT within the St. Louis River Estuary were evaluated (Figure 1). The reference sites were used to evaluate substrate attributes for successful wild rice establishment. These substrate attributes were mapped at the restoration sites to develop a predictive model to inform future restoration work.

Barr's Field Sampling Plan for St. Louis River Wild Rice Restoration Substrate Sampling and Mapping (Barr, 2017) (Appendix A) provides location maps for the reference and restoration sites that were evaluated.

Previously seeded sites were used as reference areas. It is assumed that seed rain, is not a limiting factors to wild rice presence. Substrate condition is assumed to be the remaining primary environmental variable affecting wild rice establishment, after the other Implementation Plan model variables are considered.

The Field Sampling Plan (Barr, 2017), identified 49 initial sample points within the seven reference sites, and 28 sample points within the four restoration sites. The following sampling design considerations were used to determine the initial sample points at all sites (reference and restoration):

1. Define a transect through the longest axis of the reference site polygon.
2. Dissect the transect into 7 equal segments.
3. Draw a perpendicular transect at the point of each segment.
4. Equally space one or two sample points along the perpendicular transects.
5. Adjust spacing of initial sample points to focus on areas identified as 'medium' and 'high' potential by the 2014 Implementation Plan model.
6. Adjust sample points in the field as needed to accommodate vegetation and/or water depth conditions. For example, if a sample point was located in an area inaccessible due to high density vegetation (e.g., cattails), the sample point was moved to an accessible location where a sample could be collected. If water depth was greater than 5 feet at a sample point, the sample point location was moved inland to a location where water depth was less than 5 feet.

Within the four restoration sites, the number of samples was selected based on site acreage (Table 1). Using ArcGIS, the tool "Create Random Points" was used to randomly place the specified number of points within polygons provided by the MLT. These polygons included sample areas that were inaccessible, specifically due to thick emergent vegetation (e.g. cattails) and out of scope, such as water depths greater than 5 feet. If sample points were initially located within areas found to be inaccessible or out of scope for sampling, the points were relocated during field sampling toward the nearest accessible location and the point coordinates were recorded using GPS. Budget constraints limited the maximum number of sample points that could be sampled. Additional sample points were added after early sample events, to refine areas of uncertainty. A total of 62 sample points were evaluated in the reference sites and 104 within the four restoration sites after adjustments were made in the field (Table 1).

Table 1: Site Acreage and Point Distribution

Reference Sites	Acres	Number of Sample points
Clough Island Wetlands (East)	10	10
Lower Duck Hunter Bay	48	10
North Bay	32	9
Radio Tower Bay	21	9
Rask Bay	33	9
Upper Duck Hunter Bay	18	8
Walleye Alley Bay	40	7
Totals	202	62
Restoration Sites	**Acres**	**Number of Sample points**
Clough Island	42	13
Foundation Bay	140	21
Little Pokegama Bay	410	41
Pokegama Bay	233	29
Totals	825	104

2.2 Data Collection and Equipment

The following biological/environmental variables were assessed at the soil sample points:

- Presence/absence of wild rice within a 25 foot radius of the soil sample.
- Visual classification of dominant vegetation type (submerged, floating, emergent) within a 25 foot radius of the soil sample.
- Visual estimate of vegetation volume (high, medium, low) within a 25 foot radius of the soil sample.

The following soil variables were assessed for the sediment sample:

- A visual estimate of percent organics present in surficial sediment using the Braun-Blaunqet (1932) scale (0-5%, 5-25%, 25-50%, 50-75%, 75-100%).

- A determination of the texture of the sediment sample using the ASTM (2006) soil texture classes.

- Visual determination of presence/absence of anthropogenic debris in surface sediment and identification of debris, as applicable (type, appearance; e.g., sawdust, milled wood, coal, other non-native materials).

For safety and efficiency, at least two crew members performed the daily field sampling. The mode of transportation and work platform was a pontoon boat with a "moon pool" located in the center. The pontoon boat was also outfitted with "spud poles" which stabilized the boat while sampling. Water depth, GPS location, and a substrate sample of approximately the top one-half foot of the sediment was acquired through the moon pool using a push core. Soil penetration was measured (see equipment description below) three times and averaged for the reported value.

Equipment used for the sediment sampling included:

- A GPS unit (Trimble GeoXH 6000) was used to collect sample point/geographic coordinates. All data was post-processed to enhance accuracy and reported in UTM Zone 15N, NAD83. The GPS unit was attached to a stadia rod fitted with an 8-inch disc on the bottom to directly survey bed elevation.

- A portable static cone penetrometer (Humboldt HS-4210A) to determine the 1-foot substrate penetration force.

- A custom built push core with check valve was used to collect a sediment sample from the top 0.5 feet of the bed surface.

- A tablet iPad™ equipped with the ESRI™ Collector application (app) was used for sample point and real-time data collection.

- A digital camera was used to collect a photograph of each sample.

Measureable and observational data were recorded directly into a customized data entry form on Tablet iPads™ equipped with the ESRI™ Collector application (app). This approach standardized the type of data collected as well as the acceptable attribute values for each data field. An example of the data sheet is located in Appendix A.

The datasheet combines the observations made and collected by field staff at a sample point (data, locations, photos, etc.) into a single record using a unique site and sample point identifier. The database format to collect and store field data measurements is directly compatible with the NOAA Great lakes DIVER database (Appendix A).

3.0 Results

The data were plotted on three sets of map figures: (1) the data collected for model inputs (Figures 2 through 8 for the reference sites, and 9 through 12 for the restoration sites), (2) vegetation volume, types, and observed debris in the restoration sites (Figures 13-16), and (3) maps of the predictive model generated in ArcGIS using spatial interpolation and mapped field data in the restoration sites (Figures 17-20) Additional tables with results for the various sites and parameters are located in Appendix B, Tables of Results .

3.1 Reference Sites

3.1.1 Wild Rice Observations in Reference Sites

Initial data collection focused on the reference sites to identify parameters in which wild rice has been successful in seeded areas. The reference sites likely had an overall bias toward soft sediments types as their selection was based upon the Implementation Plan model, which targeted areas with "soft, silt or organic-dominated" substrate characteristics, and areas where wild rice is already present within the plant community. Of the 62 sample points within the reference sites, wild rice was observed within a 25-foot radius at 41 of them, and absent at 21 (Table 1, Appendix B). Wild rice was present at over 80 percent of the sample points in North Bay, Radio Tower Bay, Rask Bay, Upper Duck Hunter Bay and Walleye Alley Bay. Wild rice was absent at over 70 percent of the sample points in Clough Island Wetlands and Lower Duck Hunter Bay (Chart 1).

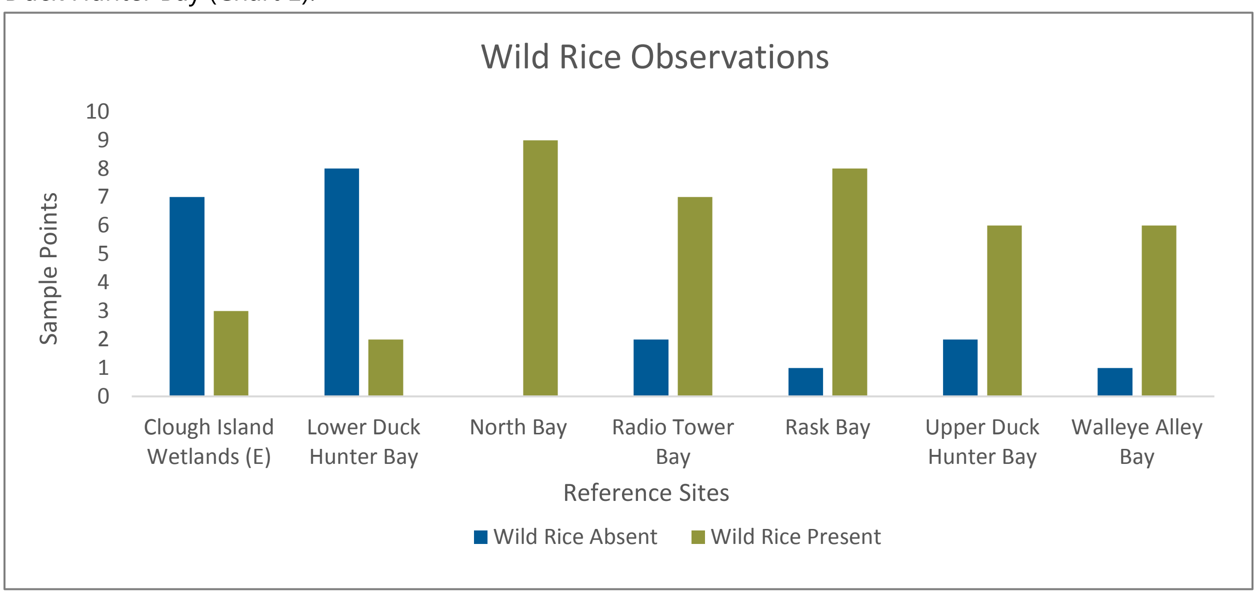


Chart: 1 Wild Rice Observations in Reference Sites

3.1.2 Sediment Texture in Reference Sites

Sediment texture (ASTM, 2006) at the reference sites included organic soils (OL/OH), peat, (PT), silt (ML), silty sand (SM), poorly graded sand with silt (SP/SM), poorly graded sand (SP) and well-graded sand (SW). As previously noted, the reference sites were chosen for seeding based upon known organic content of the substrate, resulting in little variation in sediment texture. Across the 62 reference sample points, 47 (76 percent) exhibited organic soils, at which 38 (81 percent) wild rice was present. Additionally, wild rice was present at two sites with peat and one site with poorly graded sand with silt (Chart 2). Clough Island Wetlands (East) showed the most variable soil texture with organic soil, silt and sand. A summary of the soil textures for each reference site is located in Appendix B, Table 2.

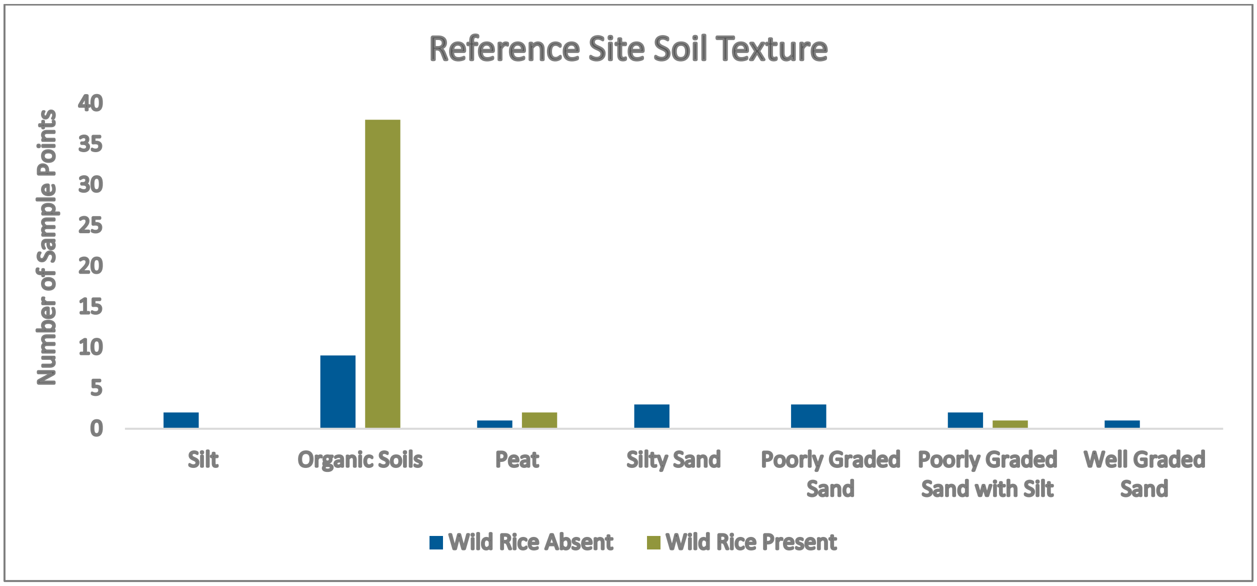


Chart: 2 Soil Texture within Reference Sites

3.1.3 Sediment Penetration in Reference Sites

As described in Section 2.0, three measurements of sediment penetration in tons per square foot (tsf) were collected at each sample point, and averaged. Sediment penetration values ranged from 0 tsf to 17 tsf at the reference sites, although the 17 tsf reading appears to be an outlier, with the interquartile range, the middle 50% of values, ranging between 0.25 tsf and 1.4 tsf. The range of soil penetration values at sample points where wild rice is present was 0 to 1 tsf (Chart 3). Appendix B, Table 3 shows the minimum, maximum and average soil penetration values at the reference sites. In general, the average penetration force was lower where wild rice was observed (Chart 3).

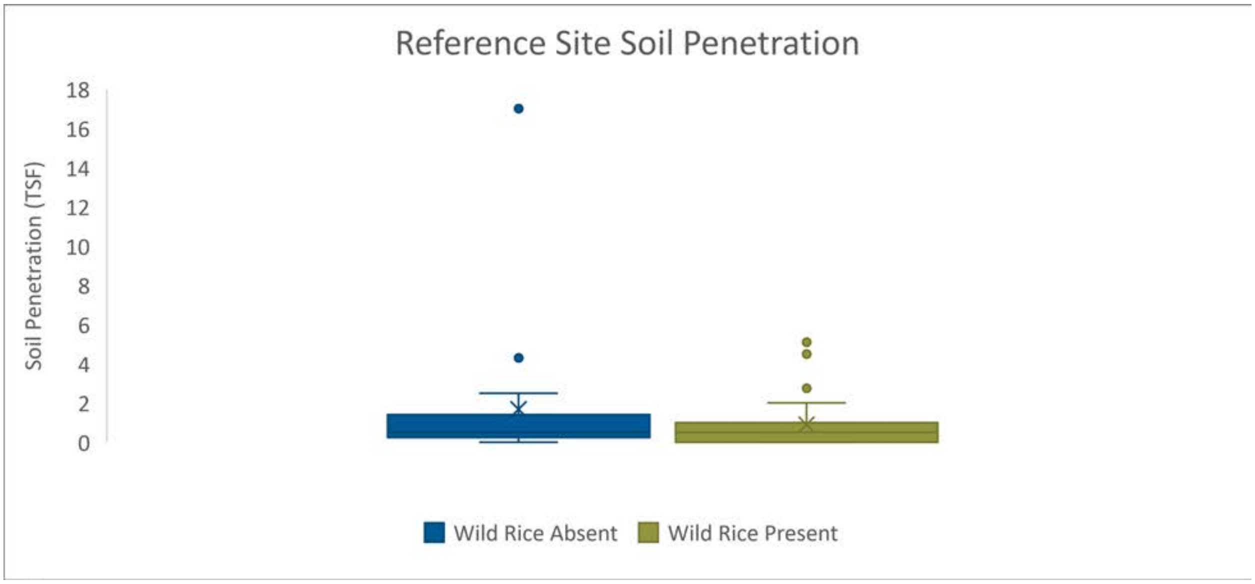


Chart: 3 Soil Penetration within Reference Sites

3.1.4 Organic Content at Reference Sites

Estimated percent organics present in surficial sediments were based on visual observation and recorded using the Braun-Blaunqet (1932) scale. In the reference sites, wild rice was not present (except in one sample) in substrate with organic content less than 50%. Wild rice was present in 80 percent of the sample points that exhibited greater than 50 percent organics (Chart 4). Radio Tower Bay, Rask Bay, and Walleye Alley Bay all had soil samples with greater than 50 percent organic content (Appendix B, Table 4).

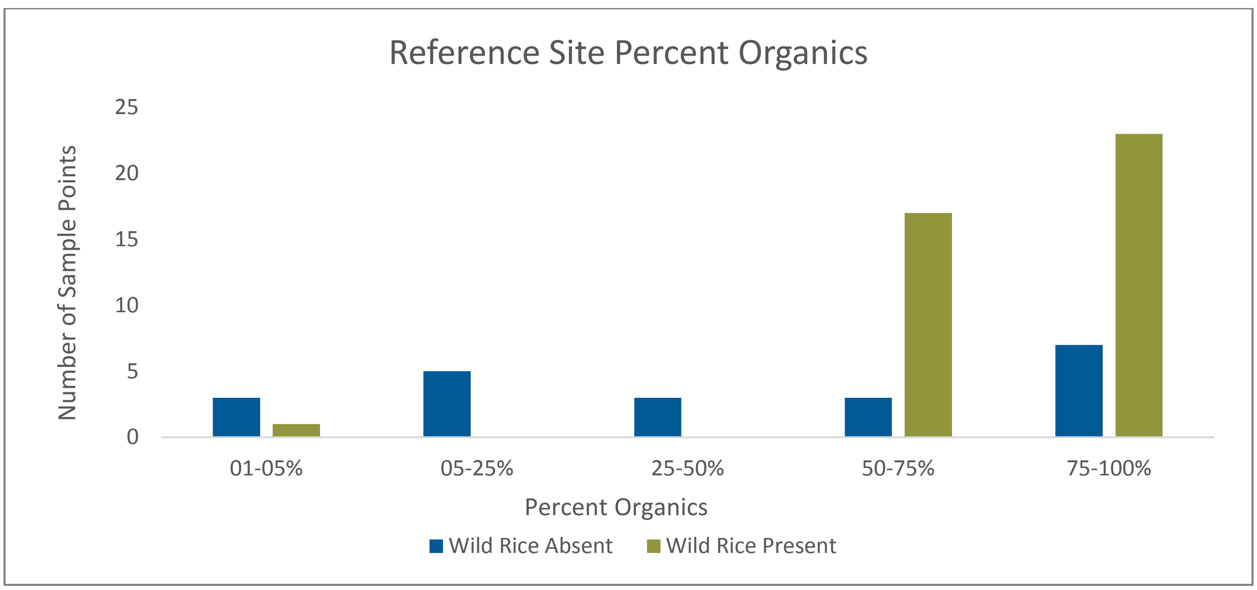
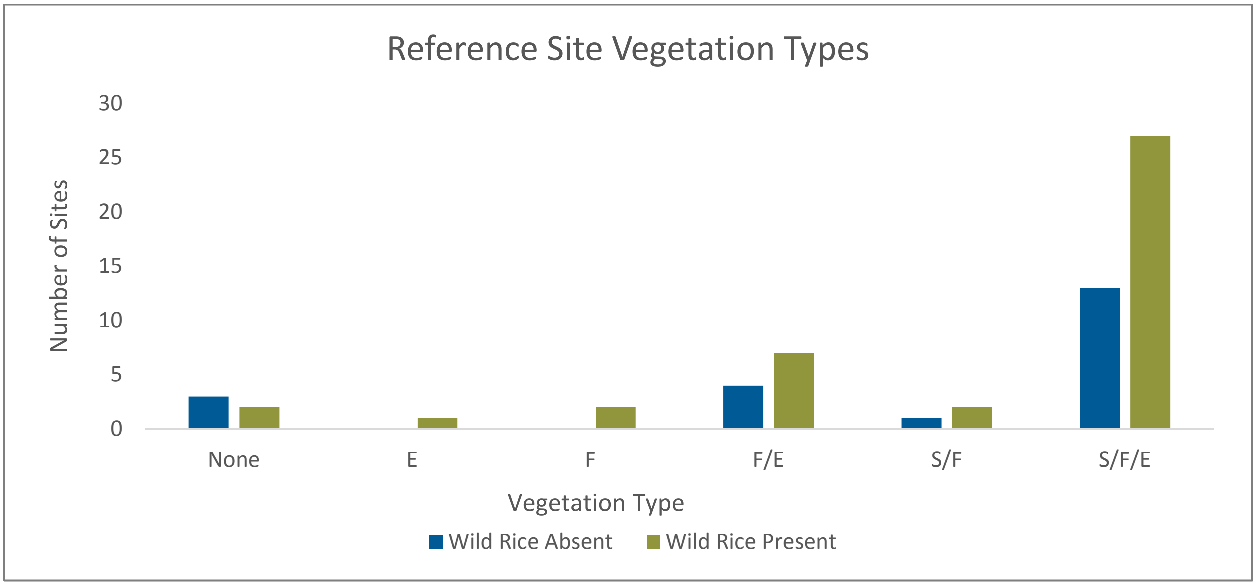


Chart: 4 Percent Organics within Reference Sites

3.1.5 Vegetation and Debris in Reference Sites

Vegetation type and volume were estimated for each sample point in the reference sites, and presented on Figures 13 through 16. This information was documented for planning of vegetation reduction or vegetation removal that may be required to prepare a site for wild rice seeding. Within the reference sites, 44 percent of the 62 sample points had wild rice present, along with all three vegetation types – submerged, floating and emergent (Chart 5). Wild rice was also present at sample points where the vegetation volume was typically medium to low (Chart 6). Vegetation types and volume results specific to each sample site are located in Appendix B, Table 5 and 6, respectively.



*Vegetation types in Chart 5 reference the following: E: Emergent, F: Floating, F/E: Floating and Emergent, S/E: Submergent and Emergent, S/F/E: Submergent, Floating and Emergent

Chart: 5 Vegetation Types within Reference Sites

Debris was encountered in the reference sites, including Clough Island Wetlands East, Foundation Bay, and Upper Duck Hunter Bay. The debris observed consisted of wood shavings and wood chips. Foundation Bay contained nine sample points where debris was observed. Sample points within the reference sites where debris was observed are located on the vegetation and debris maps (Figures 13 to 16).

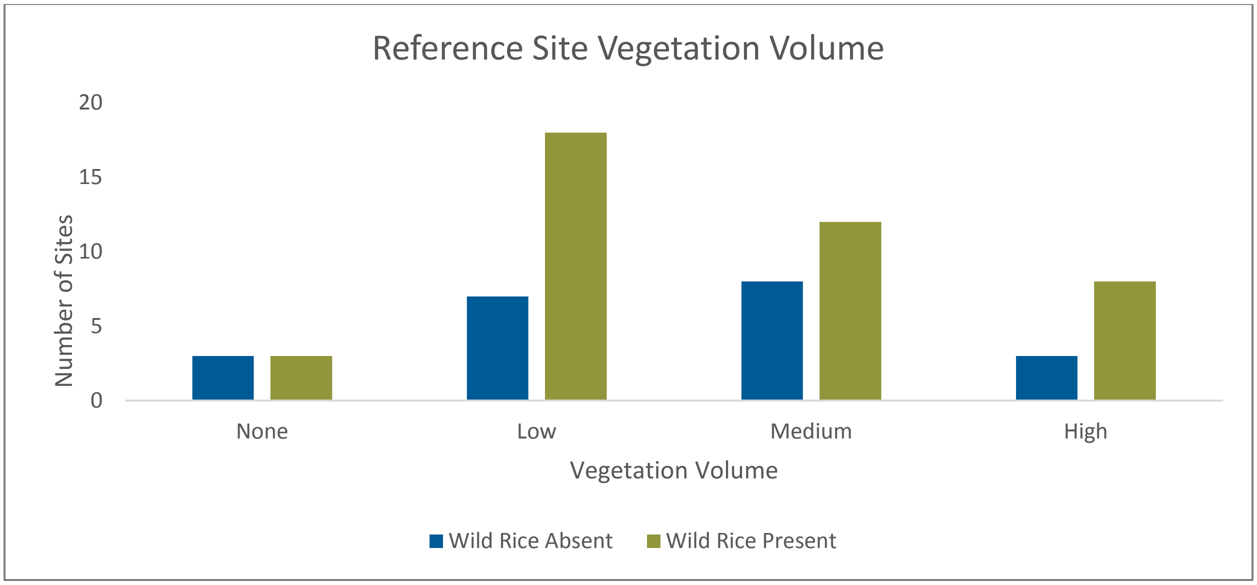


Chart: 6 Vegetation Volume within Reference Sites

3.2 Restoration Sites

3.2.1 Wild Rice Observations in Restoration Sites

Within the restoration sites, a total of 104 sample points have been analyzed. Among all sites, wild rice was present at 22 of the sample points (i.e., 21 percent). There was a higher percentage of wild rice in the sample points at Foundation Bay with 38 percent and Little Pokegama Bay with 20 percent of the samples having wild rice present (Appendix B, Table 7).

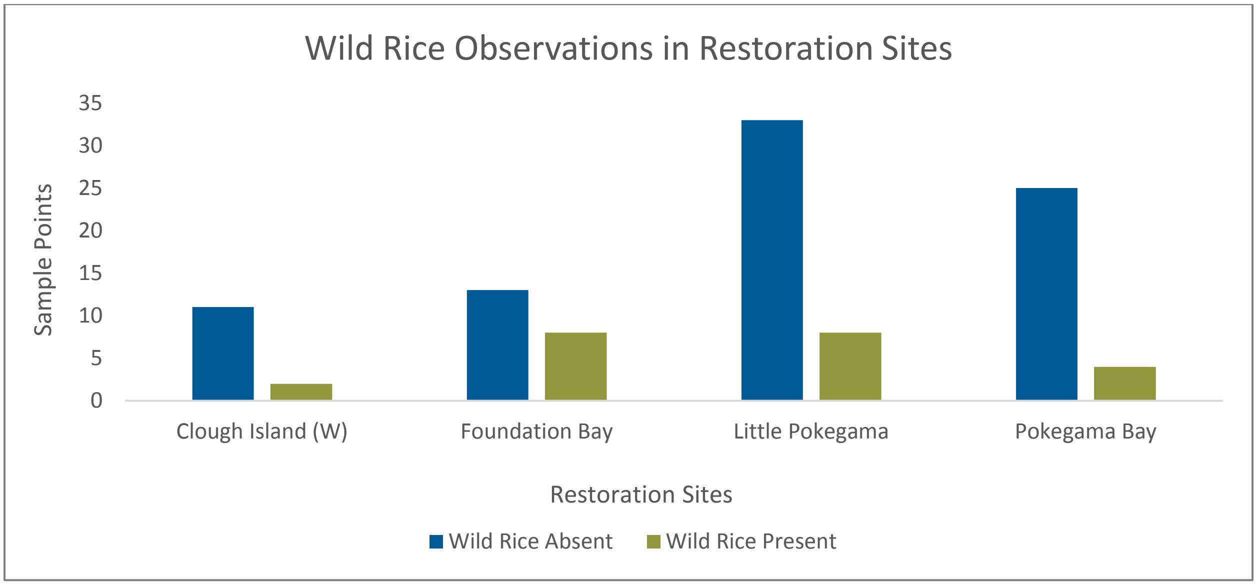


Chart: 7 Wild Rice Observations in Restoration Sites

3.2.2 Sediment Texture in Restoration Sites

The sediment at the restoration sites consisted of soil textures including organic soils (OL/OH) peat (PT), clay (CL), silt (ML), silty sand (SM), poorly graded sand with silt (SP/SM), and poorly graded sand (SP). Of the 22 sample points where wild rice was present, 45 percent exhibited organic soils. The remaining 55 percent of the sample points where wild rice was present, were clay, silt and peat soil textures. Little Pokegama Bay exhibits the most variability in soil texture, including sediments composed of clay, silts, organic soils, peat and sands (Chart 8). Pokegama Bay and Little Pokegama Bay have a higher number of sample points exhibiting organic soils, with 38 percent and 32 percent, respectively, and Clough Island (West) exhibited the highest percent of sample points with organic soils at 62 percent (Appendix B, Table 8).

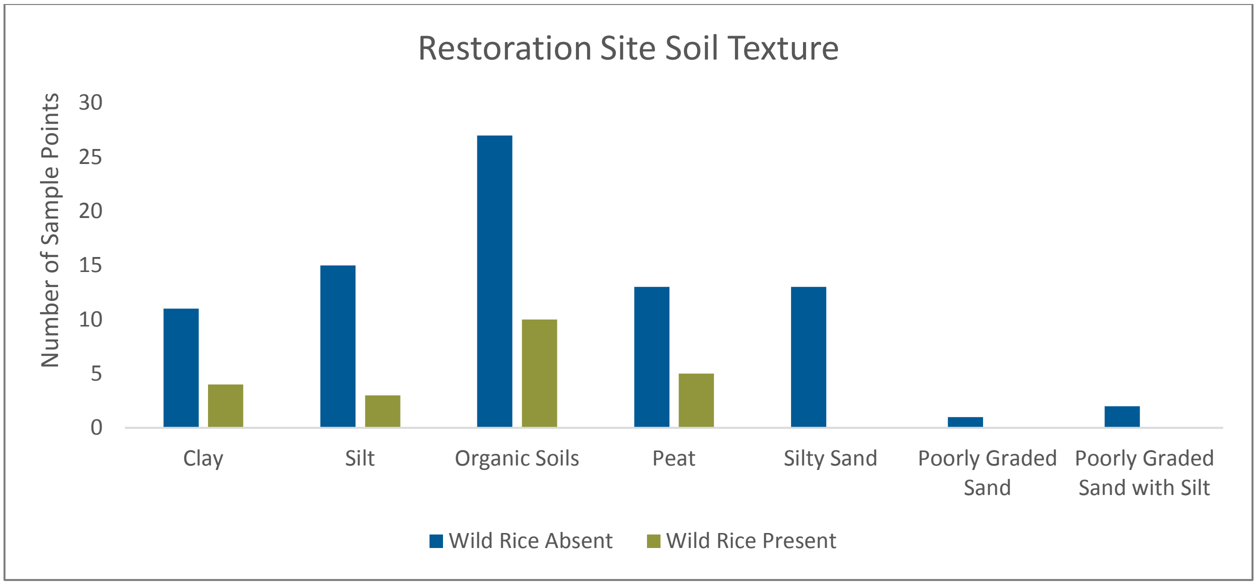


Chart: 8 Restoration Site Soil Texture

3.2.3 Sediment Penetration in Restoration Sites

The sediment penetration for the restoration sites range from 0 to 9.0 tsf. The average minimum penetration among all sites was 0.0 tsf. The average measured penetration among sites where wild rice was present was less than 1.0 tsf. The maximum measured penetration among sites where wild rice was present is 4.0 tsf (Chart 9). Appendix B, Table 9, reports the minimum, average, and maximum soil penetration for each restoration site.

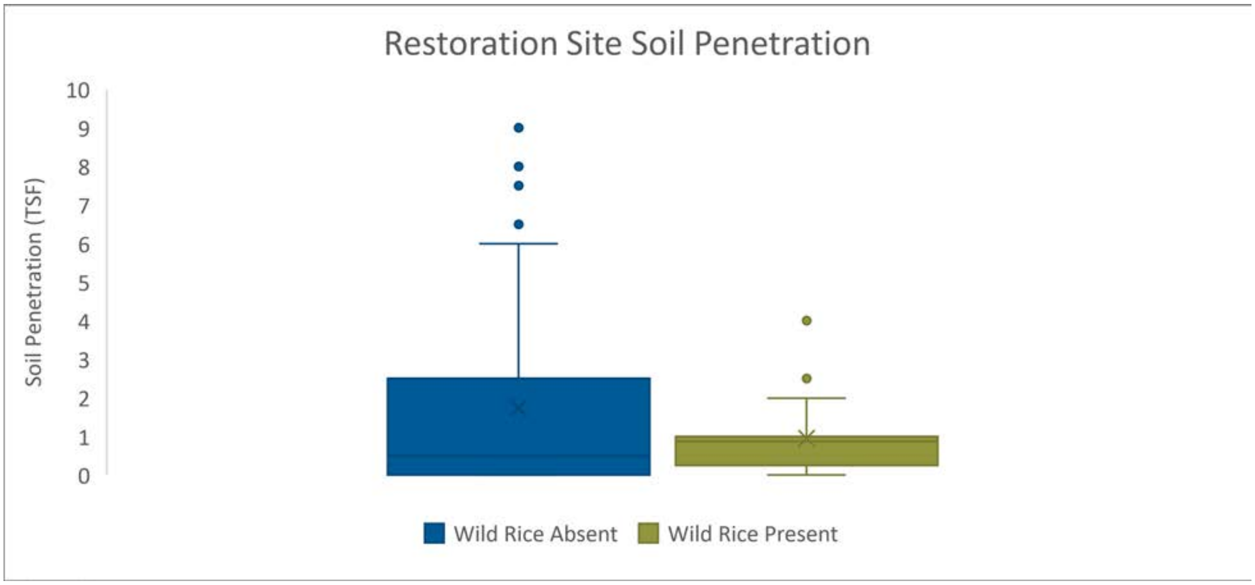


Chart: 9 Restoration Site Soil Penetration

3.2.4 Organic Content at Restoration Sites

In the restoration sites, the sediment organic content ranged between 0 percent and 100 percent. In sample points where wild rice was present, the sample points exhibited a percent organic greater than 5 percent. Approximately 41 percent of all restoration site sample points exhibited percent organics greater than 50 percent (Chart 10). Percent organic results specific to each restoration site is located in Appendix B, Table 10.

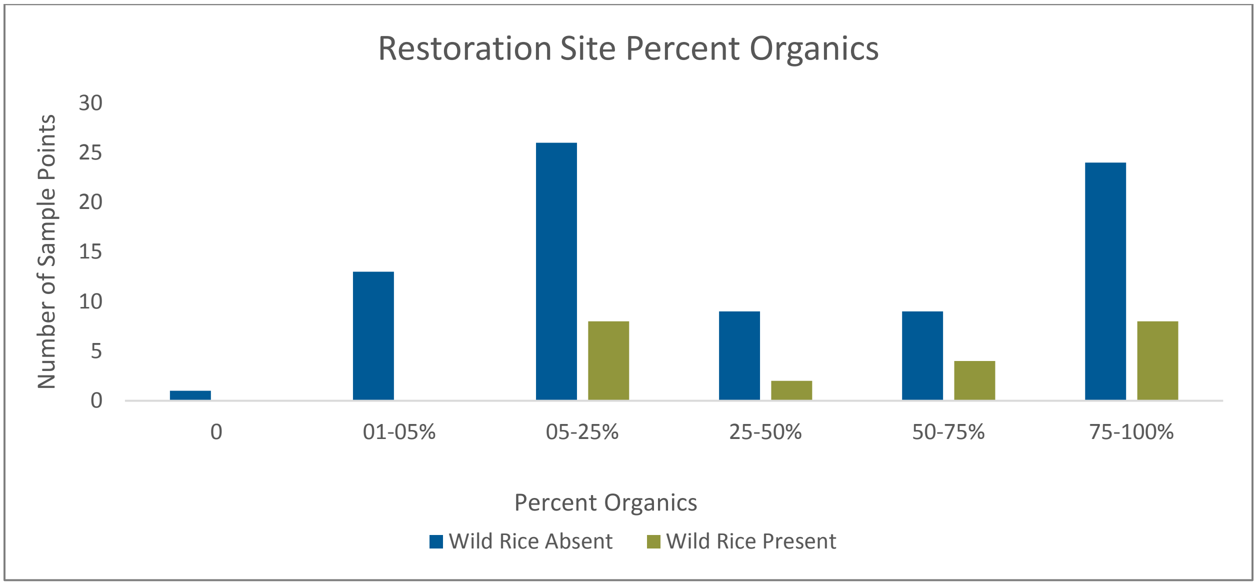
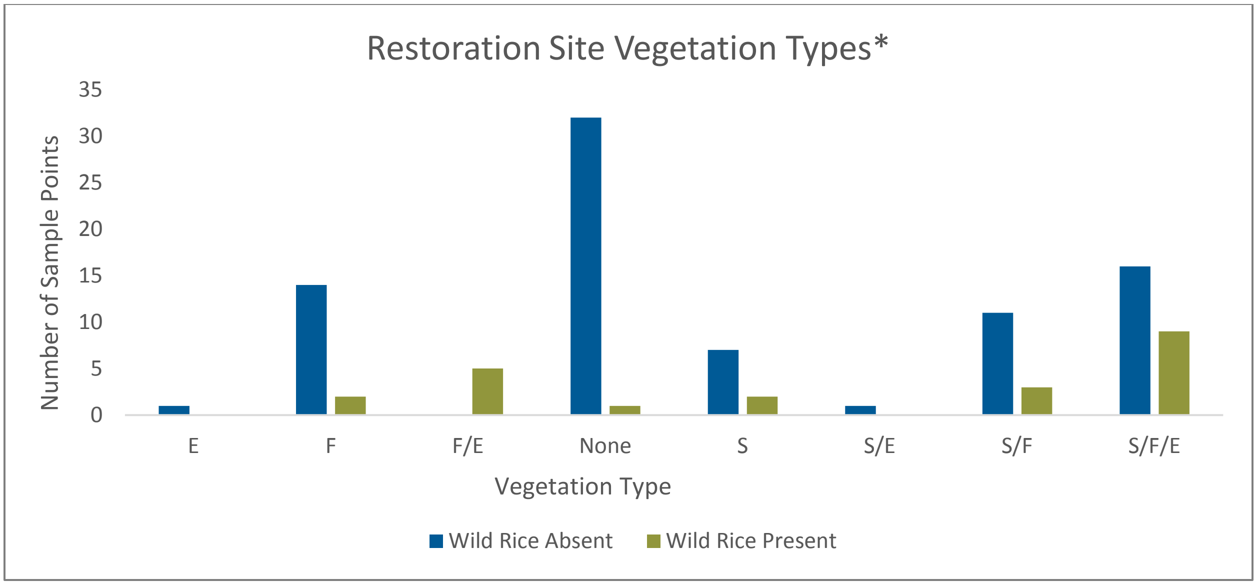


Chart: 10 Restoration Site Percent Organics

3.2.5 Vegetation and Debris in Restoration Sites

Vegetation volume and type for each restoration site is presented on Figures 13 through 16. This information was documented for planning of vegetation reduction or vegetation removal that may be required to prepare a site for wild rice seeding. Within the restoration sites, 9 percent of the sample points had wild rice present, along with all three vegetation types – submerged, floating and emergent (Chart 11). Wild rice was also present at sample points where the vegetation volume was typically medium to low volumes (Chart 12). Vegetation types and vegetation volume results for each restoration site is located in Appendix B, Table 11 and 12, respectively.



*Vegetation types in Chart 11 reference the following: E: Emergent, F: Floating, S: Submergent, F/E: Floating and Emergent, S/E: Submergent and Emergent, S/F: Submergent and Floating, S/F/E: Submergent, Floating and Emergent

Chart: 11 Vegetation Types within the Restoration Site

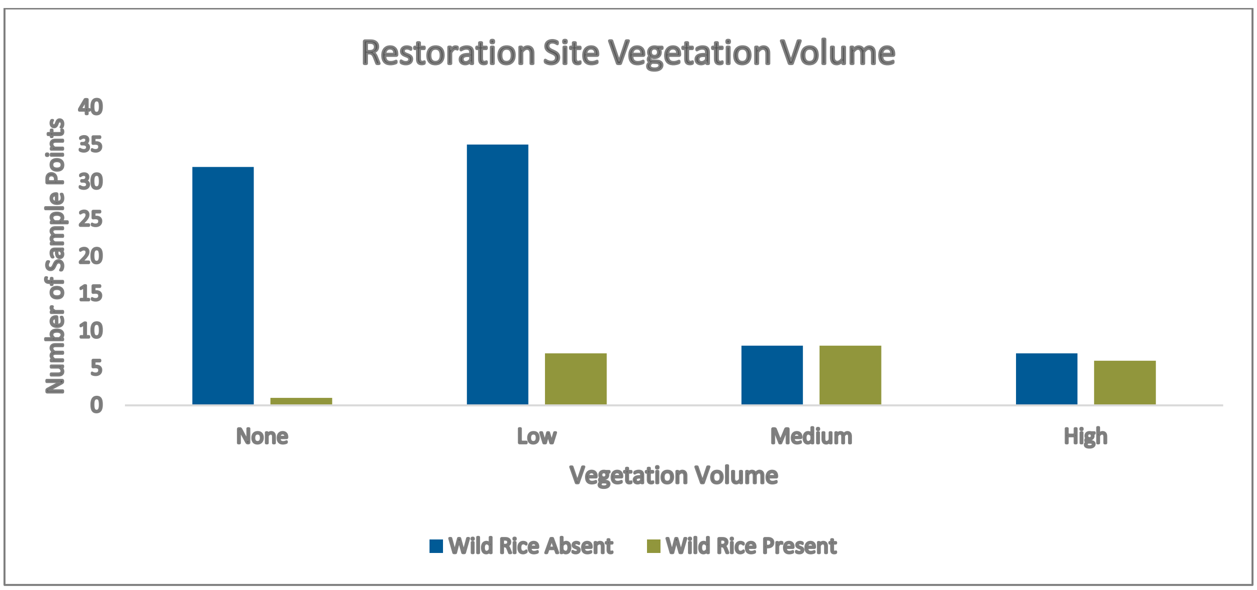


Chart: 12 Restoration Site Vegetation Volume

Debris was encountered in Clough Island West, Foundation Bay, and Little Pokegama Bay Restoration Sites. The debris observed was wood shavings and wood chips. Foundation Bay had nine sites where debris was observed. Sample points where debris was observed within the reference sites are located on the vegetation and debris maps (Figures 13 to 16).

3.3 Wild Rice Parameter Correlation

For the goal of the study, the most important sample points to analyze are sample points where wild rice is present, whether due to seeding or naturally. Therefore, the following statistics are only comparing the parameters at 63 sample points where wild rice was present.

3.3.1 Soil Texture and Soil Penetration

Wild rice was present in organic soils, peat, clay, silt and a single location in poorly graded sand with silt. The soil penetration of organic soils ranged from 0 tsf to 4.5 tsf with an average soil penetration of 0.7 tsf. Of the 7 sample points that exhibited peat soils, the soil penetration ranged from 0.75 tsf to 4 tsf with an average of 1.5 tsf. Of the four sample points that exhibited clay soil texture, the soil penetration ranged from 0.25 tsf to 2 tsf and of the three sample points that exhibited silt soil texture, the soil penetration ranged from 1 tsf to 2.5 tsf. There was a single sample point of poorly graded sand with silt that wild rice was present at, and that had a measured soil penetration of 5.1 tsf.

The box and whisker plot (Chart 10) shows that the soil penetration between the interquartile ranges of the organic soils is between 0 tsf and 1 tsf (fairly soft).

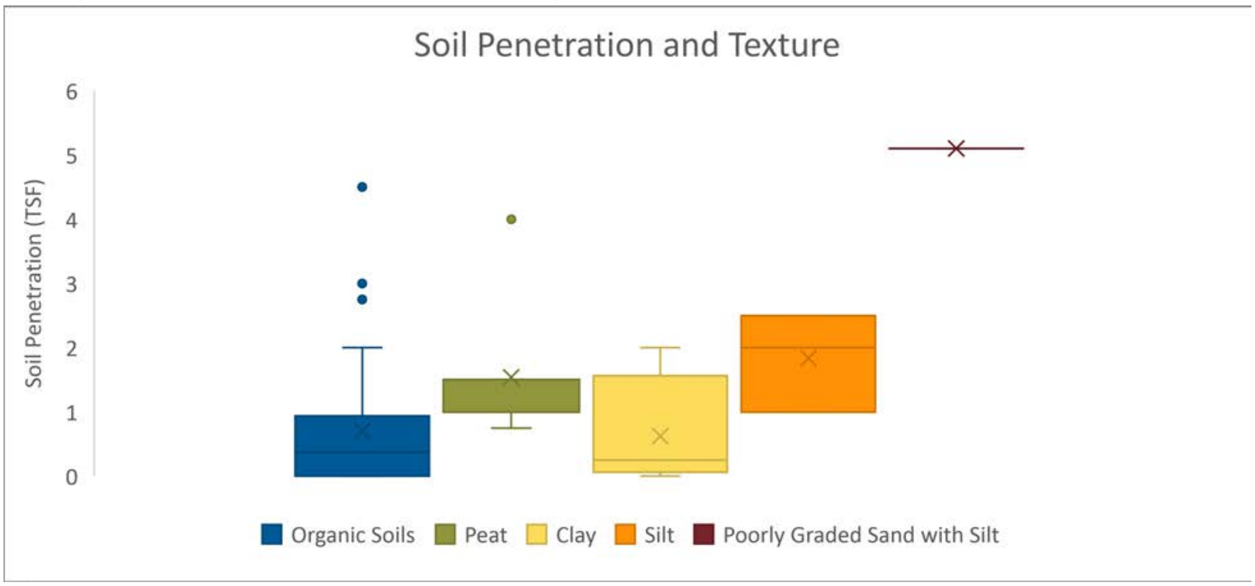


Chart: 13 Soil Penetration and Texture Where Wild Rice is Present

3.3.2 Soil Texture and Percent Organics

To measure the percent organics in the soil sample, the Braun-Blaunqet scale was used, which groups the percent organics into ranges. Peat and organic soils have a high percent of organics with that majority of the samples greater than 50 percent. Clay and silt have a low percent organic range of 5 to 25 percent and the single poorly graded sand with silt has also has a low organic percent of 1 to 5 percent.

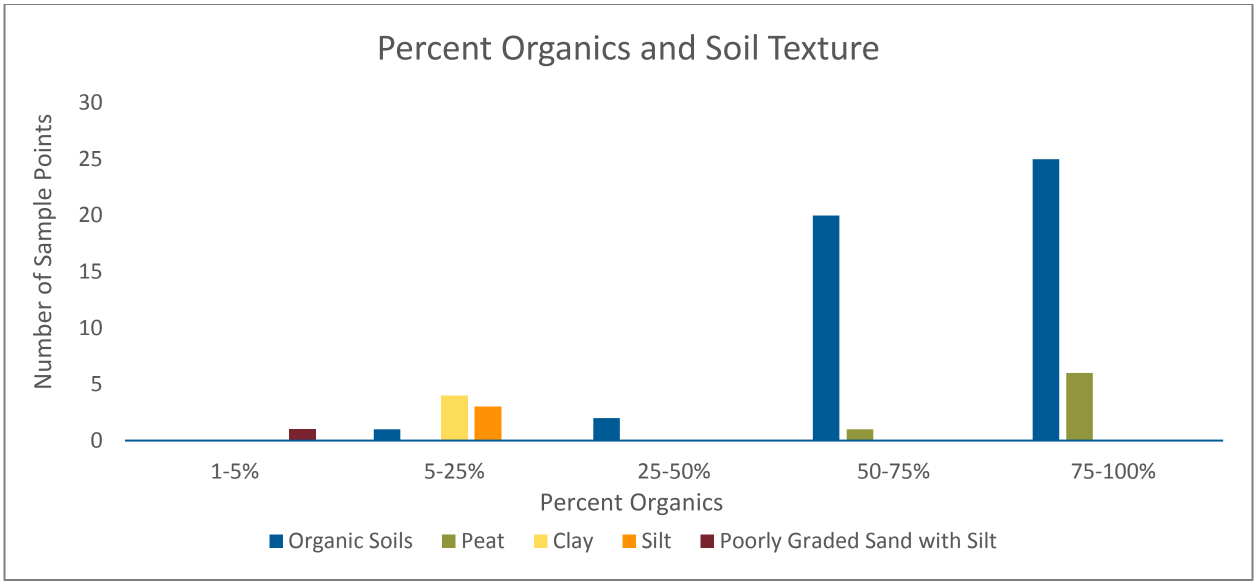


Chart: 14 Percent Organics and Soil Texture

3.3.3 Soil Penetration and Percent Organics

Soil penetration and percent organics were evaluated to determine the correlation of the percent organics based on measuring the soil penetration. The interquartile range was 0 to 1 tsf for the sample points that exhibited percent organics in the range of 75 to 100 percent. The interquartile range for was 0.25 tsf to 1 tsf for sample points that exhibited percent organics in the range of 50 to 75 percent. Two sample points that exhibited 25 to 50 percent organics had a soil penetration of 1 tsf. Sample points that had a lower percent organic in the 5 to 25 percent had a wider interquartile range (0.25 tsf to 2 tsf).

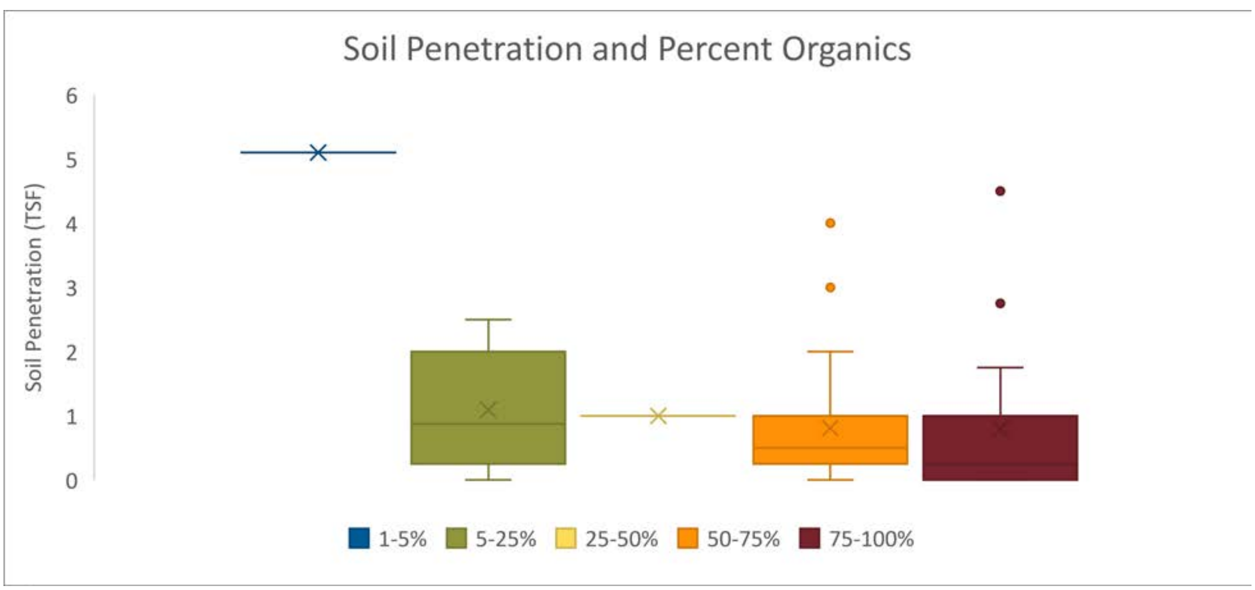


Chart: 15 Soil Penetration and Percent Organics

3.4 Limitations

We found that water depth can be a problematic factor in the prediction of wild rice restoration potential. While the sampling plan limited sediment data collection to water depths between one foot and five feet, it should be noted we observed wild rice growing in water depths greater than five feet, in Rask Bay, Foundation Bay, and Little Pokegama Bay. It should also be noted that during the time of this survey, the water elevation recorded at the National Oceanic and Atmospheric Administration (NOAA)/United States Geological Survey (USGS) water level station #9099064 in Duluth, MN was recorded at 602.9 ft above mean sea level (msl), 1.8 feet above the 601.1 ft reference water level elevation used in this survey. In the past 40 years, the average water level elevation at this station is 601.55 ft and since 2013 the average water level elevation has been 602.15 ft above msl (Graph 1). To accommodate the historic high water level elevations, we have mapped where the water depths were greater than five feet and incorporated that into the wild rice restoration model.

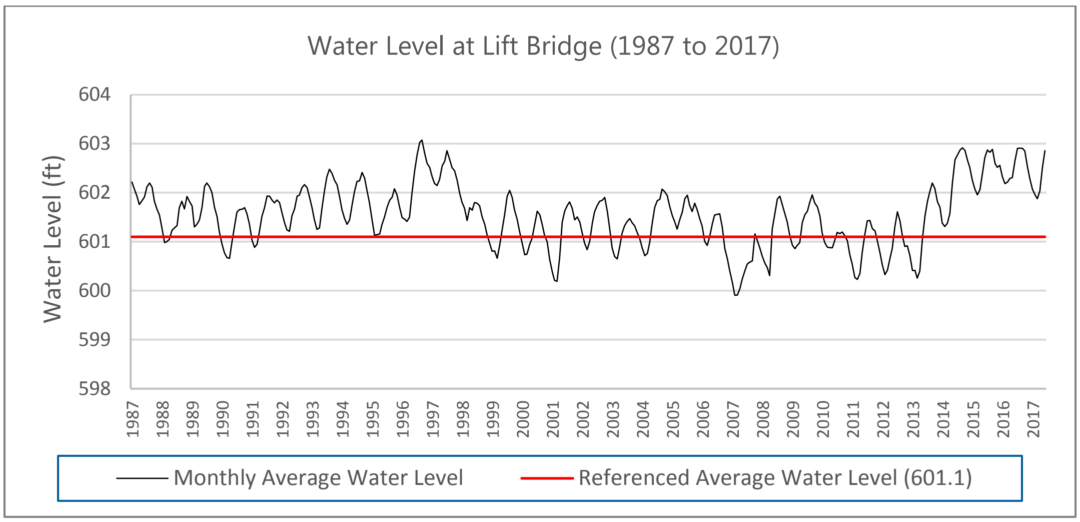


Chart: 16 Water Level in Past 40 years at Lift Bridge for NOAA Station #9099064

3.5 Wild Rice Restoration Potential Model Setup

Using ArcGIS and the substrate sampling data, a series of maps showing high, medium and low potential for wild rice restoration were developed. Soil texture, soil penetration and percent organics were used as a guide for mapping the suitability of wild rice restoration. At sample points where wild rice was observed, 75 percent of samples exhibited organic soils, a maximum soil penetration of 4.5 tsf and an organic percent range between 50 to 100 percent. These attributes were used to query the sample points within the restoration sites of high potential of restoration. At sample points where wild rice was observed, 22 percent of the sample points had peat, silt, and clay soils; a maximum soil penetration of 4 tsf; and an organic percent range between 5 to 100 percent. These attributes were used to query the points within the restoration sites of medium potential of restoration. Low potential areas for restoration included sample points that exhibited silty sands, poorly graded sand, and well graded sand, soil penetration greater than 5.0 tsf and percent organics less than 25 percent. Low wild rice restoration potential areas also included areas with depths that are greater than 5 feet.

The sample points within the restoration sites were queried and defined as high, medium, and low potential for wild rice restoration. A predictive surface was then created using the inverse distance weighted (IDW) interpolation. That general IDW surface was then modified to create polygons of high, medium and low based on additional field data including water depth and areas of high vegetation.

We found that water depth can be a problematic factor in the prediction of wild rice restoration potential. While the sampling plan limited sediment data collection to water depths between one foot and five feet.

Table 2: Wild Rice Restoration Substrate Model Components

Wild Rice Restoration Potential	Substrate Texture	Soil Penetration (tsf)	Percent Organics
High	Organic Soils	Less than 4.5	>50
Medium	Peat, Clay, and Silt	Less than 4.0	5 to 100
Low	Silty Sand, Poorly Graded Sand, Poorly Graded Sand with Silt, Well Graded Sand	Greater than 5.0	0 to 25

Note: Model was based on current water depth of five feet or less;

3.6 Wild Rice Restoration Potential Model Results

The third map set, Wild Rice Restoration Potential Model Output, identifies the wild rice establishment potential in each restoration site (Figures 17 to 20).

The wild rice restoration potential model has been implemented by querying the sample point data within the restoration sites. The results of this model shows that Little Pokegama Bay and Pokegama Bay have the most acreage that have a high potential for restoration, approximately 91 acres and 63 acres, respectively. Clough Island West, the smallest potential restoration area has approximately 14 acres that resulted in a high potential for restoration. The area within Foundation Bay resulted in approximately 69 acres of medium potential for restoration and 19 acres of high potential for restoration. A summary of the area of wild rice restoration potential, area of existing wild rice, area of vegetation volume and number of debris sites for each restoration site, is summarized in Table 8.

Table 3: Overview of Wild Rice Restoration Potential

Restoration Site	Wild Rice Restoration Potential (Acres)	Area of Existing Wild Rice (Acres)	Area of Volume of Vegetation (Acres)	Number of Debris Sites
Clough Island West	High: 14 Medium: 2 Low: 22	5	High: 11 Low: 11 None: 20	1
Foundation Bay	High: 19 Medium: 69 Low: 28	18	High: 24 Medium: 6 Low: 95 None: 93	9
Little Pokegama Bay	High: 91 Medium: 104 Low: 131	37	High: 123 Medium: 5 Low: 110 None: 166	1
Pokegama Bay	High: 63 Medium: 75 Low: 97	9	High: 44 Medium: 28 Low: 11.5 None: 51	0

3.6.1 Clough Island West

Clough Island West contains high, medium, and low wild rice restoration potential areas (Figure 17). The high potential area is approximately 14 acres along the shoreline into the south bay, in the vicinity of where wild rice was observed during field work. A predicted medium potential area, approximately 2 acres, was in the middle of the site where the soil texture differs from the organic soils found throughout most of the site. Although there were organic soils toward the west portion of the restoration areas, current water depth was greater than 5 feet, therefore suggesting the western portion to be of low potential for wild rice restoration. Existing shoreline vegetation consisted of high vegetation volume, including cattails and floating mats at this site. There was also wood shaving debris found in the northern portion of the restoration area. The highest potential for wild rice restoration in Clough Island West restoration site is along the shoreline and in the southeastern bay.

3.6.2 Foundation Bay

Foundation Bay contains high, medium and low wild rice restoration potential areas (Figure 18). The high potential area is approximately 19 acres; located in the southeast and central area of the restoration site where soft organics were observed. Medium wild rice restoration potential, approximately 70 acres, has been interpolated throughout the restoration site. Specifically, this reduced potential rating along the west-southwest shoreline is due to the abundance of peat substrate, which may be derived from the sedge mats and cattails along the shoreline. The northwest portion consists of silt and silty sand, which is most likely the result of a reduction in velocity of the river as flow spreads in this area, depositing silt- to sand-sized sediment. Wild rice was growing in this area; therefore, we thought it appropriate to model wild rice capable of growing in silt substrate. Approximately 30 acres of low wild rice restoration potential area has been interpolated throughout the restoration site, particularly due to a water depth greater than 5 feet and silty sand sediment texture. Anthropogenic wood chip debris was also observed at 9 of the sample points (Figure 14). The anthropogenic wood chips were located south in the bay, near the existing subsurface foundation. The highest potential of wild rice restoration in Foundation Bay is in the south bay along the east shoreline and in the western portion of the site.

3.6.3 Little Pokegama Bay

Little Pokegama Bay contains high, medium and low wild rice restoration potential areas. The high potential area is approximately 90 acres in size spread throughout the restoration site. Wild rice was observed in the southwest and northeast areas of the restoration area, where soft organic soils were observed. Additional high potential areas were in the center of the restoration site where organic soils were observed and water depth decreases. This area is also in close proximity to a small area of emergent vegetation to the north, which may help reduce the strong current from the north. Along the shoreline, medium wild rice restoration potential has been defined; this reduced potential is due to the abundance of peat substrate, which may again, be derived from the sedge mats and cattails along the shoreline. There is also a portion of medium restoration potential north to south before water depth increases in the bay. This area consists of silt sediment texture, which again, may be the result of silt deposition due to the reduction of stream flow from the main channel. In total, approximately 104 acres were interpolated as medium potential for wild rice restoration. Water depth increases in the center and to the north of the restoration site. We did not observe wild rice in the deeper water depth in the center of the site, but the substrate did exhibit organic soils texture. In the deeper portions to the north of the site, the sediment was clay texture and no wild rice was observed. At one site, LP 40, wood chip debris was observed (Figure 15). The highest potential of wild rice restoration in Little Pokegama Bay is along the shoreline in the southeast, in the small bay at the north and between the shoreline and the bar to the west along the site boundary. The center of the site is limited due to depth, but does exhibit organic, soft soils.

3.6.4 Pokegama Bay

Pokegama Bay contains high, medium and low wild rice restoration potential areas. The high potential area, approximately 60 acres, is located in the southern bays of the restoration area. Approximately 75 acres of medium potential restoration area was interpolated in the larger bay in the mouth of the Pokegama River. Most of the sediment observed in the medium potential areas was clay texture, which again, could be the result of the reduction in stream flow from the St. Louis River, depositing silt-sized sediments. Medium potential was also observed in the small bays along the northeast shoreline, which may be a result of protection from the estuary to the north. Water depth increases to greater than five feet in the northern areas of Pokegama Bay and south into the smaller western bay, reducing the potential for successful rice restoration. Water depth is also greater than five feet along the west shoreline; causing shoreline erosion on this high sandy bluff is resulting in silty sand soil texture. There was no anthropogenic debris observed in the sediment borings. The highest potential of wild rice restoration is in the small southwest bay where there is organic rich sediments and protection from the wave action of the estuary. High potential of wild rice restoration is also in the southeast bay, but potential high flows from the St. Louis River should be taken into consideration.

4.0 Discussion

This study built upon the 2014 Implementation Plan by measuring additional parameters, including soil texture, organic content and substrate penetration force. The August 2017 substrate sampling study within selected portions of the St. Louis River Estuary mapped and quantified substrate parameters for high, medium, and low prediction of wild rice establishment success. The evaluation of these additional parameters provided more information as to substrate suitability for the growth of wild rice. We found that wild rice occurs mostly in organic soils and peat. These soils, most suitable for the establishment of wild rice, generally have a low soil penetration, between 0 and 1.4 tsf. Organic soils and peat generally have an organic percentage of greater than 50 percent, which generally exhibit a soil penetration of less than 1 tsf.

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