Oregon Undergraduate Research Journal
3.1 (2012) ISSN: 2160-617X (online)
http://journals.oregondigital.org/ourj/
DOI: 10.5399/uo/ourj.3.1.2391

Assessing the Relationship Between Topography and Plant Diversity in Restored and Remnant Wet Prairies

Claire Reed-Dustin, Willis Logsdon, Rachel Lytton, Sam Maloney, Audie Paulus, Tatiana Piazza, and Tiziana Stuparitz*, Environmental Studies Program.

ABSTRACT

Wet prairies provide numerous ecosystem services and habitat for native plant species. This study examines the relationship between microtopographic variation and plant diversity in six restored and remnant wet prairies in the West Eugene Wetlands to aid future restoration projects. It was predicted that variation in elevation is influential in determining native plant community composition. Along transects within previously established macroplots, soil surface elevation and water depth were measured and percent cover of grasses, forbs, and non-forbs, and measured vegetation and litter height were determined. A linear regression was performed comparing native species richness to the topographic coefficient of variation, which yielded an R^2 value of 0.43 and a p-value of 0.16. Although these results are not statistically significant, they demonstrate a meaningful correlation between native plant richness and the coefficient of variation of topography. Further observations additionally suggest that this relationship is present. We suggest further research to determine significant results and suggest the integration of the restoration of microtopography into wetland management.

1. INTRODUCTION

Wet prairie habitats once covered 31% of the Willamette Valley ecosystem; today, 98% of these areas are severely damaged or destroyed (Wold et al. 2011). These native ecosystems are valued for their aesthetic beauty as well as for their benefits to society. Specifically, the West Eugene Wetlands provide numerous ecosystem services including carbon storage, flood control, storm water purification, and nutrient capturing and cycling. The 3,171-acre area of the West Eugene Wetlands is comprised mainly of wet prairie, which is dominated by grasses and wildflowers, and home to a variety of wildlife (City of Eugene & LCOG 2011). Wet prairie restoration in the West Eugene Wetlands is therefore an important issue for local government agencies, including the Lane Council of Governments (LCOG) and the City of Eugene.

* Authors are members of the University of Oregon Environmental Leadership Program, a collaborative, interdisciplinary service-learning program housed in the University of Oregon Environmental Studies Program. For more information, visit http://envs.uoregon.edu/elp_program/. Please direct correspondence to clairereeddustin@gmail.com.

Understanding the most feasible and effective techniques for wet prairie restoration is essential for the future of these habitats.

The role of microtopography in restored wetlands is of growing interest to wetland ecologists as restoration techniques continue to evolve and improve. Microtopographic variation is a common attribute of natural wetlands, yet is not often observed in restored or created wetlands (Bruland & Richardson 2005; Moser et al. 2007). In the West Eugene Wetlands, for example, many restored prairies occupy lands that were historically leveled for grass seed production. The presence of microtopographic variation in restored wet prairies has implications for soils, hydrology, and vegetation (Bruland & Richardson 2005). Microtopographic heterogeneity in restored wetlands can increase native species abundance and diversity (Moser et al. 2007). The promotion of native plant diversity and cover in restored wet prairies is essential to restoration projects, and is often hindered by the invasion of exotic species (Pfeifer-Meister et al. 2008).

Microtopographic heterogeneity in natural wetlands is caused by a variety of factors, including erosion, sediment accumulation, tree fall, animal tracks, and animal burrowing (Bruland & Richardson 2005). To imitate the microtopographic heterogeneity of natural wetlands, restoration scientists have used several techniques, including disking and excavation (Moser et al. 2007). Both disking and excavation use machinery to disturb soils in order to mimic the natural microtopographic variation in native wetlands.

A series of environmental conditions influence vegetative communities in wetlands, including hydrology and soils. Bruland and Richardson (2005) found that the reestablishment of microtopography by excavation in a restored wetland increased the variety of hydrologic, edaphic, and vegetative conditions. For example, soil temperature, pH, and nutrient levels varied across hummocks, hollows, and flats. Plant species diversity varied across microtopographic zones as well, with the greatest diversity in the flats and no single species occurring in all three zones. The variability in microtopography thus produced different conditions for vegetation growth (Bruland & Richardson 2005). According to Moser et al. (2007), microtopographic heterogeneity in a disked wetland promoted greater plant diversity and cover than a non-disked wetland. Disked wetlands also had greater microtopography than non-disked wetlands, and experienced greater species richness and cover. Furthermore, a study by Seabloom et al. (2003) found that plant communities were more homogeneous in a restored wetland without microtopographic reestablishment than in natural wetlands. By producing different vegetative zones, it appears that microtopographic heterogeneity increases plant diversity and cover in restored wetlands.

Wet prairie restoration values the achievement of a high percent cover of native species and high native species diversity. However, the encroachment of exotic species complicates the achievement of native plant diversity and cover in restored wetlands. Exotic plants have been hypothesized to competitively exclude native species in high-nutrient, moderate-moisture environments, thus displacing native species to low-nutrient, high-moisture environments (Pfeifer-Meister et al. 2008). Pfeifer-Meister et al. (2008) found that although two exotic grasses produced the most biomass in all combinations with two native grasses, the native grasses were not completely excluded from high-nutrient, moderate-moisture environments. The provision of a variety of moisture conditions in restored wet prairies through microtopography may therefore have implications for reducing competition between native and exotic species.

Microtopographic heterogeneity has important implications for the restoration of wet prairies in the Willamette Valley. By promoting different vegetative conditions through soil and hydrologic conditions, microtopography can help to promote greater plant diversity and cover in restored wetlands (Bruland & Richardson 2005; Moser et al. 2007). The reestablishment of microtopographic variation may also be an important restoration tool in reducing the impact of invasive species on restored wet prairies. The goal of the Institute for Applied Ecology (IAE), LCOG, and the City of Eugene in restoring the West Eugene Wetlands is to increase the diversity and cover of native wetland flora and fauna which, in turn, will help reduce competition from and invasion by exotic species. Wetlands that have lost their microtopographic heterogeneity provide a narrow range of habitat conditions for wetland species and therefore would be expected to have less plant biodiversity. To inform local restoration efforts, we examined the relationship between microtopographic variation and native species diversity in restored and remnant wet prairies in the Willamette Valley, including the role of microtopographic variation in protecting against exotic species invasion.

2. STUDY SITES

From April 6 to May 11, 2012, we collected data from six restored and remnant wet prairie sites in the West Eugene Wetlands: Speedway, Oxbow West, Vinci, Coyote Prairie, Dragonfly Bend and Willow Creek (Figure 1). The Bureau of Land Management owns Speedway, Vinci and Oxbow West, the City of Eugene owns Coyote Prairie and Dragonfly Bend, and the Nature Conservancy owns Willow Creek. The study sites were designated as high, moderate or low quality wet prairies by IAE (Figure 1). The designation was based on qualitative assessments of percent cover of tufted hair grass (*Deschampsia cespitosa*), because this native species prevents the invasion of exotic species.

Native bunch grasses dominated all sites, except for Speedway, which was dominated by annual grasses and contained a high number of invasive species, and Willow Creek, which was dominated by annual grasses and native forbs. The endangered Willamette daisy (*Erigeron decumbens*) occurs at Speedway, Vinci, and Oxbow West. Kincaid's lupine (*Lupins sulphureus*), also an endangered species, occurs at Dragonfly Bend. We took particular care to avoid trampling these plants during data collection.

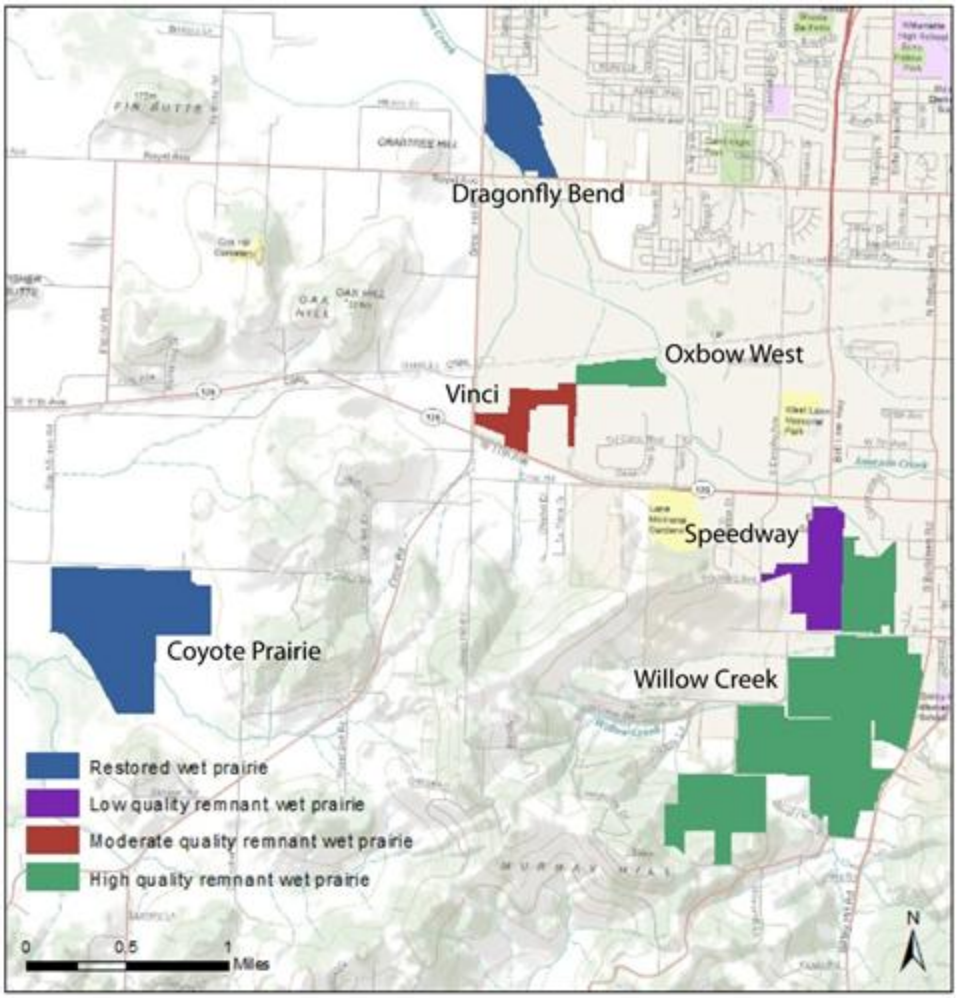

Figure 1. Location and classification of six microtopography research study sites in the West Eugene Wetlands, Eugene, Oregon.

3. METHODS

3.1. SAMPLING DESIGN

At each site, we located a point of origin within a pre-existing macroplot study area managed by IAE, LCOG, or the City of Eugene. From the point of origin, we established a baseline transect based on the site descriptions provided by IAE. Using the systematic sampling method, we set up transects perpendicular to the baseline transect, with the first transect randomly located and each subsequent transect following at an equal interval of 4-5 meters. Along each transect, the first sample point was randomly located and each following point was spaced at an equal interval of 4-5 meters for a total of 200 sample points per study site. At each sample point, we collected data for topography, water level, vegetation height, and litter (fallen dead vegetation) depth.

3.2. MICROTOPOGRAPHY & WATER DEPTH

In order to measure microtopography at each site, we used a surveyor's level (Harrelson et al. 1994). First, we set up the tripod, and secured and leveled the instrument to ensure consistency in our measurements. Next, we took a backsight reading to the point of origin, which had an arbitrary elevation of 100 meters. The height of the instrument (HI) was then calculated by adding the backsight reading to the standard elevation value of 100 meters. At each sample point along each transect, a foresight (FS) was recorded. The elevation of each sample point was calculated by subtracting the foresight from the height of the instrument (HI – FS = ELEV). At the approximate mid-point and end of the survey, we took another backsight to the benchmark to ensure the level had not moved or shifted significantly (Harrelson et al. 1994). In addition to measuring elevation, at each point we recorded the depth of standing water with the surveyor's rod to the nearest millimeter.

3.3. VEGETATION HEIGHT & LITTER

We used a meter stick to measure vegetation height and litter depth to the nearest millimeter. We did not manipulate plants or litter to ease the process of taking measurements. Upon resting the meter stick on top of the soil, any litter disturbed in the process was carefully replaced to its former condition. We waited for the vegetation to stop moving completely, and then recorded the height of the tallest vegetation in contact with the meter stick. In addition, we measured the depth of litter above the soil.

3.4. PLANT COMMUNITY COMPOSITION

Along each transect, we used a 1 meter x 1 meter quadrat frame to determine the percent cover of plant functional groups (grasses, rosette forbs, non-rosette forbs, and shrubs/trees). We placed a quadrat frame on the right side of the transect at a predetermined, random location along the transect. To estimate percent cover, we used the Daubenmire cover class method at intervals 0-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95-100% (NOAA 2005). For each quadrat, the total cover was equal to or greater than 100% because of the overlapping of different functional groups. To reduce observer bias, we worked in pairs while estimating percent cover. This process was repeated once or twice along each transect at randomly determined locations for a total of 20 plots per study site.

3.5. DATA ANALYSIS

We first calculated the Shannon's Diversity Index, Pielou's Evenness Index, and the topographic coefficient of variation for each site. The Shannon's Diversity Index (Equation 1) and Pielou's Evenness Index (Equation 2) were calculated using previously-collected percent cover data compiled by IAE.

Equation 1 Shannon's Diversity Index: $H' = -\Sigma\, p_i \ln (p_i)$

where p_i = proportion of individuals of species i

Equation 2. Pielou's Evenness Index: $J' = H'/H'_{max}$

where $H_{max} = \ln(S)$ and S = number of species

We used the topographic coefficient of variation as a measure of site variability, which we calculated by dividing the standard deviation of the topographic elevation points by the total number of points.

The total species richness (number of species), native species richness, and introduced (non-native) species richness were calculated using data from IAE. From the data we collected in the field, we then calculated the arithmetic mean and standard deviation of the litter depth, vegetation height and water depth for each site. To assess the relationship between microtopography and species diversity, we conducted several linear regressions between native and introduced species richness, diversity and evenness versus the topographic coefficient of variation. Presence and absence data collected by IAE of obligate species (found in only uplands or lowlands) and facultative species (found in either uplands or lowlands) was compared to the coefficient of variation for each site to assess plant diversity. Finally, we assessed plant community composition qualitatively and compared plant functional groups across study sites.

4. RESULTS

4.1. SPECIES RICHNESS, EVENNESS AND DIVERSITY

Data provided by IAE showed that total plant species richness ranged from 59 species at Willow Creek to 25 species at Coyote Prairie. Willow Creek had the greatest native species richness, while Oxbow West had the lowest. Vinci had the greatest number of invasive species, while Coyote Prairie had the fewest (Figure 2).

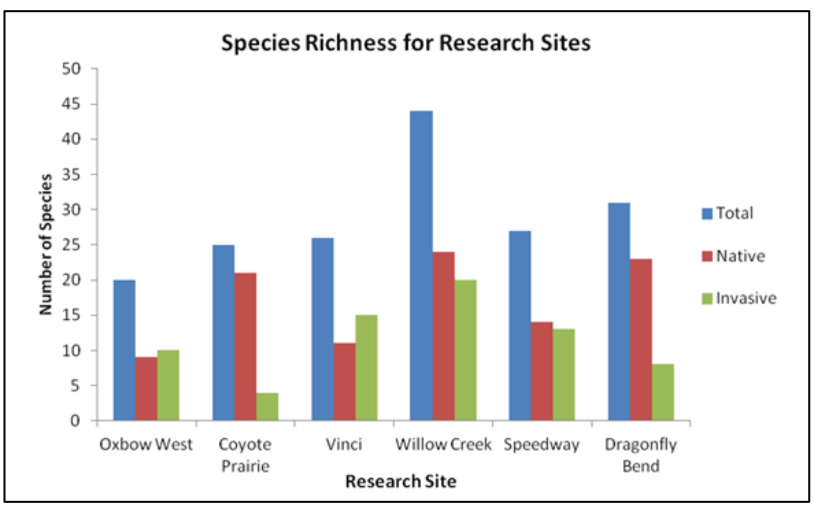

Figure 2. Total, native, and introduced plant species richness for all research sites.

Pielou's Evenness Indices ranged from a low of 0.44 for Willow Creek and a high of of 0.92 for Coyote Prairie (Table 1).

Table 1. Diversity and Evenness Indices for Six Sites in the West Eugene Wetlands, Eugene, Oregon

Site	Shannon's Diversity Index	Pielou's Evenness Index
Oxbow West	1.98	0.66
Coyote Prairie	2.68	0.92
Vinci	2.13	0.65
Willow Creek	1.68	0.44
Speedway	2.20	0.67
Dragonfly Bend	3.17	0.83

Diversity indices ranged from 3.17 observed at Dragonfly Bend to 1.68 at Willow Creek (Table 1). All sites had high species diversity as measured by Shannon's Diversity Index. An index of 1.7 or higher is considered indicative of high diversity (Thorpe, personal communication, May 18, 2012). The two restored sites, Dragonfly Bend and Coyote Prairie, had the highest indices. Speedway and Vinci, the two low quality remnant prairie sites, had medium indices, whereas both high quality remnant prairie sites Oxbow West and Willow Creek had the lowest indices (Table 1).

4.2. MICROTOPOGRAPHY

The values of coefficient of variation ranged from 0.0003 to 0.0012 across sites (Table 2). Willow Creek has the highest coefficient of variation, while Oxbow West had the lowest.

Table 2. Coefficient of variation of topography for all research sites

Site	Coefficient of variation
Oxbow West	0.00030
Coyote Prairie	0.00110
Vinci	0.00056
Willow Creek	0.00120
Speedway	0.00058
Dragonfly Bend	0.00043

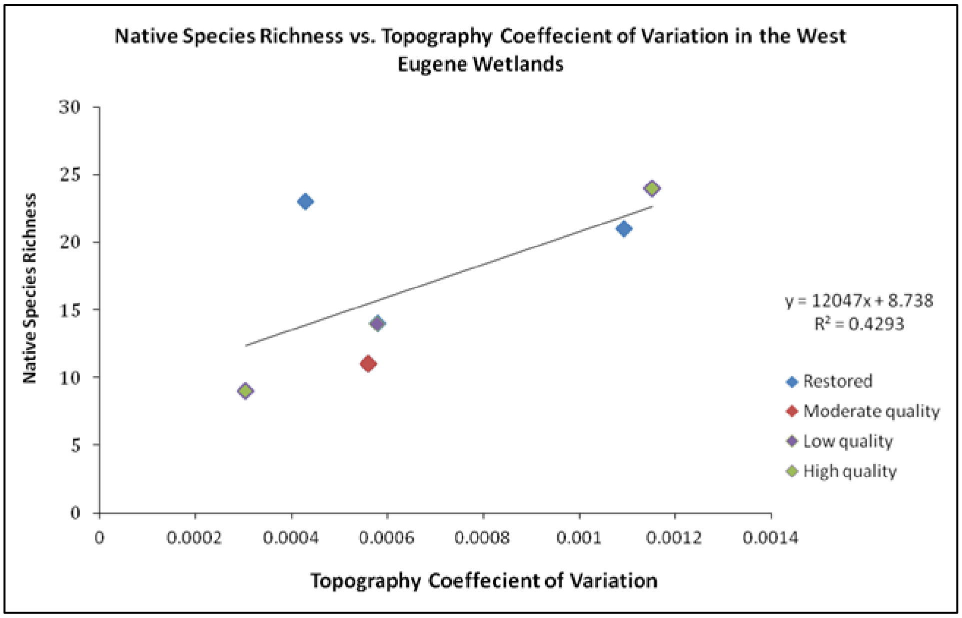

Figure 3. Topographic coefficient of variation as a function of native species richness for the six research sites.

No significant correlation was found between the coefficient of variation and Shannon's Diversity Indices (R2 = 0.04; p-value=0.7), Pielou's Evenness Indices (R2 =0.01; p-value=0.8), total species richness (R2 =0.03; p-value=0.2) or introduced species richness (R2 =0.03; p-value=0.7).

4.3. HYDROLOGY AND VEGETATION

Mean water depth throughout the study sites ranged from 0.000 cm at Dragonfly Bend to 0.767 cm at Vinci (Table 3).

Table 3. Vegetation height, litter and water depth measured at six study sites in the West Eugene Wetlands, Eugene, Oregon

Site	Vegetation height (cm)	Litter depth (cm)	Water depth (cm)
Oxbow West	18.37 ± 10.29	0.618 ± 1.25	0.282 ± 0.686
Coyote Prairie	11.87 ± 12.24	0.509 ± 0.670	0.00830 ± 0.292
Vinci	13.30 ± 11.54	0.617 ± 1.34	0.767 ± 1.32
Willow Creek	13.13 ± 7.58	1.25 ± 1.74	13.13 ± 7.58
Speedway	16.66 ± 10.96	0.515 ± 1.00	0.207 ± 0.744
Dragonfly Bend	24.07 ± 15.35	0.186 ± 0.625	0.00 ± 0.00

The two restored wet prairies, Coyote Prairie (0.083 cm) and Dragonfly Bend (0.00 cm), had the lowest mean water depth. There was no significant relationship between mean water depth and mean vegetation height ($R2 < 0.20$) or between mean water depth and mean litter depth ($R2 < 0.01$).

The mean vegetation height ranged from 13.13 cm (Willow Creek) to 24.07 cm (Dragonfly Bend) with high standard deviations (Table 3). A linear regression comparing vegetation height to litter depth indicated that as vegetation height increased litter height decreased ($R2 = 0.38$).

The plant community composition data revealed that bunchgrasses dominate the majority of the sites, with Oxbow West and Dragonfly Bend exhibiting especially high percent cover of bunchgrass (Table 4).

Table 4. Plant Community Composition Data

Site	Grasses			Rosette Forbs			Non-Rosette Forbs		
	Rhiz. & stolon.	Bunchgrasses	Annual/single blade	<15 cm	15-30 cm	>30 cm	<15 cm	15-30 cm	>30 cm
Oxbow West	1	3	1	1	1	1	1	1	1
Coyote Prairie	1	2	1	1	1	1	1	1	1
Vinci	1	2	1	2	1	1	1	1	1
Willow Creek	1	2	1	1	1	1	1	1	1
Speedway	2	1	3	2	1	1	2	1	1
Dragonfly Bend	1	3	2	1	1	1	1	1	1

1=0-5%; 2= >5-25%; 3= >25-50%; 4= >50-75%; 5= >75-95%; 6= >95-100%

Speedway was dominated by annual/single blade grasses and also had the highest percent cover of rhizomatous grasses, rosette and non-rosette forbs, shrubs and trees and litter cover. The percent cover of rhizomatous grasses and forbs greater than 15 cm was generally low throughout the six study sites.

4.4. FACULTATIVE AND OBLIGATE PLANT SPECIES

Willow Creek had the greatest richness of facultative, facultative upland, obligate wetland and obligate upland species. Oxbow West and Dragonfly Bend also had a high species richness of facultative, facultative wetland and facultative upland categories. Speedway and Coyote Prairie have low species richness of facultative, facultative wetland, obligate wetland and obligate upland categories (Table 5).

Table 5. Facultative and obligate presence/absence data across all sites West Eugene Wetlands

	Oxbow West	Vinci	Speedway	Dragonfly Bend	Coyote Prairie	Willow Creek
Total FAC	7	7	5	6	4	12
Total FACU	14	13	13	5	5	17
Total FACW	7	9	6	10	7	9
Total OBL	2	1	1	3	1	3
Total UPL	2	4	2	4	2	4
Total NL	2	3	0	3	4	11
Total	34	37	27	31	23	56

FAC=Facultative; FACU=Facultative upland; FACW=Facultative wetland; OBL=Obligate wetland; UPL=Obligate upland; NL=Not listed.

5. DISCUSSION

5.1. SPECIES DIVERSITY

We observed that Willow Creek, one of the high-quality remnant sites, had the highest species richness, as well as highest introduced and native species richness. These observations can be explained by the management practices of prescribed burning in return intervals of two to five years, as well as mowing and hand-pulling of exotic species. This produces an environment in which introduced species are not competitively dominant and do not outcompete the native species observed at the sites, allowing natives to dominate. Generally, we observed high native species richness in high-quality and moderate-quality sites. Invasive species richness varied across all sites and was likely dependent on the management practices of each site.

Willow Creek and Oxbow West's low evenness index can be explained by the observation that these sites are dominated by a few native plant species. Both sites are high-quality remnant prairies actively managed using techniques such as prescribed fire. In this context, low evenness indicates high percent cover of native species. The other four sites had high evenness indices indicating that no single species dominated. However, these sites varied in quality, so evenness could not be used as an indicator of native species cover.

Shannon's Diversity Index incorporates both species richness and evenness, and therefore provides a more complete indicator of diversity. Willow Creek's lower diversity index supports the observation that a few native plant species dominate this site. Diversity indices of over 1.7 for each site indicate that all sites have a high number of species and are not dominated by a few common species. The high SDI indicates that there is a high number of native species, and no species, either native or introduced, is competitively dominant at each site. The high SDI for the two restored sites, Coyote Prairie and Dragonfly Bend, demonstrates that these sites have a high nativeness due to their high diversity index and their active management for the removal of introduced species.

5.2. MICROTOPOGRAPHY

The relationship between native species richness and the coefficient of variation was not statistically significant (R2=0.43; p-value=0.16) and therefore did not support our hypothesis that native plants diversity in wetland prairies increases with topographic variation. Although not statistically significant, there was a positive relationship that explained 42.9% of the observed variation. We believe our results, in combination with patterns in the data, indicate that there is a relationship between these variables. When we computed the regression without data for restored sties the results were statistically significant. This is important to recognize for management and future research because the history and management of restored sites is so different from remnant sites.

We recommend further research to assess the hypothesis that microtopography is positively correlated with site diversity and evenness indices. For example, an extended study that includes a larger sample size for microtopography and percent cover data may produce more significant data than observed during a short pilot study. Within the scope of this study, due to high variability among sites, detecting relationships was difficult. In future studies we would recommend a study design that reduces unnecessary variability between study sites by comparing sites with similar history and management.

5.3. HYDROLOGY

Seasonality explains the lack of precision of the water depth data, as indicated by the large range and standard deviations of the water depth data. Precipitation and site hydrology varied greatly throughout our study as we collected data over a six-week period. This effect was likely produced by high variation due to seasonal changes in precipitation and site hydrology, confounding a relationship between water depth and species diversity. In order to collect more comparable data, water depth data should be collected during a shorter period of time when all sites are subject to the same weather conditions and precipitation.

5.4. VEGETATION

The observed relationship between plant height and litter depth did not correlate with topographic variation. Our plant community composition data indicated that bunchgrasses dominated most sites. High-quality sites were dominated by bunchgrasses and forbs. Low-quality sites had a high percent cover of introduced plants such as rhizomatous grasses and rosette forbs. This observation is not surprising considering the habitat quality designations are partly based on the level of introduced species.

5.5. FACULTATIVE AND OBLIGATE SPECIES

The observed relationship between plant height and litter depth did not correlate with topographic variation. Our plant community composition data indicated that bunchgrasses dominated most sites. High-quality sites were dominated by bunchgrasses and forbs. Low-quality sites had a high percent cover of introduced plants such as rhizomatous grasses and rosette forbs. This observation is not surprising considering the habitat quality designations are partly based on the level of introduced species.

6. CONCLUSION

Although not statistically significant, we believe that our results suggest that the presence of microtopography in remnant and restored wetlands plays an important role in the presence of native plant species. Research sites with high variation in microtopography appear to host more native and specialized plant species, suggesting a wider range of niches available for species. The variation in microtopography provides hummocks and hollows that define particular niches that support native species colonization and prevent colonization by invasive species (Bruland & Richardson 2005).

Wet prairie restoration continues to be a priority for restoration ecologists in the Willamette Valley because of the rarity of these habitats. The methods used in restoration projects must therefore be the most effective in restoring native species cover and diversity. While our pilot study suggests that there is a relationship between variation in microtopography and increased native plant richness, we recommend further research to assess relationships between microtopography and plant community composition in sites with similar histories and management practices. If this relationship is confirmed, we recommend that wet prairie management protocol include the restoration of microtopography to increase the cover and diversity of native plant species. The presence of introduced species at low quality sites could possibly be reduced through practices that include the restoration of microtopography. These methods will increase the colonization of native plants by decreasing competition with introduced species that prefer a more homogeneous flat terrain.

ACKNOWLEDGEMENTS

Funding to support this research was generously provided by the U.S. Environmental Protection Agency through a Wetland Program Development Grant. Matching funds and assistance were provided by the Institute for Applied Ecology, the City of Eugene, Lane Council of Governments, and the UO Environmental Studies Program. We would like to thank Andrea Thorpe and Tom Kaye, Institute for Applied Ecology; Jeff Krueger, Lane Council of

Governments; Diane Steeck, City of Eugene; and Peg Boulay and Alayna Linde, UO Environmental Studies Program. This was an Environmental Leadership Program project.

REFERENCES

Bruland, G. L., and C. J. Richardson. (2005). Hydrologic, edaphic, and vegetative responses to microtopographic reestablishment in a restored wetland. *Restoration Ecology, 13,* 515–523.

City of Eugene and Lane Council of Governments. (2011). West Eugene Wetlands Annual Report 2010. Unpublished report. Eugene, Oregon.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. (1994). Stream channel reference sites: an illustrated guide to field technique. *General Technical Report RM-245. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment*, Fort Collins, Colorado. Available from, http://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf.

Moser, K., C. Ahn, and G. Noe. (2007). Characterization of microtopography and its influence on vegetation patterns in created wetlands. *Wetlands*, *27*, 1081-1097.

National Oceanic and Atmospheric Administration. (2005). Daubenmire Method. Available at: http://www.cbrestoration.noaa.gov/documents/cb4017-020g.pdf.

Pfeifer-Meister, L., E. M. Cole, B. A. Roy, and S. D. Bridgham. (2008). Abiotic constraints on the competitive ability of exotic and native grasses in a Pacific Northwest prairie. *Oecologia, 155,* 357-366.

Seabloom, E.W., and A.G. Van der Valk. (2003). The development of vegetative zonation patterns in restored prairie pothole wetlands. *Journal of Applied Ecology, 40,* 92-100.

Wold, E. N., J. E. Jancaitis, T. H. Taylor, and D. M. Steeck. (2011). Restoration of agricultural fields to diverse wet prairie plant communities in the Willamette Valley, Oregon. *Northwest Science*, *85,* 269-287.