

# Leque 2<sup>nd</sup>-year Post-Restoration Tidal Marsh Monitoring Report

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W. Gregory Hood  
Skagit River System Cooperative, LaConner, WA

prepared for  
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*Great Blue Heron in patchily vegetated, Bolboschoenus maritimus, marsh one year after restoration.*

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## **Recommended citation**

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## Introduction

The Leque tidal marsh restoration site is located in the Stillaguamish River Delta opposite the mouth of the old Stillaguamish River. European-American settlement in the late 19<sup>th</sup> century converted most of the Stillaguamish Delta from tidal marsh and floodplain swamp to agricultural use through the construction of dikes that prevented tidal and riverine flooding and allowed replacement of native vegetation by agricultural crops. Leque Island was diked in the 1870s and used for farming until 1990, when farming became infeasible on the site.

To provide critical rearing habitat for threatened Chinook salmon, the 103-ha (254.5-ac) Leque site was restored to tidal and riverine flooding in 2019 through the nearly complete removal of dikes around its perimeter. Additionally, six large tidal channels were excavated de novo or enlarged on the site to approach allometric predictions derived from nearby reference tidal marshes (Hood 2015, 2018). The channel conceptual restoration plan was modified during implementation by omitting excavation of the two smallest channels in the design, extending the excavation of some other channels, and excavating seven large ponds, located adjacent to and communicating with the three largest tidal channels. Omission of the two smallest channels was a minor modification. Excavation of the large ponds was done to provide additional sediment for a spur dike, built at the request of the town of Stanwood to protect a nearby proposed public park. An additional benefit was that the ponds would provide shallow water habitat for waterfowl. Because the ponds are directly connected to tidal channels, they were also thought likely to provide significant habitat to juvenile salmon.

Dike removal and channel construction were hypothesized to be sufficient for allowing native vegetation recolonization of the site and for juvenile Chinook salmon to occupy the excavated channels and benefit from primary and secondary production on the site. Tidal marsh vegetation colonization is typically not constrained by the supply of seeds or other propagules from nearby tidal marshes, so no vegetation planting occurred as part of the restoration. This report describes early assessment of vegetation colonization two years after site restoration. It also describes the planform tidal channel geometry of excavated tidal channels, the location of surveyed channel cross-sections and profiles, and spot measurements of excavated pond elevations.

## Methods

Channel planform was digitized from aerial photographs in a GIS. Aerial photos were acquired from Google Earth; the most recent available photo dated from July 2020. During the summers of 2020 and 2021, vegetation on the restoration site was monitored by point sampling with an RTK-GPS (3-cm horizontal and vertical resolution). Points were distributed along random transects that spanned most of the site, with a total of 543 points sampled in 2020 and 392 points in 2021, each point about 30 m apart. At each GPS point the dominant and subdominant vascular plant species were noted, while the RTK-GPS acquired the horizontal and vertical location of the point. Relative plant abundance at each point was determined by

visual estimation of aerial cover within a 1-m radius from the sample point. The GPS data were transferred to a GIS for comparison of observed and predicted vegetation distributions similar to the method published in Hood (2013).

A Predictive Vegetation Model (PVM) was based on adjacent reference marshes to account for the particular salinity, soils, and tide range found in the area, and used methods described elsewhere (Hood 2013). However, it had a relatively small sample size to parameterize the model (302 sampling points distributed over 10 species), due to the small size of the reference marshes. The only species with large sample sizes in the Stillaguamish Delta were *Schoenoplectus pungens* (n = 62) and *B. maritimus* (n = 191). *Carex lyngbyei* had a sample size of 15, *Agrostis* sp. had 9; all other species were less common. Nevertheless, this PVM successfully predicted vegetation patterns in the nearby zis a ba restoration site (Hood 2019).

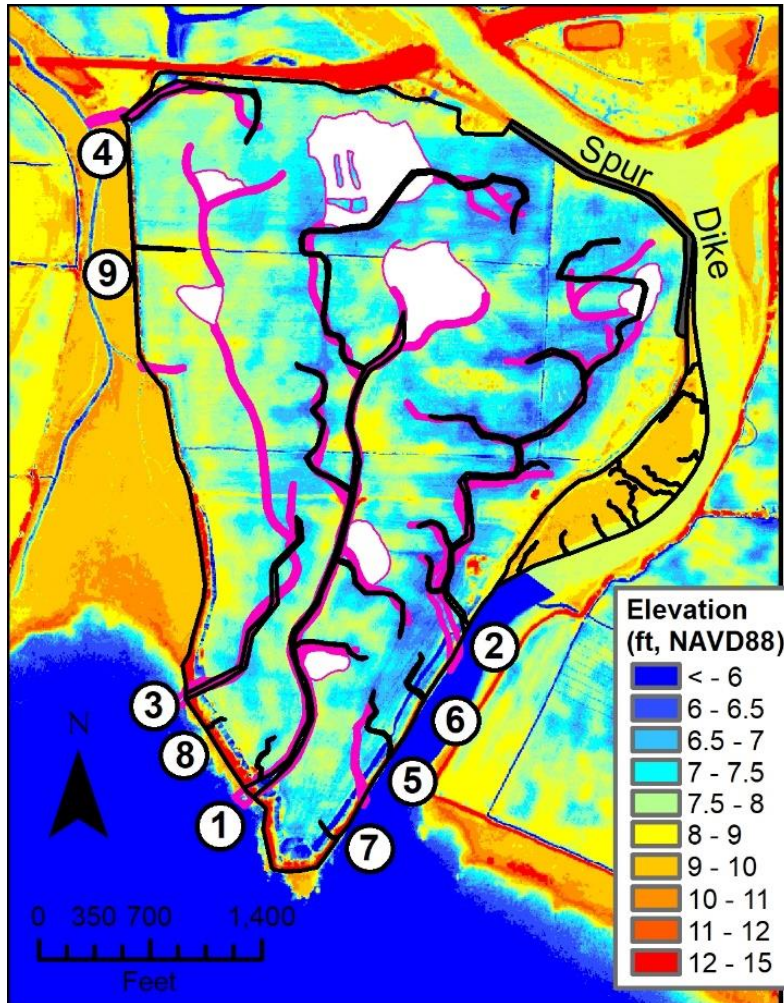
## Results

### *Tidal channel planform*

Tidal channel excavation resembled the conceptual planform design developed prior to restoration, but there were some significant alterations of the original design (Fig. 1). Three of the smallest channels (numbers 6, 7, and 8) were not excavated. Two others (numbers 5 and 9) were moved slightly to the south. One (number 3) was made much longer than planned. The six excavated channels amounted to a total channel area of 4.10 ha (10.13 ac) and total channel length of 6,580 m (21,589 ft). These values are greater than those of the conceptual design plan (Table 1). Overall, the total area of restored tidal channels was 19% greater than originally planned, while total channel length was 12% greater. Perhaps the most notable departure from the original channel design was a last minute decision to excavate large, shallow ponds. Their excavation was required to make up for a cut/fill imbalance, but they were also thought to be capable of providing habitat for waterfowl and fish. The excavated ponds were all connected to the excavated tidal channels to allow drainage on low tides. Their area was more than twice the area of the restored tidal channels, and amounted to about 8% of the total restoration site area. The area of the shallow pans (incidental, unvegetated, topographic depressions that tend to pond water to depths of a few inches at low tide; Fig. 2) was comparable to that of the restored tidal channels.

**Table 1.** Restoration channel metrics relative to conceptual design. Total site area is 103 ha, so the total area of each feature class approximates its percentage representation in the site.

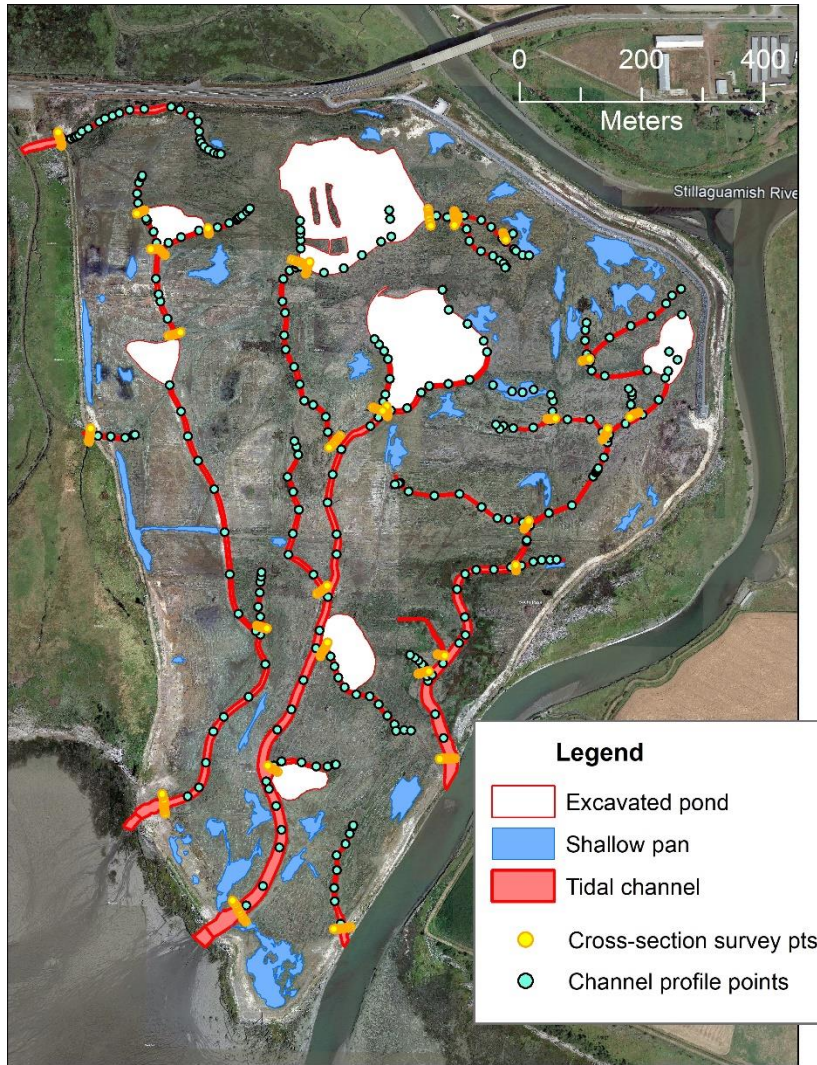
	Restoration	Conceptual design
Total channel area (ha)	4.10	3.45
Total channel length (m)	6,580	5,875
Channel outlet count	6	9
Excavated pond area (ha)	8.46	0
Shallow pan area (ha)	4.19	0



**Figure 1.** Location of excavated tidal channels (pink) and ponds (white) within the Leque restoration site, compared to conceptual plan channels (black outline polygons). Numbers identify conceptual plan channels at their outlets. The background image represents a lidar-derived DEM and shows that planned channels were located in topographic lows.

### *Tidal channel cross-sections and profiles*

Tidal channel cross-sections and profiles were surveyed in July 2021 and their locations are shown in Figure 2. Channel evolution through deepening, shoaling, or lengthening will be evaluated in the future by comparison with repeated channel cross-section and profile surveys. The excavated tidal channels had clay bottoms and sides, so further erosion leading to deepening or lengthening, if it occurs, is likely to be a very slow process. Incidental shallow pans, bare of vegetation and retaining a few centimeters of water at low tide, were observed in the field and in the 2020 aerial photos. If the sediments were more erodible, these would be areas likely to support headcutting of additional tributary channels.



**Figure 2.** Location of channel cross-section and profile survey points relative to channels and ponds.

### *Pre-restoration site vegetation*

Two years prior to restoration, the Leque site consisted of farmed grain fields, planted by the Washington Department of Fish and Wildlife to attract waterfowl, and sometimes fallow grass fields (Fig. 3). Field reconnaissance during this time showed that the grass fields consisted of non-native, pasture grasses typical of Western Washington, such as *Elymus repens* (quackgrass), *Lolium perenne* (ryegrass), *Agrostis stolonifera* (bentgrass) in wetter areas, *Dactylis glomerata* (cat grass), and the pasture weed (unpalatable to cattle), *Holcus lanatus* (velvet grass). With the exception of *Agrostis stolonifera* in occasional small patches, none of these grasses have persisted after site restoration to tidal inundation.



**Figure 3.** North half of the Leque restoration site two years prior to restoration, showing typical farmed (tan) and fallow (green, grassy) fields.

In the year prior to dike breaching, there was extensive disturbance of the site by heavy, tracked machinery and dump trucks involved in excavation of tidal channels. The intensity of this disturbance is only lightly hinted at in Figure 4. Field visit during the peak of construction showed that the site was bare throughout as a result of intense construction activity involving excavation of 12.5 ha (31 acres) of tidal channels and ponds. Typical saltmarsh vegetation was nowhere visible on the site, so current vegetation (see below) is not a legacy of prior land use.



**Figure 4.** Extensive crisscrossing of tracks of heavy equipment on the Leque restoration during early stages of channel and pond excavation. Vegetation was mostly obliterated by the end of construction.

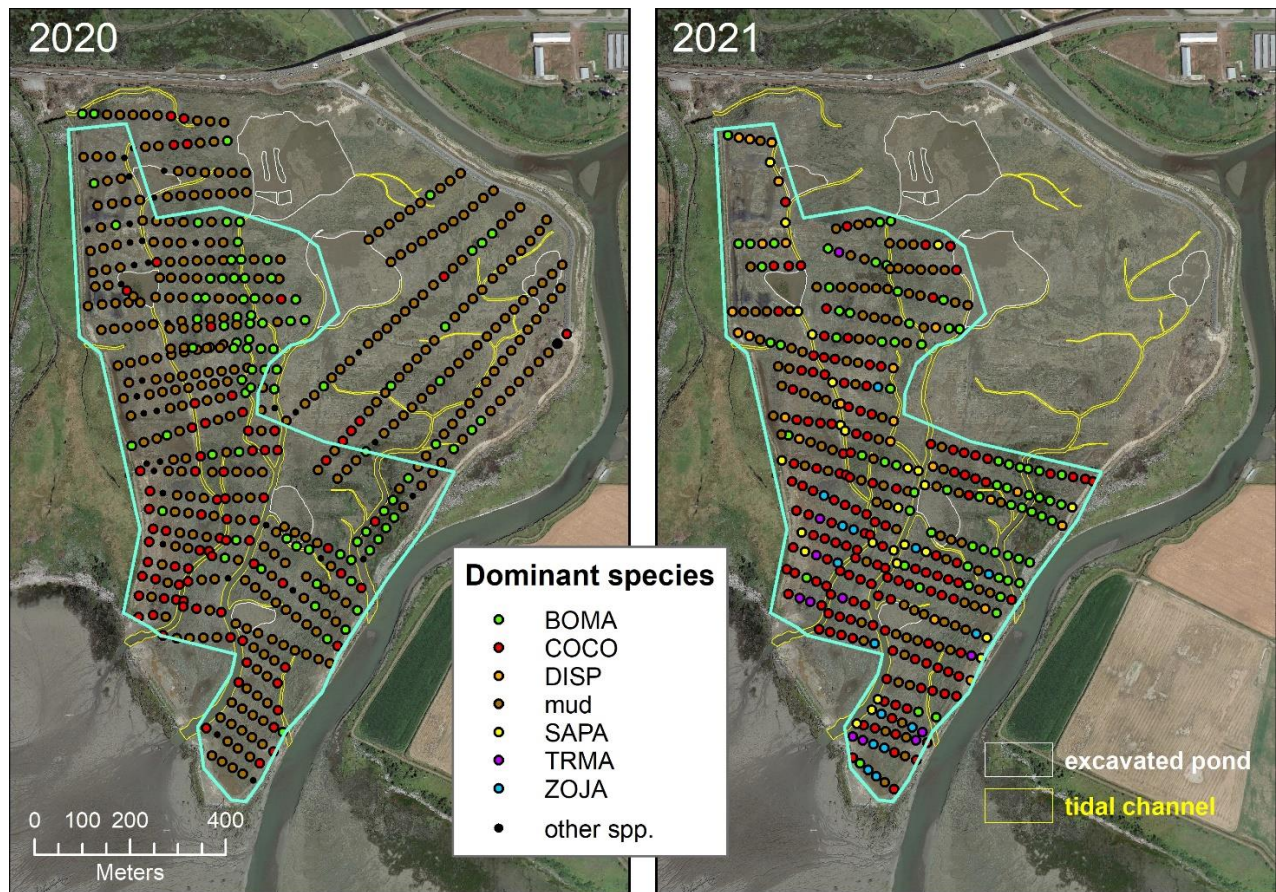
## Vegetation colonization

Two years after site restoration, the Leque Island site is just beginning to be recolonized by vegetation. Most of the site still consists of bare ground. To maximize sampling efficiency, vegetation sampling avoided large areas devoid of vegetation. A portion of the area sampled in 2020 was not sampled in 2021, because it was 80% bare in 2020 and appeared similarly bare in 2021. In the sampled area common to both years (light blue polygon in Fig. 5), bare ground comprised 56% of the 2020 vegetation survey, but only 26% of the 2021 vegetation survey, which indicates a 52% decrease in bare ground (Table 2). The decrease in bare ground was due primarily to a doubling in the occurrence of the non-native weed, *Cotula coronopifolia* (brass buttons), as well as significant increases in the native species, *Distichlis spicata* (saltgrass), *Sarcocornia pacifica* (pickleweed), and *Triglochin maritima* (seaside arrowgrass), as well as the non-native eelgrass, *Zostera japonica*, which was found in shallow marsh surface pans. The predicted dominant species for this site was *Bolboschoenus maritimus* (maritime bulrush), which in both years accounted for 18% of the sampled vegetation points in the common survey area. There was no evident increase in this species from 2020 to 2021, so colonization of the Leque restoration site by this species is much slower than at the nearby zis a ba restoration site.

**Table 2.** Frequency of occurrence as dominants, for plant species colonizing the Leque restoration site during 2020 versus 2021. Significant increases are **bolded**; declines are in **red**.

	2020 count	2021 count	2020 sample proportion	2021 sample proportion	% change
<i>Agrostis stolonifera</i> *	20	0	5.3%	0%	<b>-100%</b>
<i>Atriplex patula</i> *	3	0	0.8%	0%	<b>-100%</b>
<i>Bolboschoenus maritimus</i>	69	70	18.2%	17.9%	1.4%
<i>Cotula coronopifolia</i> *	71	144	18.7%	36.7%	<b>103%</b>
<i>Distichlis spicata</i>	3	23	0.8%	5.9%	<b>667%</b>
MUD	211	102	55.5%	26.0%	<b>-52%</b>
<i>Sarcocornia pacifica</i>	1	27	0.3%	6.9%	<b>2600%</b>
<i>Triglochin maritima</i>	2	11	0.5%	2.8%	<b>450%</b>
<i>Zostera japonica</i> *	0	15	0.0%	3.8%	<b>∞%</b>

\*Non-native species

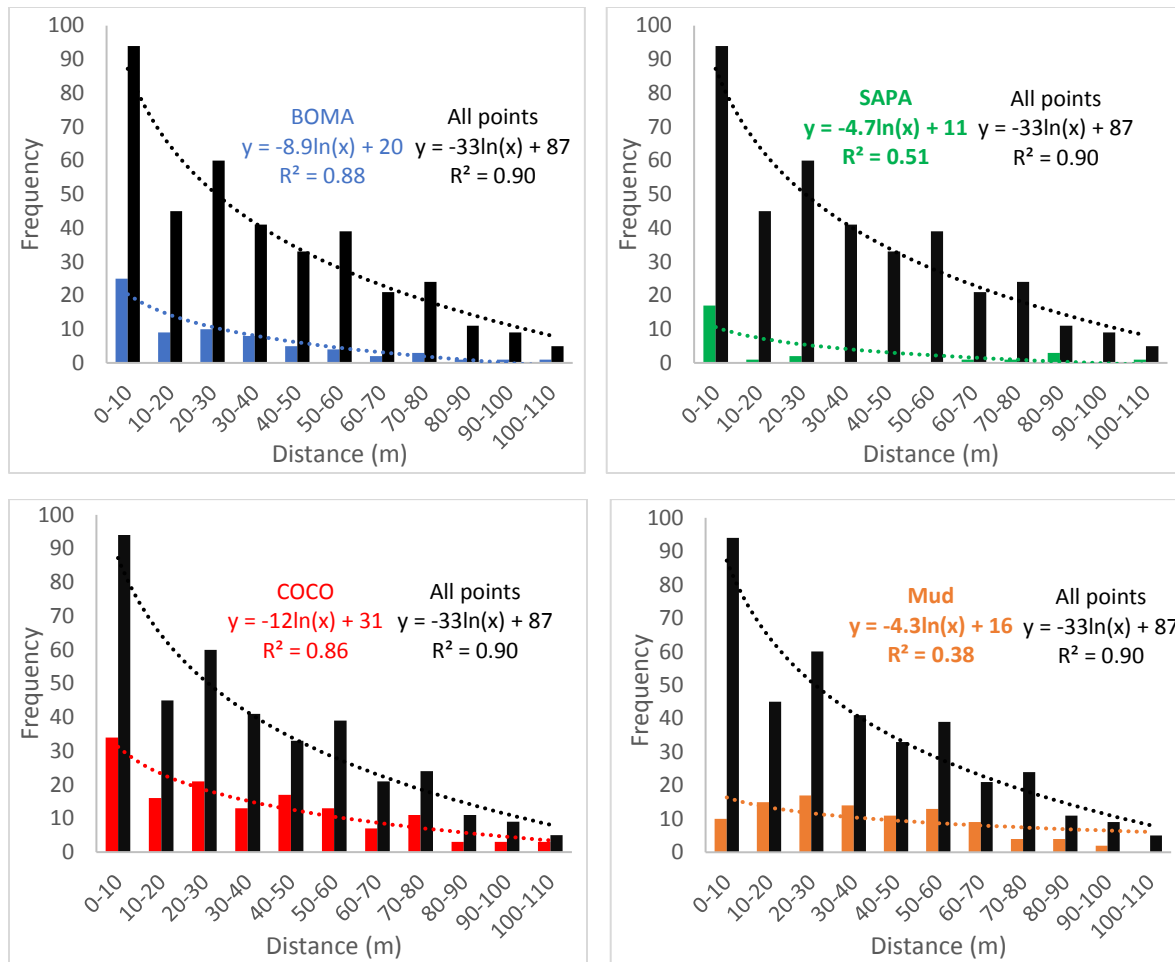


**Figure 5.** Dominant vegetation at RTK-GPS point samples. BOMA = *Bolboschoenus maritimus*; COCO = *Cotula coronopifolia*; DISP = *Distichlis spicata*; SAPA = *Sarcocornia pacifica*; TRMA = *Triglochin maritima*; ZOJA = *Zostera japonica*.

During field surveys, *B. maritimus* appeared to be associated with tidal channel banks, though not exclusively (Fig. 6). Plots of the frequency distributions of the distances of *Bolboschoenus*, *Sarcocornia*, *Distichlis*, and *Cotula* from channel banks initially appeared to support this field observation by showing an exponential decline in occurrence frequency with distance from the channel network for almost all species (*Triglochin* and *Zostera* were too infrequently observed to meaningfully plot their frequency distributions). However, when the frequency distributions for all sample points regardless of species present was similarly plotted as a control, it was shown that all sample plots, collectively, had a similar exponential decline in occurrence frequency with distance from the channel network (Fig. 7). This is an indication that the channel network is well dispersed throughout the site, so that few areas of marsh are far from the network; most are near the channels.



**Figure 6.** Two views of *Bolboschoenus maritimus*, showing occurrence along channel margins.



**Figure 7.** Frequency distributions of *Bolboschoenus maritimus* (blue), *Sarcocornia pacifica* (green), non-native *Cotula coronopifolia* (red), and mud (orange) relative to all RTK-GPS point sample locations.

Because the sampling points themselves had a negative exponential frequency distribution relative to distance from the channel network, the salient question then became does any species have a distribution that deviates from the total sampling point distribution, i.e., are any species disproportionately close to or far from the channel network? To answer this question, chi-square tests for goodness of fit were used to compare species frequencies with total sample frequencies, i.e., with the null distribution.

At distances greater than 50 m from the channel network, species frequencies were often < 5 per 10-m distance bin, which is problematic for chi-square analysis, so beyond this distance, pairs of frequency bins were lumped together to increase species frequencies within these bins. This produced series of 2 x 8 chi-square tests, with each species compared to all sample points over eight distance bins. As an additional exploration of the potential association of marsh plants with tidal channel margins, 2 x 2 contingency chi-square tests were constructed

for each species, where a particular species was compared to all sample points crossed with two distance categories: less than 10 m vs. more than 10 m from the channel network.

The 2 x 8 chi-square tests (Appendix A) revealed significant differences in species frequency distributions from the null only for *Sarcocornia pacifica* ( $p = 0.001$ ,  $\chi^2 = 25.582$ ,  $df = 7$ ), while bare ground had a suggestion of a possible deviation from the null ( $p = 0.085$ ,  $\chi^2 = 12.498$ ,  $df = 7$ ). A closer examination of the standardized cell frequencies across the distance bins suggested that for several species the 0-10 m bin had the strongest deviation from the null distribution, which spurred further investigation with the 2 x 2 chi-square tests.

The 2 x 2 chi-square tests revealed significant differences in species frequency distributions from the null for SAPA ( $p < 0.0001$ ,  $\chi^2 = 20.439$ ,  $df = 1$ ). Comparison of standardized frequencies showed that 65.4% of all SAPA occurrences were within 10 m of the channel network, compared to 24.6% of all sample points, which suggests this distance bin is the most responsible for the difference between the *Sarcocornia pacifica* and null distributions. Bare ground also had a significant difference from the null in the 0-10 m bin ( $p = 0.002$ ,  $\chi^2 = 9.763$ ,  $df = 1$ ). In this case, only 10.1% of all bare ground points were found within 10 m of the channel network, compared to 24.6% for all sample points. *Bolboschoenus maritimus* also had an association with channel margins, with 36.2% of all *Bolboschoenus* occurrences within 10 m of the channel network, compared to 24.6% for the null ( $p = 0.044$ ,  $\chi^2 = 4.066$ ,  $df = 1$ ).

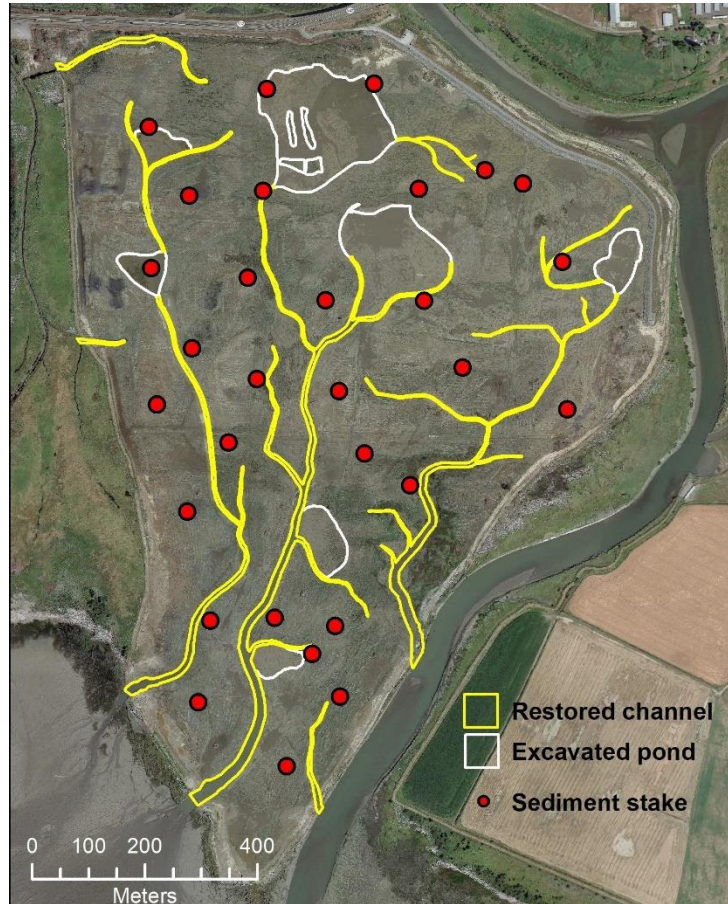
*Distichlis spicata* and *Cotula coronopifolia* did not differ from the null distribution. In fact, the standardized frequencies of *Cotula* were very similar to those of the null in all eight distance bins.

To further investigate potential species differences in their relationship to tidal channels, a one-way ANOVA tested for species differences in mean distances from the channel network (Appendix B). Data were log-transformed to satisfy assumptions of parametric testing, as indicated by the previously described negative logarithmic frequency distributions (Fig. 7). Residual analysis indicated transformation was appropriate. Overall, a significant difference in mean distance was found among the five groups tested (bare ground, *Bolboschoenus*, *Sarcocornia*, *Distichlis*, and *Cotula*;  $F_{4, 360} = 7.850$ ,  $p < 0.0001$ ). More specifically, Tukey's HSD *post hoc* test found significant differences between: *Sarcocornia* ( $\bar{x} = 26.9$  m) and bare ground ( $\bar{x} = 41.4$  m) ( $p < 0.0001$ ); *Bolboschoenus* ( $\bar{x} = 27.8$  m) and bare ground ( $\bar{x} = 41.4$  m) ( $p = 0.001$ ); and between *Sarcocornia* ( $\bar{x} = 26.9$  m) and *Cotula* ( $\bar{x} = 36.4$  m) ( $p = 0.004$ ).

### *Sediment stakes*

Sediment stakes have been installed in the restoration site (Fig. 8), and will be monitored on an annual basis at the end of each water-year. Five stakes are located in three excavated ponds, with three stakes in the largest pond. One stake is located in one of the deeper shallow pans. The remaining 24 stakes are dispersed throughout the marsh surface.

Because sediment stakes were only installed this year, it is too soon to describe any results. However, we can anticipate testing the following hypotheses in the future following many years of annual sediment stake measurements: [1] accretion is correlated with proximity to tidal channels (i.e., tidal channels are the primary source of sediment); [2] accretion is negatively correlated with elevation (consistent with theory); [3] accretion rate is comparable to the current rate of sea level rise (given sufficient sediment supply accretion rates can accelerate with increasing rates of sea level rise, so current sea level rise rates are the appropriate comparison).



**Figure 8.** Location of Leque restoration sediment stakes.

## Discussion

One of the most visually striking aspects of the Leque restoration site is the currently patchy vegetation colonization of the site. Bare ground predominates while patches of *Bolboschoenus* intermittently border tidal channels and *Cotula* is scattered at slightly lower elevations in the southern half of the Leque restoration site. Two years after restoration, the site is not revegetating as quickly as at the nearby zis a ba restoration site. While this is disappointing, it is also normal for typical restoration sites; zis a ba was extraordinary in its rapid revegetation. It seems likely that *Bolboschoenus* will continue to spread to match predictions of the vegetation model of site dominance by this species, as occurred in the nearby zis a ba restoration site. The rapid colonization of the zis a ba site has been attributed to extensive excavation of tidal channels on that site, which diverts the energy of tidal exchange from sheet flow on the marsh surface to channelized flow in tidal channels. The lowered tidal energy on the marsh is thought to improve seed settlement and germination (Hood 2019). Since extensive tidal channel excavation also occurred on the Leque site, we expected similarly rapid vegetation recovery on the Leque site, assuming this hypothesis on the role of tidal

energy dissipation in vegetation colonization was correct. The second year of vegetation monitoring so far does not support this hypothesis. Perhaps vegetation colonization will accelerate dramatically next year and support the hypothesis, or perhaps we will have to revisit the hypothesis next year and evaluate why Leque and Zisaba differ despite both having extensive tidal channel excavation.

Tidal channels do appear to facilitate vegetation colonization of the restoration site, as shown by statistical analysis of vegetation distributions, which show disproportionate abundance of *Sarcocornia pacifica* (pickleweed) and *Bolboschoenus maritimus* (marine bulrush), as well as a disproportionate paucity of bare ground, within 10 m of the tidal channel network. In contrast, *Cotula coronopifolia* (brass buttons) was evenly distributed, regardless of distance from the channel network. These observations suggest that while seeds of all plant species may be transported to the restoration site via tidal channels during flood tides, once the tide tops the channel banks, *Sarcocornia* and *Bolboschoenus* seeds do not travel far from the banks, while *Cotula* seeds are easily dispersed over the marsh surface. Perhaps there is some difference between species in seed settling rates or flotation. Seed size and buoyancy have been implicated in dispersal patterns of water-borne seed in fluvial and lacustrine systems (Hyslop and Trowsdale 2012). An alternative explanation is that all seeds are well dispersed throughout the site, but environmental conditions near channel banks are more appropriate for *Sarcocornia* and *Bolboschoenus* seed germination, while *Cotula* seeds have broader environmental tolerances.

The other visually striking feature of the Leque restoration site is the abundance of large excavated ponds, created to benefit waterfowl and, potentially, juvenile salmon. However, previous experience with the Wiley Slough restoration project in the South Fork Skagit Delta, suggests the excavated ponds may have a limited life span, because similar ponds in the Wiley Slough site have experienced significant sedimentation and conversion to marsh in the 10 years since restoration of that site. On the other hand, previously excavated duck ponds in the east lobe of the Deepwater Slough site have persisted, though they are much deeper, with only modest shrinkage and conversion to marsh in the 20 years since that site was restored to tidal inundation. The likely difference between the two sites (in addition to pond depth) is the rate of sediment supply via river distributaries. Given that Leque is relatively distant from its nearest significant source of sediment, the mouth of the Stillaguamish River (i.e., Hat Slough), pond sedimentation rates may be slower than that observed for Wiley Slough, which is located immediately adjacent to the principal distributary of the South Fork Skagit Delta. On the other hand, Leque Island is exposed to significant southerly storm fetch which likely carries a lot of suspended sediment to the site during storms. This fetch effect may counter the isolation of the site from sediment sources and increase the rate of pond siltation. Thus, particular attention should be paid to monitoring the rate of pond siltation. The installed sediment stakes will be one way to monitor pond sedimentation and persistence. Another will be to use aerial photography to monitor vegetation colonization of the ponds, which can be done annually by reference to Google Earth or other contracted photos.

The 4 ha (10 ac) of shallow pans that were observed on the site may rapidly fill with sediment, but they may also affect early vegetation colonization by providing topographic variation that favors species diversity. As of the initial, colonizing, stage of vegetation development there is some indication that they may support Japanese eelgrass, though presence of this species is relatively sparse. Future vegetation monitoring should pay attention to vegetation dynamics within these pans. If the pans are shown to have a beneficial effect on vegetation diversity, future restoration designs might choose to intentionally provide such features.

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## APPENDIX A

### BOMA vs. All Pts.

#### ▼ Crosstabulation: Two-Way

##### Counts

	ALL_PTS	BOMA	Total
0-10 m	94	25	119
10-20	45	9	54
20-30	60	10	70
30-40	41	8	49
40-50	33	5	38
50-70	60	6	66
70-90	35	4	39
90-110	14	2	16
<b>Total</b>	<b>382</b>	<b>69</b>	<b>451</b>

##### Column Percents

	ALL_PTS	BOMA	Total	N
0-10 m	24.6	36.2	26.4	119
10-20	11.8	13.0	12.0	54
20-30	15.7	14.5	15.5	70
30-40	10.7	11.6	10.9	49
40-50	8.6	7.2	8.4	38
50-70	15.7	8.7	14.6	66
70-90	9.2	5.8	8.6	39
90-110	3.7	2.9	3.5	16
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>69</b>		<b>451</b>

#### Chi-Square Tests of Association for BIN and CONTRAST\$

Test Statistic	Value	df	p-Value
Pearson Chi-Square	6.126	7	0.525

#### ▼ Crosstabulation: Two-Way

##### Counts

	ALL_PTS	BOMA	Total
0-10 m	94	25	119
10+	288	44	332
<b>Total</b>	<b>382</b>	<b>69</b>	<b>451</b>

##### Column Percents

	ALL_PTS	BOMA	Total	N
0-10 m	24.6	36.2	26.4	119
10+	75.4	63.8	73.6	332
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>69</b>		<b>451</b>

#### Chi-Square Tests of Association for BOMA vs. all pts

Test Statistic	Value	df	p-Value
Pearson Chi-Square	4.066	1	0.044

## DISP vs. All Pts

### ▼ Crosstabulation: Two-Way

#### Counts

	ALL_PTS	DISP	Total
0-10 m	94	7	101
10-20	45	1	46
20-30	60	5	65
30-40	41	1	42
40-50	33	0	33
50-70	60	5	65
<b>Total</b>	<b>333</b>	<b>19</b>	<b>352</b>

#### Column Percents

	ALL_PTS	DISP	Total	N
0-10 m	28.2	36.8	28.7	101
10-20	13.5	5.3	13.1	46
20-30	18.0	26.3	18.5	65
30-40	12.3	5.3	11.9	42
40-50	9.9	0	9.4	33
50-70	18.0	26.3	18.5	65
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>333</b>	<b>19</b>		<b>352</b>

**WARNING** More than one-fifth of the fitted cells are sparse (frequency < 5).  
Significance tests computed on this table are suspect.

### Chi-Square Tests of Association for DISP and D\_V\_APTSS\$

Test Statistic	Value	df	p-Value
Pearson Chi-Square	5.373	5	0.372

### ▼ Crosstabulation: Two-Way

#### Counts

	ALL_PTS	DISP	Total
0-10 m	94	7	101
10+	239	12	251
<b>Total</b>	<b>333</b>	<b>19</b>	<b>352</b>

#### Column Percents

	ALL_PTS	DISP	Total	N
0-10 m	28.2	36.8	28.7	101
10+	71.8	63.2	71.3	251
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>333</b>	<b>19</b>		<b>352</b>

### Chi-Square Tests of Association for DISP and D\_V\_APTSS\$

Test Statistic	Value	df	p-Value
Pearson Chi-Square	0.652	1	0.419

## SAPA vs. All pts.

### ▼ Crosstabulation: Two-Way

#### Counts

	ALL_PTS	SAPA	Total
0-10 m	94	17	111
10-20	45	1	46
20-30	60	2	62
30-40	41	0	41
40-50	33	0	33
50-70	60	1	61
70-90	35	4	39
90-110	14	1	15
<b>Total</b>	<b>382</b>	<b>26</b>	<b>408</b>

#### Column Percents

	ALL_PTS	SAPA	Total	N
0-10 m	24.6	65.4	27.2	111
10-20	11.8	3.8	11.3	46
20-30	15.7	7.7	15.2	62
30-40	10.7	0	10.0	41
40-50	8.6	0	8.1	33
50-70	15.7	3.8	15.0	61
70-90	9.2	15.4	9.6	39
90-110	3.7	3.8	3.7	15
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>26</b>		<b>408</b>

**WARNING** More than one-fifth of the fitted cells are sparse (frequency < 5).  
Significance tests computed on this table are suspect.

#### Chi-Square Tests of Association for SAPA vs All pts

Test Statistic	Value	df	p-Value
Pearson Chi-Square	25.582	7	0.001

### ▼ Crosstabulation: Two-Way

#### Counts

	ALL_PTS	SAPA	Total
0-10 m	94	17	111
10+	288	9	297
<b>Total</b>	<b>382</b>	<b>26</b>	<b>408</b>

#### Column Percents

	ALL_PTS	SAPA	Total	N
0-10 m	24.6	65.4	27.206	111
10+	75.4	34.6	72.794	297
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>26</b>		<b>408</b>

#### Chi-Square Tests of Association for SAPA vs All pts

Test Statistic	Value	df	p-Value
Pearson Chi-Square	20.439	1	0.000

## COCO vs. All pts

### ▼ Crosstabulation: Two-Way

#### Counts

	ALL_PTS	COCO	Total
0-10 m	94	34	128
10-20	45	16	61
20-30	60	21	81
30-40	41	13	54
40-50	33	17	50
50-70	60	20	80
70-90	35	14	49
90-110	14	6	20
<b>Total</b>	<b>382</b>	<b>141</b>	<b>523</b>

#### Column Percents

	ALL_PTS	COCO	Total	N
0-10 m	24.6	24.1	24.5	128
10-20	11.8	11.3	11.7	61
20-30	15.7	14.9	15.5	81
30-40	10.7	9.2	10.3	54
40-50	8.6	12.1	9.6	50
50-70	15.7	14.2	15.3	80
70-90	9.2	9.9	9.4	49
90-110	3.7	4.3	3.8	20
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>141</b>		<b>523</b>

#### Chi-Square Tests of Association for COCO and C\_V\_APTSS

Test Statistic	Value	df	p-Value
Pearson Chi-Square	1.872	7	0.967

## Mud vs. All pts

### ▼Crosstabulation: Two-Way

#### Counts

	ALL_PTS	MUD	Total
0-10 m	94	10	104
10-20	45	15	60
20-30	60	17	77
30-40	41	14	55
40-50	33	11	44
50-70	60	22	82
70-90	35	8	43
90-110	14	2	16
<b>Total</b>	<b>382</b>	<b>99</b>	<b>481</b>

#### Column Percents

	ALL_PTS	MUD	Total	N
0-10 m	24.6	10.1	21.6	104
10-20	11.8	15.2	12.5	60
20-30	15.7	17.2	16.0	77
30-40	10.7	14.1	11.4	55
40-50	8.6	11.1	9.1	44
50-70	15.7	22.2	17.0	82
70-90	9.2	8.1	8.9	43
90-110	3.7	2.0	3.3	16
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>99</b>		<b>481</b>

### Chi-Square Tests of Association for MUD and B\_VS\_MUD\$

Test Statistic	Value	df	p-Value
Pearson Chi-Square	12.498	7	0.085

### ▼Crosstabulation: Two-Way

#### Counts

	ALL_PTS	MUD	Total
0-10 m	94	10	104
10+	288	89	377
<b>Total</b>	<b>382</b>	<b>99</b>	<b>481</b>

#### Column Percents

	ALL_PTS	MUD	Total	N
0-10 m	24.6	10.1	21.6	104
10+	75.4	89.9	78.4	377
<b>Total</b>	<b>100</b>	<b>100</b>	<b>100</b>	
<b>N</b>	<b>382</b>	<b>99</b>		<b>481</b>

### Chi-Square Tests of Association for MUD and B\_VS\_MUD\$

Test Statistic	Value	df	p-Value
Pearson Chi-Square	9.763	1	0.002

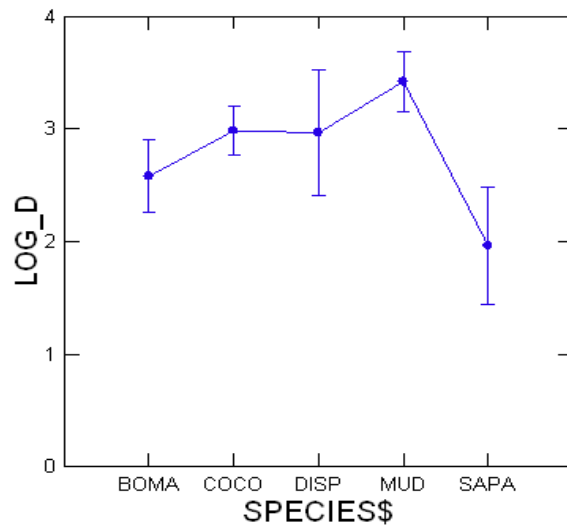
## APPENDIX B

### ▼ Analysis of Variance

Variables	Levels				
SPECIES\$ (5 levels)	BOMA	COCO	DISP	MUD	SAPA

Dependent Variable	LOG_D
N	365
Multiple R	0.283
Squared Multiple R	0.080

### Least Squares Means



Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
SPECIES\$	57.786	4	14.446	7.850	0.000
Error	662.491	360	1.840		

### ▼ Hypothesis Tests

Post Hoc Test of LOG\_D

Using least squares means.

Using model MSE of 1.840 with 360 df.

Tukey's Honestly-Significant-Difference Test					
SPECIES\$(i)	SPECIES\$(j)	Difference	p-Value	95% Confidence Interval	
				Lower	Upper
BOMA	COCO	-0.406	0.242	-0.945	0.134
BOMA	DISP	-0.387	0.759	-1.276	0.503
BOMA	MUD	-0.841	0.001	-1.416	-0.267
BOMA	SAPA	0.617	0.275	-0.232	1.467
COCO	DISP	0.019	1.000	-0.812	0.850
COCO	MUD	-0.436	0.094	-0.915	0.043
COCO	SAPA	1.023	0.004	0.234	1.811
DISP	MUD	-0.455	0.594	-1.309	0.399
DISP	SAPA	1.004	0.073	-0.055	2.063
MUD	SAPA	1.459	0.000	0.646	2.272