AN ABSTRACT OF THE THESIS OF

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Title: Plant Community Dynamics in Remnant and Restored Willamette Valley Wetland Prairies.

Abstract approved:

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Mary M. Santelmann

Invasion by exotic species can pose a major challenge for developing native plant communities in wetland restoration projects. Often native plant communities do not develop as anticipated in restored wetlands due to colonization by exotic species that dominate the native plant community. Despite the time and expense to restore wetlands, there has been little long term research to compare plant communities in restored and natural wetland sites. Research into plant community diversity across several wetland sites over several years can provide a broader perspective into how these ecosystems recover from long-term disturbance.

The objective of this study was to compare plant community change from 2000 to 2005 between restored and remnant wetland prairie sites in the southern Willamette Valley in Oregon to determine if exotic species abundance was consistent between these groups. Specific objectives included 1) comparing the diversity and abundance of all species in remnant and restored wetland prairie sites, 2) evaluate the trajectory of community change between remnant and restored wetland prairie sites to determine if there was rapid change in restored sites, and 3) describe the plot level heterogeneity of the plant community in all sites to determine how microsites influence diversity.

In 2005, species abundance was re-measured in four remnant wetland prairies

and four restored wetland prairies that had been selected for an unrelated vegetation survey in 2000. Species were characterized by life form, origin, and wetland indicator status. Species abundance between groups of remnant and restored sites were compared using a multi-response permutation procedure (MRPP). The plant community trajectory was evaluated with nonmetric multidimensional scaling (NMS) and tested for significance with multivariate analysis of variance (MANOVA). Species area curves were compared between sites and within remnant and restored groups of plots.

Within-year and between-year significance tests indicated that remnant and restored sites were similar in exotic species abundance, graminoid abundance, and wetland species abundance with no significant difference between these remnant and restored wetland prairie sites. Individual sites in both groups experienced changes in exotic species abundance which confounded the statistical results. Species heterogeneity was no more spatially diverse across the remnant site plots than restored site plots. Species area curves did not show significant differences between remnant and restored plots but individual plots did show homogeneous community characteristics at smaller spatial scales.

Restoration sites had developed high graminoid cover by the 2000 survey which was conducted two to three years after restoration was initiated. All sites were equally likely to contain exotic species. Exotic species common across all sites included *Centaurium umbellatum*, *Holcus lanatus*, and *Hypericum perforatum*. Native species common across sites included *Deschampsia cespitosa*, *Danthonia californica* and *Juncus tenuis*.

These results suggested that differences between remnant and restored Willamette Valley wetland prairie sites were not generalizable at the landscape scale and were more dependent on site specific management activities and local barriers to colonization. Five years may not be enough time to see evidence that suggests if restored plant communities will develop spatial characteristics of the remnant sites. This research does suggest that multi-site comparisons help distinguish individual sites that are not developing characteristics of remnant wetland plant communities.

Plant Community Dynamics in Remnant and Restored
Willamette Valley Wetland Prairies

by
Rachel A. Schwindt

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Rachel A. Schwindt, Author

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TABLE OF CONTENTS

Page

INTRODUCTION 1

Objectives/Hypotheses 6

BACKGROUND 7

Study Area and Setting 7

Previous research 11

METHODS 14

Study site descriptions 14

Study site summary 16
Finley Wildlife Refuge remnant site 17
Fisher Butte remnant site 18
Jackson Frazier Wetland remnant site 18
Rose Prairie remnant site 19
Balboa restoration site 20
Greenhill Prairie restoration site 21
Marys River Natural Area restoration site 21
Oak Creek Mitigation Bank restoration site 22

Data Analysis 26

Within- year community composition 27
Between- year community composition 28
Plant community trajectory 28
Wetland community heterogeneity 29
Species area relationship 29
Data analysis summary 30

RESULTS 31

GPS variance 31

Within- and between-year community composition 31

Species diversity 31
Species abundance 33
Wetland indicator species 43

Plant community trajectory 47

TABLE OF CONTENTS (Continued)

Page

Wetland community heterogeneity 51

Species area relationship 56

DISCUSSION 60

Are plant communities less diverse and are exotic species more abundant in restored wetland prairie sites relative to remnant wetland prairie sites? 60

Do restored wetland prairies have a rapid change in plant community composition compared to remnant wetland prairies? 62

Does the heterogeneity of the plant community indicate a range of microsites available for a diverse plant community? 68

Study evaluation 69

CONCLUSION 71

BIBLIOGRAPHY 73

APPENDIX 83

LIST OF FIGURES

Figure | Page

1. 1850s Willamette Valley wetland prairie estimated from soil and historic land surveys by the Oregon Natural Heritage Program (ONHP, 2002)..............10

2. Study site locations in the southern Willamette Valley. 15

3. Plot layout showing 10x10 m plot and 20x50 m plot. 25

4. Exotic species abundance (percent cover of plot) in 100 m^2 plot by year. 37

5. Perennial abundance (percent cover of plot) in 100 m^2 plot by year. 38

6. Graminoid abundance (percent cover of plot) in 100 m^2 plot by year. 39

7. Two way cluster dendrogram of restored and remnant 100 m^2 study sites in 2000. 0=remnant, 1=restored. 41

8. Two way cluster dendrogram of remnant and restored 100 m^2 study sites in 2005. 0=remnant, 1=restored. 42

9. Facultative wetland species abundance (percent cover of plot) in the 100 m^2 plots by year. 45

10. Facultative upland species abundance (percent cover of plot) in the 100 m^2 plots by year. 46

11. Facultative species abundance (percent cover of plot) in 100 m^2 plot by year. 47

12. Wetland prairie 100 m^2 plots categorized by restored and remnant wetland groups. Plots are shown in species space from nonmetric multidimensional scaling. 48

13. Combined rate and direction of change in community composition for each 100 m^2 plot by translating time zero to common origin. 50

14. Two way cluster dendrogram of restored and remnant 1000 m^2 modified-Whittaker plots in 2005. 0=remnant, 1=restored. 55

15. Species area curves for a) remnant wetland prairie, n=4 sites b) restored wetland prairie sites, n=4 sites; with means and standard error bars. 57

16. Remnant wetland prairie species area curve. 58

LIST OF FIGURES (Continued)

Figure Page

17. Restored wetland prairie species area curve. 59

LIST OF TABLES

Table Page

1. Study site summary with location, area, and management information. 16

2. Summary of plots involved in analyses. 30

3. Community diversity summary including Shannon-Wiener diversity index and total richness divided into proportion by native and introduced species by year. 33

4. Dominant species abundance (percent cover of plot) in 100 m^2 plots by year. 34

5. Total abundance (percent cover of plot) of bare ground and vegetative growth forms in 100 m^2 plots by year. 35

6. Total abundance (percent cover of plot) of wetland indicator species groups in 100 m^2 plots by year. 44

7. Community diversity summary including Shannon-Weiner diversity index, Coefficient of Variation of Sorensen dissimilarity, and total richness divided into proportion by native and introduced species in 20 x 50 m^2 plot. 52

8. Functional group abundance (percent cover of plot) for perennials, introduced species, graminoids, and wetland indicator species averaged over ten 1 m^2 microplots within 1000 m^2 plot in 2005. 53

9. Summary of species area curve slope (z), fit (R^2), and richness by area for modified-Whittaker plots in 2005. 56

10. Summary of known impacts on-site and adjacent to the wetland prairie sites both prior to this study and up to the summer of 2005. 67

Plant Community Dynamics in Remnant and Restored Willamette Valley Wetland Prairies

INTRODUCTION

Wetland losses across the United States have led to declines in native plant species diversity and loss of habitat for numerous species (Dahl, 1990; Gibbs, 2000). In response to these losses restoration is increasingly used to mitigate human disturbance in wetland ecosystems (Keddy, 1999). The goal of ecological restoration is to restore "one or more valued processes or attributes of a landscape" such as flood water storage or native species habitat (Davis and Slobodkin, 2004). While restoration may not bring an ecosystem back to a previous historic state more often it is an attempt to bring an ecosystem within the bounds of an expected path of plant community development (Clewell et al., 2005). But wetlands are complex and often native plant communities do not develop as anticipated (Zedler, 1996). Many times exotic plant species colonize restoration projects and subsequently dominate the native plant communities (Galatowitsch and van der Valk, 1996a). Land managers whose restoration goals include specific species assemblages may find that they are not able to meet those goals over time. Despite the time and expense to restore wetlands, there has been little long term research to compare plant communities in restored and natural wetland sites (Zedler and Callaway, 1999). Comparisons of plant community attributes in restored wetlands to those in native remnant wetlands several years after restoration can provide baseline information on how these ecosystems recover after long-term disturbance. Research into plant community diversity across several wetland sites can provide land managers with a landscape scale perspective into the spatial distribution of wetland plant communities.

Restoration is the intentional change of an ecosystem that has become degraded and is designed to assist ecosystem recovery to a desired condition (Society for Ecological Restoration International Science & Policy Working Group, 2004). This approach seeks to increase habitat by providing new spaces for native species.

In contrast, ecosystem conservation attempts to maintain existing habitat that may be degraded in some way but still contains remnant native populations (Young, 2000). In this paper, restoration refers to areas that had been converted to a different landuse and then repaired to bring back the native community. Remnant sites are defined as areas that were not converted to a new landuse, therefore historic community structure has been maintained. These remnant ecosystems may have been impacted by surrounding landuse or changes in natural disturbance regimes. Because the eventual plant community in restored wetlands is essentially unknown, restored ecosystems provide a unique opportunity to view plant community change in progress.

Plant communities can change over time due to many extrinsic factors such as disturbance or moisture availability (Foster et al., 2002). Plant community dynamics have been historically viewed as orderly successional pathways determined by the environment and the species composition (Young et al., 2001). Current views on plant community dynamics recognize that ecological succession is complicated by random events or disturbances that may introduce a new combination of species (Booth and Swanton, 2002). The idea of alternative stable states suggests that there can be several possible trajectories that communities may follow depending on historical events and the random order of colonization after disturbance (Young et al., 2001). In many wetland restorations expected plant community development often does not materialize due to complex successional paths resulting from differing initial wetland conditions, random disturbance events, and a relict non-native seedbank (Kellogg and Bridgham, 2002; Young et al., 2001; Zedler and Callaway, 1999). In addition, successional studies indicate that initial colonizing species may be replaced due to fluctuating weather patterns or disturbance events (Bartha et al., 2003; Rogers and Hartnett, 2001). Restored wetlands may not develop into expected plant communities due to colonization by incoming species or chance dominance by a species already present in the community.

Invasions by exotic plant species can pose a major challenge for developing native plant communities in wetland restoration projects (Galatowitsch and van der Valk, 1996a; Jancaitis, 2001). Exotic plant species utilize available resources and can impede natural pathways of succession after restoration (Levine et al., 2003; Pywell et al., 2003; Yurkonis et al., 2005). Native species richness can be reduced by a few competitive exotic plant species (Meiners et al., 2001). Invasion is often associated with disturbances that open space for invading propagules and increase general resource availability (Burke and Grime, 1996; Davis et al., 2000). Introduced species can also indicate disturbances from changes in environmental gradients such as hydrology (Magee and Kentula, 2005). Wetland restoration projects may not be near native wetland complexes that provide native propagules and native species may not be able to disperse into these sites before there is complete exotic species cover.

In many ecosystems, exotic species abundance is often comparable to native species abundance which may indicate that exotic species are utilizing available resources possibly due to disturbance (Davis, 2001; Foster et al., 2002; Levine, 2000; Stohlgren et al., 2002). However, in the absence of disturbance, native species can inhibit exotic species invasion (Corbin and D'Antonio, 2004). Invasion can be reduced by abundant native species cover (Cleland et al., 2004). Restorations often start with bare surfaces and have an established weedy seedbank that quickly germinates. However, restorations initially planted with native species can develop similar native richness to undisturbed sites after several years (Kellogg and Bridgham, 2002). This suggests that while competition for resources is an important component of community composition, native species may be constrained by disturbance or dispersal limitations that are not as detrimental to some exotic species (Davis et al., 2000; MacDougall and Turkington, 2005). When exotic species richness in restorations is similar to exotic species richness in natural sites this may indicate that native species have dispersal limitations between sites that exotic species don’t have (Seabloom and van der Valk, 2003b).

Restoration projects often have lower vegetative cover, lower overall richness, and a smaller subset of the species found in comparable reference sites (Galatowitsch and van der Valk, 1996b; Martin et al., 2005; Seabloom and van der Valk, 2003b). Restoration "success" is often based on which plant species colonize restorations, the persistence of these species, and the diversity of species within functional groups after restoration (Ruiz-Jaen and Aide, 2005). Many permitting agencies require wetland monitoring based on a set goal of plant community development within an allotted time period such as 5 years (State of Oregon, 2000; Zedler and Callaway, 1999). But it is often unclear if restored wetlands will approximate a chosen reference site (Zedler and Callaway, 1999). Restored wetlands are often isolated from other wetland complexes and are influenced by local hydrologic and land use impacts (Magee and Kentula, 2005).

Restored wetlands often have altered microtopography due to previous land uses such as farming which disturbs the soil. Soil tilling can create homogeneous soil structure and resources that affect plant diversity after restoration (Baer et al., 2004). A heterogeneous environment may provide refugia for some wetland species during drier years (van der Valk, 1981). In turn, spatially diverse wetland plant communities can indicate heterogeneous topography (Vivian-Smith, 1997). Restored wetland sites that lack topographic heterogeneity can have lower diversity of species that occur in specialized portions of the moisture gradients (Magee and Kentula, 2005; Seabloom and van der Valk, 2003b). This suggests that restored wetlands may lack the spatial variability of remnant wetlands. Hydrology is responsible for the formation and persistence of wetland ecosystems and restoration often includes hydrological modifications such as dike removal or backfilling drainageways. Variation in the plant community composition across the wetland may indicate an underlying change in environmental gradient (Euliss et al., 2004). Though plant community spatial variability can be similar in restored and remnant wetlands there can be differences in species ranges across moisture gradients (Seabloom and van der Valk, 2003a). A decrease in hydrophytic species abundance could indicate that a restoration is not meeting hydrologic criteria for wetland classification.

Private, state, and federal land managers are conducting wetland prairie restoration projects in the Willamette Valley in Oregon to increase populations of threatened species and mitigate for wetland losses due to development. Loss of habitat poses a serious threat to native plant biodiversity in the Willamette Valley and has led to several Federal Threatened and Endangered Species listings (U. S. Fish and Wildlife Service, 2000). Agricultural conversion, urban development, and fire suppression have reduced wetland prairies to less than one percent of their historic cover (Wilson, 1998). Although exotic plant species invade remnant wetlands in the Willamette Valley it is unclear if the exotic species composition is comparable to that of restored wetland prairies and if native species richness or abundance decreases over time or remains stable. It is not clear if remnant wetland prairies have stable hydrophytic vegetation and if the species within these groups are consistent or change over time.

There have been few landscape scale studies in the Willamette Valley that have investigated whether plant species assemblages change over time in restored wetland prairie plant communities and if initial plant invaders persist at stable levels or decline. Restored wetland prairies may have less spatial variability which could indicate fewer specialized niches for diverse species assemblages. A lack of native species colonizing restorations while exotics increase may suggest barriers to native species dispersal. This study adds a temporal element to unpublished research by Slane (2000) on wetland prairie communities. Insight into the direction and magnitude of community change in both restored and remnant wetland prairies can help land managers manage for diverse native plant communities.

Objectives/Hypotheses

Plant community composition can provide a way to understand environmental conditions in wetlands because plant species respond to and integrate site conditions over time. The array of species present in a wetland often represents a broad range of adaptations and tolerances. The overall objective of this study was to identify plant community patterns across a diverse set of Willamette Valley wetland prairies. Specific questions addressed in this study included: 1) Are plant communities less diverse and are exotic species more abundant in restored wetland prairie sites relative to remnant wetland prairie sites? Restored wetland prairies may have higher cover of a single dominant exotic species; 2) Do restored wetland prairies have a rapid change in plant community composition compared to remnant wetland prairies? Restored wetland prairies may have high initial exotic cover which turns over to new species. There may be more compositional change in restored wetlands due to a rapid change in the availability of resources; 3) Does the heterogeneity of the plant community indicate a range of microsites available for a diverse plant community? A remnant wetland prairie may have a vertical structure that helps foster a diverse community.

To test if there was a difference in the plant community composition between the remnant and restored sites several hypotheses were developed:

H_1: Restored wetland prairies have a greater abundance of exotic species and upland species while remnant sites have more native perennials, native graminoids and wetland species groups.

H_2: Exotic species richness is higher in restored wetland prairies while remnant sites exhibit no difference in exotic plant species richness within years or between the two time periods.

H_3: The direction and magnitude of plant community compositional change is greater in the restored wetland prairies than remnant wetland prairies.

H_4: Plot level species heterogeneity is higher in the remnant wetland prairies sites.

BACKGROUND

Study Area and Setting

The Willamette Valley is a 30 to 50 km wide alluvial plain formed by the Willamette River and extends roughly 290 km from the city of Eugene in the south to Portland in the north (Hulse et al., 2002). Tributaries flowing from the Coast Range on the west and the Cascade Range on the east join the Willamette River as it flows northward to its confluence with the Columbia River. The climate in the Willamette Valley is characterized by cool, wet winters and warm, dry summers with a mean annual precipitation (1971-2000) of ~110 cm for the southern Willamette Valley. Seventy-five percent of this precipitation falls between October and March (Oregon Climate Service, 2005). Average temperatures for the southern Willamette Valley range from 8^{o}C in January to 27.5^{o}C in July (Oregon Climate Service, 2005). A variety of crops are grown in this region with cool season grass seed production especially prominent in the southern Willamette Valley (Oregon Seed Extension Program, 2005).

Prior to Euro-American settlement, wetland prairies were part of a mosaic that also included riparian forests, oak savannas, and upland prairie and extended throughout the lowlands in the Willamette Valley (Habeck, 1961). It is estimated that bottomland prairies covered one-quarter of the Willamette Valley (Figure 1) in the 1850s (Titus et al., 1996). Prairies in the Willamette Valley were maintained by both natural fires and possibly anthropogenic burning practices. In the Willamette Valley and Southwest Oregon, there is evidence that Kalapuya Indians periodically burned portions of the prairie which created an open landscape for hunting wildlife and optimized conditions for specific edible plants (Boyd, 1999; Johannessen et al., 1971). Burning reduced woody species that would encroach into the prairies though fire would not harm the underground buds and bulbs of the native grasses and forbs (Habeck, 1961). Historically, wetland prairies contained a mixture of low growing grasses and herbaceous plants (Habeck, 1961). Especially prominent were grasses such as *Deschampsia cespitosa* (tufted hairgrass) and herbs such as *Eriophyllum lanatum* (wooly sunflower) (Wilson, 1998). In effect, the burning kept the prairies in an early successional grassland state.

Fire was suppressed after the 1850's when settlers moved into the Willamette Valley (Johannessen et al., 1971). Woody native species such as *Fraxinus latifolia* (Oregon ash) expanded into mesic areas (Clark and Wilson, 2001). During this time many of the exotic species that are found in wetland prairies today were introduced as land was converted to pasture and crops. An early 1900's survey of grass species near Salem, Oregon found 55 introductions out of 106 species (Habeck, 1961). Introduced plant species such as *Rosa eglanteria*, *Rubus discolor*, and *Phalaris arundinacea* have encroached into wetland prairies (Clark and Wilson, 2001).

Wetland prairies have poorly draining soils or underlying bedrock that impede drainage and create hydric soil conditions which make them unique from upland prairies (Wilson, 1998). Much of the soil composition is influenced by deep clay deposits formed after the Missoula floods between 15,000 and 12,700 years ago. During these floods water swept down the Columbia River from an ancient glacial lake to deposit a layer of sand, gravel, and clay up to 10 m deep in the southern Willamette Valley (Hulse et al., 2002; O'Connor et al., 2001). There is some evidence now that subsequent clay deposits formed in the southern Willamette Valley when Mount Mazama erupted around 7,700 years ago and blanketed the Northwest in ash (Baitis and James, 2005). Due to the heavy clay soils, very wet prairie areas remained as pasture and hay fields until the 1950's but much of it was drained and converted to grass seed fields during the 1950s and 1960s (Johannessen et al., 1971; Titus et al., 1996). The remaining natural wetlands are often remnants of historically extensive wetland complexes now separated by agriculture and development (Magee and Kentula, 2005).

Loss of habitat has resulted in several threatened or endangered plant species listing. *Lomatium bradshawii* (Bradshaw's desert-parsley) and *Erigeron decumbens* var. *decumbens* (Willamette daisy) are both listed as endangered and *Sidalcea* *nelsoniana* (Nelson's checker-mallow) is listed as threatened (U. S. Fish and Wildlife Service, 2006). Loss of wetland prairie has also had a significant impact on migrating waterfowl such as trumpeter swans and the snow goose which historically used wetland prairies for feeding and roosting (Taft and Haig, 2003).

Current wetland prairie restoration in the Willamette Valley is influenced by state programs for mitigation and conservation. Mitigation compensates for wetland loss due to permitted development such as filling or excavation. Mitigation can involve either restoration which improves hydrology and reestablishes hydrophytic vegetation or enhancement which improves a degraded wetland that still has some hydrophytic species present. Federal and state law requires developers to either mitigate on site or, when that is not feasible, to purchase credits from mitigation banks (Oregon Department of State Lands, 1999). Mitigation banks are wetland areas held in reserve for wetlands destroyed elsewhere within a watershed. Mitigation banks are usually owned by private entrepreneurs but can be owned by municipalities. For example, the city of Eugene owns one of the largest mitigation banks in the state of Oregon. Developers can purchase credits from a mitigation bank that will replace the type of wetland they plan to fill based on the acres of wetland to be destroyed. Currently the Willamette Valley has eight mitigation banks covering over 200 hectares with a variety of wetland prairie, riparian, emergent wetlands (Oregon Department of State Lands, 2006).

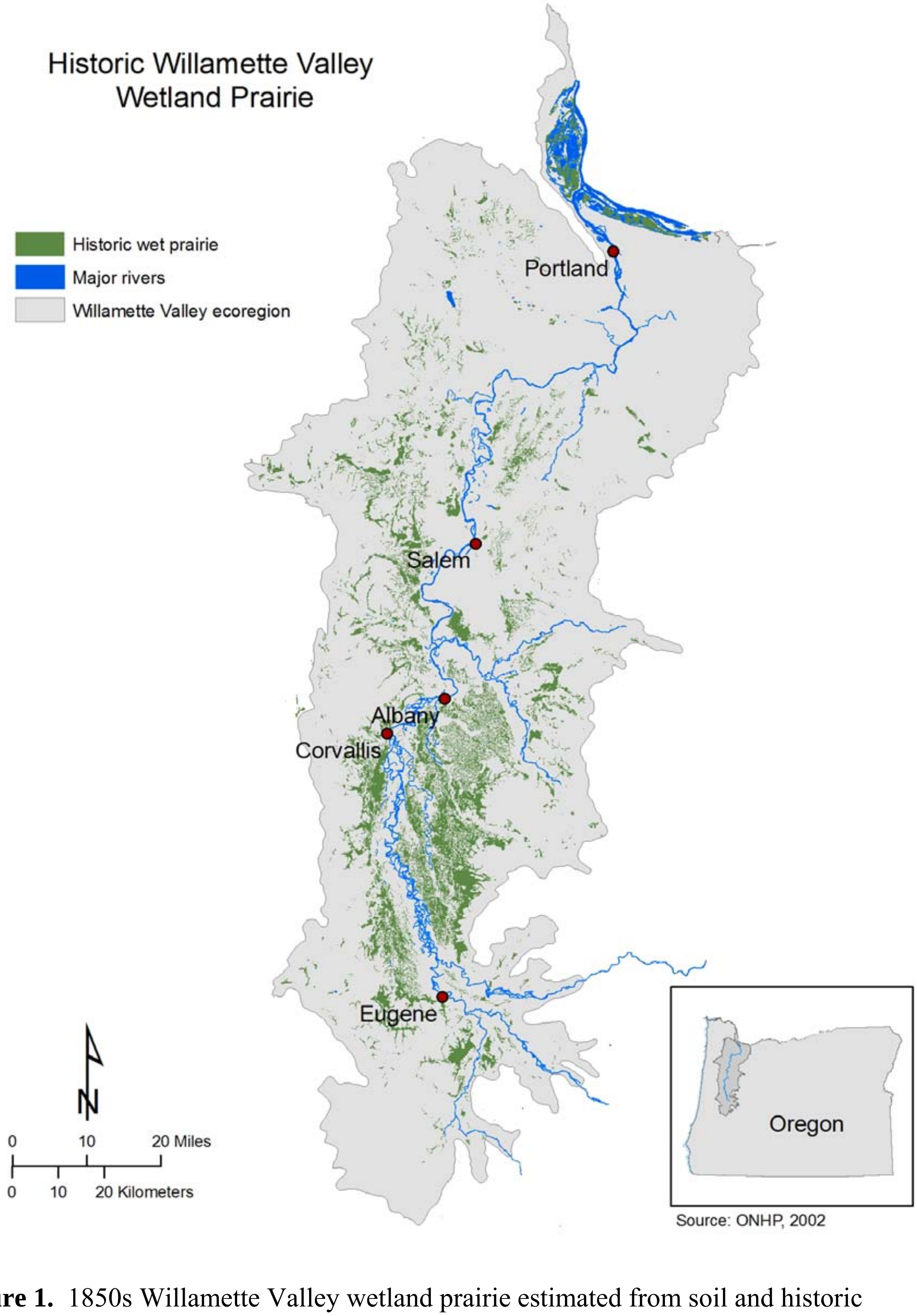


Figure 1. 1850s Willamette Valley wetland prairie estimated from soil and historic land surveys by the Oregon Natural Heritage Program (ONHP, 2002).

Previous research

Willamette Valley wetland prairies support a diverse flora of graminoids and forbs with some shrubs and trees. The most comprehensive research into wetland prairie ecology has been in the few remaining remnant sites in the southern Willamette Valley. In these remnant sites, natives comprise the majority of the species but exotic species sometimes exceeded 30% of the species total (Pendergrass, 1995; Streatfeild, 1995). Exotic species abundance can range from 10% to 80% of the total vegetation cover depending on the plant community (Pendergrass, 1995). The majority of natives are perennial forbs, though the most abundant species are perennial graminoids such as *Deschampsia cespitosa* and *Danthonia californica* (Pendergrass, 1995; Streatfeild, 1995). Exotic species are dominated by perennial graminoids such as *Agrostis tenuis* and *Anthoxanthum odoratum* (Pendergrass, 1995; Streatfeild, 1995).

Willamette Valley wetland prairies exhibit unique topography that fosters diverse plant communities along moisture gradients. Though the overall topography is generally flat, remnant wetland prairies often exhibit complex vertical microtopography and some have a broader pattern of lenticular mounds (Pendergrass, 1995; Streatfeild, 1995). Microtopography results from tufted graminoids that form pedestals 3-20 cm above the soil (Jancaitis, 2001). The spaces between the pedestals are flooded longer into the growing season and support a diverse plant community adapted to these wetter spaces (Wilson, 1998). Lenticular mounds cover much larger areas and can be 30 cm to 2.4 meters high and 2.5 to 25 meters wide (Dorner, 1999). Several theories account for these structures which can occur in prairies throughout the U. S. but the most compelling explanations are seismic activity or pocket gophers, though there has been no definitive explanation (Berg, 1990; Cox and Hunt, 1990).

Exotic species can be found along all the moisture gradients within remnant wetland prairies. Exotic forbs and graminoid species occur on drier mounds, anthills, or pedestals (Pendergrass, 1995; Streatfeild, 1995). Exotic species such as *Hypericum perforatum*, *A. odoratum*, and *Galium parisiense* occupy drier mounds while wetter intermound areas have natives such as *D. cespitosa* and *Veronica scutellata* (Pendergrass, 1995; Streatfeild, 1995). Exotic shrubs such as *Rosa eglanteria* and exotic graminoids such as *Holcus lanatus* are able to colonize both mounds and intermounds (Streatfeild, 1995). Exotic species such as *Mentha pulegium* colonize the wettest portions of the wetland prairie (Pendergrass, 1995). Fluctuating moisture gradients may account for traits of wetland prairie species adapted to wetter conditions. Native plant species that can quickly capture resources do better in wetland prairies, possibly due to a shorter germination window (Goodridge, 2001). This would suggest that wetland prairie areas with prolonged drying may have more invasive plant species.

Management in remnant prairies has focused on describing plant community response to mowing, fire, and nitrogen manipulation (Clark and Wilson, 2001; Davis, 2001; Pendergrass, 1995; Streatfeild, 1995; Taylor, 1999). Mowing can increase abundance and cover percentage of exotic herbaceous species (Clark and Wilson, 2001). Burning can increase native forb cover, but may not have a significant affect on native graminoid species, though burning can increase exotic graminoid cover of *A. odoratum* (Clark and Wilson, 2001). Burning can decrease cover of *Madia glomerata*, a native forb, and *Hypochaeris radicata*, an exotic forb (Pendergrass, 1995; Taylor, 1999). As the length of time after a burn increases the number of exotic species can increase (Streatfeild, 1995). High intensity burns may not control trees such as *Fraxinus latifolia* or *Pyrus communis* invading into wetland prairies (Wilson et al., 1993). While burning can increase native species abundance, it can also increase exotic species abundance at the same time (Wilson, 2002). Individual species have unique responses to management prescriptions, so methods designed for control of a single species may not result in desired changes across a plant community. For example, nitrogen additions to wetland prairies can increase the biomass of both native and exotic plant species while nitrogen depletion can promote native grasses (Davis, 2001).

Research on wetland prairies restored after agricultural or industrial use has been very limited in the Willamette Valley. Restoration of mesic meadows that may have historically been wetland prairie indicate that exotic grasses tend to remain abundant while native species richness declines one to two years after restoration (Coleman, 2004). In contrast, when there is high initial native cover this can reduce exotic species germination in the first two years of restoration (Goodridge, 2001). Seeding can be an effective means to increase native species abundance, though rates of establishment can be low and vary by species (Wilson, 2004). Native species such as *Agrostis exarata*, *Downingia elegans*, *Gnaphalium palustre, Juncus oxymeris*, and *Navarretia intertexta* establish well in seeding programs (Wilson, 2004).

METHODS

Study site descriptions

In the summer of 2005, eight wetland prairies that had been previously studied in 2000 for a small mammal habitat survey in northwestern Oregon were revisited to record vegetation change. These sites had been selected to represent a valley flat slope hydrogeomorphic classification with similar elevation, soil type, and hydrology in the southern Willamette Valley (Slane, 2001). Four of the sites were remnant wetland prairies and four were restored or enhanced wetland prairies. Two remnant and two restored sites were located near the cities of Corvallis in Benton County and Lebanon in Linn County. The remaining four sites were clustered west of Eugene in Lane County (Figure 2).

All restoration sites had been restored with either plantings or repaired hydrology two to three years previous to the 2000 study. Each of the restoration sites had modifications to the soil structure either from tilling or compaction. The remnant sites had not been cultivated so there had been no soil structure modification but each had likely been either grazed or hayed. Soils in all the sites were classified as poorly draining hydric soils which indicates that water persists into the growing season (Plot attributes summarized in Table 1).

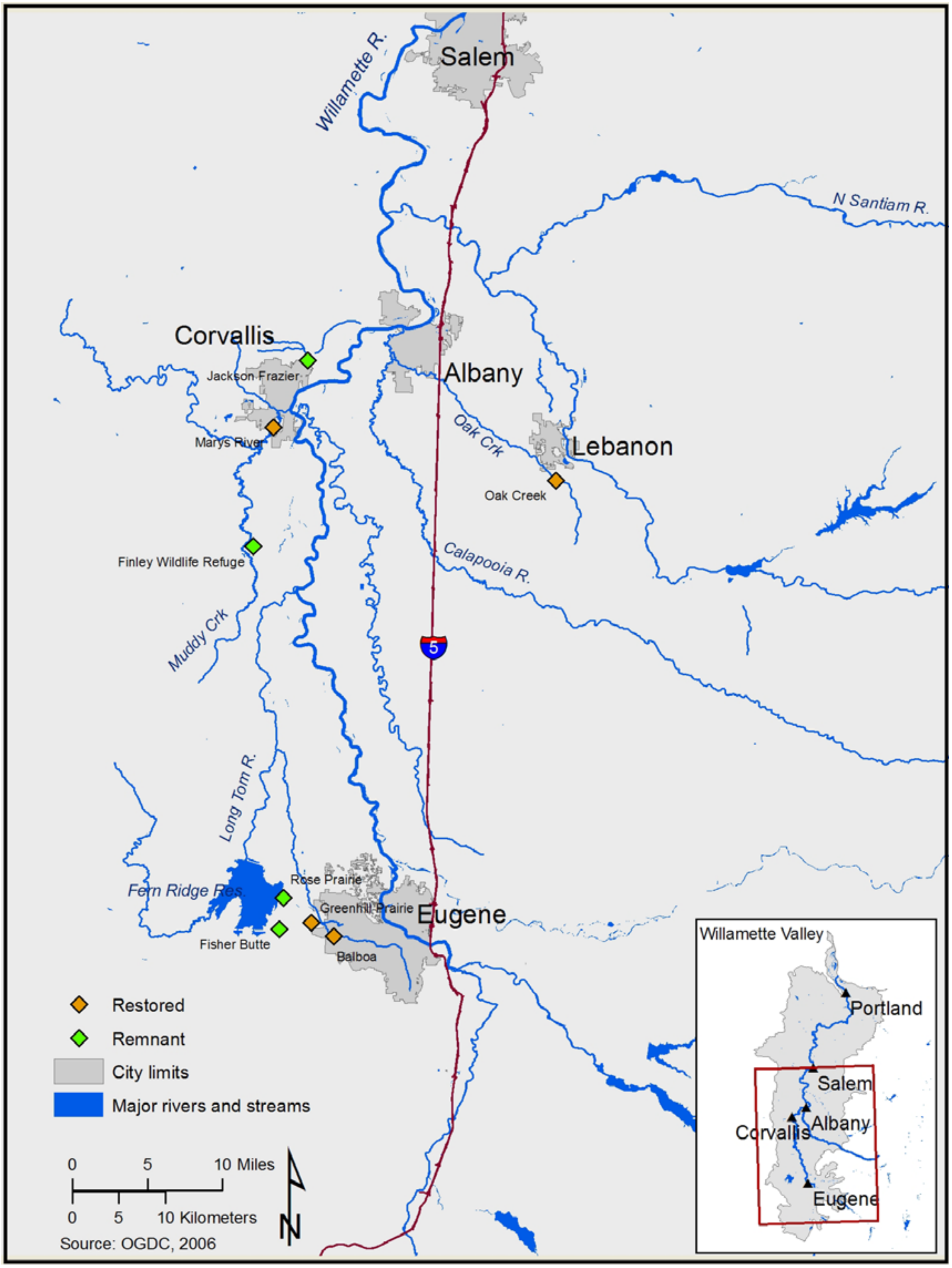


Figure 2. Study site locations in the southern Willamette Valley.

Study site summary

Table 1. Study site summary with location, area, and management information.

Study site	Location	Management 1999- July 2005	Restoration	Soil
Remnant				
Finley Refuge ~210 ha	44º 25' N 123º 18' W	Burn: 2000, 2002	na	Dayton silt loam
Fisher Butte ~30 ha	44º 3' N 123º 15' W	Burn: 2001	na	Natroy silty clay loam
Jackson Frazier ~7 ha	44º 36' N 123º 14' W	Mow: 2003	na	Bashaw clay
Rose Prairie ~16 ha	44º 4' N 123º 15' W	None	na	Natroy silty clay loam
Restoration (date restoration initiated)				
Balboa (1998) ~30 ha	44º 3' N 123º 11' W	Mow/Hand weed	Remove fill, seeding	Natroy-Urban land complex
Greenhill Prairie (1998) ~29 ha	44º 3' N 23º 12' W	Hand weed/till	Remove sod, seeding	Dayton silt loam, clay substratum
Marys River (1997) ~30 ha	44º 32' N 123º 17' W	na	Herbicide and seeding	Conser silty clay loam
Oak Creek (1998) ~36 ha	44º 30' N 122º 54' W	None	Herbicide and excavate soil	Bashaw silty clay

Finley Wildlife Refuge remnant site

The 210 hectare Willamette Floodplain Research Natural Area (hereafter Willamette RNA) is managed by the U.S. Fish and Wildlife Service as part of the W. L. Finley National Wildlife Refuge. The remnant wetland prairie occurs on the eastern portion of the refuge in Benton County about 16 km south of Corvallis (44^o 25’ 23” N, 123^o 18’ 20” W). The Willamette RNA (elev. ~78 m) is just east of Muddy Creek which drains from the Coast Range foothills into the Willamette River. The Willamette RNA is surrounded by farm fields which provide winter food such as annual ryegrass, perennial ryegrass and fescue grass for migrating dusky geese (Houck, personal communication).

The Willamette RNA portion of the refuge was established in 1966 to protect sensitive species and ecosystems and for long term scientific studies. It consists of remnant wetland prairie with some riparian forests in the southwest corner. Rare wetland prairie plants that occur here are *Lomatium bradshawii* and *Sidalcea nelsoniana* (Beall, personal communication). *Erigeron decumbens* var. *decumbens* may have been extirpated here due to bank erosion along Muddy Creek (U. S. Fish and Wildlife Service, 2000). Portions of the RNA are managed for long-term fire regime studies (Frenkel, personal communication). The northern portion of the wetland prairie where this study was conducted was burned in 2000 and 2002 (Beall, personal communication). An obscure path leading from a viewing platform allows visitors to access the wetland prairie.

The soil in the study location is “Dayton silt loam, 0 to 2 percent slopes” and is classified as a hydric soil (NRCS, 2005b).

Fisher Butte remnant site

Fisher Butte is a remnant wetland prairie within the Fern Ridge Research Natural Area. The research area was established in 1988 and is administered by the U.S. Army Corps of Engineers ~13 km west of the city of Eugene in Lane County (Pendergrass, 1995). The wetland prairie is ~30 hectares and sits just southeast of Fern Ridge reservoir at an elevation of ~114 m (44^{o} 3' 17" N, 123^{o} 15' 16" W). The site consists of wetland prairie with some emergent wetlands that formed when an access road divided the site (Taylor, 1999). There is some rural residential development uphill to the north and east of the site and Oregon State Highway 126 runs along the southern border of the wetland prairie.

Lomatium bradshawii has been found at this site and there has been research into the effects of fire on this species at this site (Pendergrass, 1995; Taylor, 1999). Fisher Butte is managed for invading species by selective brush mowing and *Fraxinus latifolia* trees have been cut and treated with herbicide (Messenger, personal communication). The site was burned in 2001 and in 2005 after field work for this project was completed.

The soil is mapped as "Natroy silty clay loam" and is classified as a hydric soil (NRCS, 2005b).

Jackson Frazier Wetland remnant site

Jackson-Frazier wetland is a ~60 hectare county park consisting of wet prairie, forested wetland, emergent wetlands and oak upland (Frenkel and Reed, 2005). The wetland lies immediately north of the Corvallis city limits in Benton County on the western side of the Willamette Valley (44^{o} 36' 19" N, 123^{o} 14' 35" W). It is an alluvial fan wetland formed from the drainage of Jackson and Frazier creeks which flow from the Coast Range foothills to the Willamette River (D'Amore et al., 2000). The ~7 hectare of wetland prairie (elev. ~66 m) are located in the southwest portion of the park. The wetland borders urban residential development on the south and agriculture on the north and east sides and is divided by Oregon State Highway 99W.

Previous land use records indicate that the area was not farmed but there was heavy cattle grazing up to the 1960's and native hay was harvested (Frenkel and Reed, 2005). In 1985 the previous owner drove large equipment over the wet prairie portion without a permit in order to dig ditches and move brush (Scientific Resources Inc, 1986). The property was acquired by Benton County in 1990 after the previous owner defaulted on property taxes. This site was made a county park in 1992 (Scientific Resources Inc, 1986).

Jackson-Frazier wetland is managed for rare plants and animals, exotic species control, as well as limited public recreational use. Rare plant species that occur here include *Lomatium bradshawii*, *Sidalcea nelsoniana*, and, in the upland prairie, *Lupinus sulphureus* var. *kincaidii* (Frenkel and Reed, 2005). The wetland prairie was mowed in 2003 with a brushhog to reduce shrub and tree encroachment and then mowed again in 2005 after fieldwork for this study was completed.

The soil classification for the wetland prairie portion of Jackson Frazier wetland is "Bashaw clay, flooded, 0 to 3 percent slopes" and is classified as a hydric soil (NRCS, 2005a). A past soil survey on the margin of the Jackson-Frazier wet prairie found a smectite clay subsurface that allowed perched water to flow across the wetland (D'Amore et al., 2000).

Rose Prairie remnant site

Rose Prairie is a ~16 hectare remnant wetland prairie within the Fern Ridge Research Natural Area established in 1988 by the U. S. Army Corps of Engineers (Taylor, 1999). The site (elev. ~114 m) is located approximately 13 km west of Eugene along the east shore of Fern Ridge Reservoir (44° 4' 6" N, 123° 14' 50" W). The reservoir was created in 1941 and the surrounding land is managed by the U.S. Army Corps of Engineers. Amazon Creek canal, a diversion channel from Amazon

Creek, flows through the wetland prairie into the reservoir. On the east side, the wetland is surrounded by agricultural grass fields and rural residential development.

Rose Prairie is managed for rare native species such as *Lomatium bradshawii* and had not been burned since 1998, though it was burned in 2005 after field work for this project was completed (Messenger, personal communication).

The soil is "Natroy silty clay loam" which is a hydric soil (NRCS, 2005b). A previous survey found that soils here were sandier than Fisher Butte which may account for a unique *Vaccinium caespitosum* community (Finley, 1994).

Balboa restoration site

Balboa unit is a 30 hectare site that is part of a larger wetland complex within the city limits of Eugene in Lane County (44^{o} 3' N, 123^{o} 11' W). The site is part of the West Eugene Wetlands Mitigation Bank (elev. ~118 m) and borders the north bank of Amazon Creek (Parks and Open Space Division, 2006). The wetlands are owned and managed by the City of Eugene and the Bureau of Land Management and are surrounded by industrial and urban development. The Balboa site had been used as an airfield and drag racing strip for 60 years before restoration and enhancement began in 1998 (Parks and Open Space Division, 2006).

The wetland is managed for rare species such as *Erigeron decumbens* var. *decumbens* and *Aster curtus*. Encroaching woody plants such as *Rubus discolor* and *Fraxinus latifolia* have been removed by cutting, mowing and burning. A gravel path with bridges divides the wetland and the edges are mowed to reduce weedy species (Parks and Open Space Division, 2006). The 2000 study site was in the Atlantic/Pacific portion of the wetland. In 2005, a new study site was set up in the 3 hectare Phase I restoration area.

The soil is "Natroy-Urban land complex" and is a hydric soil (NRCS, 2005b) .

Greenhill Prairie restoration site

The North Greenhill Prairie site (elev. ~119 m) is also part of the West Eugene Wetlands mitigation bank east of Eugene (44° 3' 40" N, 123° 12' 40" W). This 29 hectare site on the west side of Greenhill Road is owned by the Bureau of Land Management and has rural residential property surrounding the site. The previous owner had farmed 21 hectares of the site for hay prior to the BLM acquiring the property.

Restoration began in 1998 when hydrology was enhanced by dispersing water flowing through ditches along with hand weeding and mowing the perimeter (Parks and Open Space Division, 2006). The study site was in the 5 hectare Phase I portion of the BLM restoration. In this area *Mentha pulegium* had been tilled and hand weeded and the perimeter of the wetland had been mowed to reduce weed spread.

The soil is "Dayton silt loam, clay substratum" and is a hydric soil (NRCS, 2005b).

Marys River Natural Area restoration site

The Marys River Natural Area is a restored ~30 hectare mix of wetland prairie, upland, and riparian forest along the west bank of the Marys River within the Corvallis city limits in Benton County (44° 32' 20" N, 123° 17' W). The wetland (elev. ~67 m) is in the floodplain of the Marys River which drains to the Willamette River. The Natural Area was established as a permanent easement in 1996 through the Natural Resource Conservation Service Wetland Reserve Program when the previous owner decided to develop the adjacent uphill property for residential use. The ownership was transferred to the City of Corvallis through a land exchange in the fall of 1996 (Makinson, 1998). The previous landuse was perennial grass seed farming (Makinson, personal communication). Residential development occurs directly uphill to the northwest and perennial grass farms border the site to the south.

Initial restoration at the site in 1997 included spraying exotic species with herbicide and seeding *Camassia quamash* and *Deschampsia cespitosa* (Slane, 2001). The wetland prairie is divided into north and south portions by a private gravel road with a culvert that allows water flow through a drainage ditch. A raised walkway extends north and south through the western portion of the site.

The soil in the wetland prairie portion of the Natural Area is "Conser silty clay loam, 0 to 3 percent slopes" which is a hydric soil (NRCS, 2005a).

Oak Creek Mitigation Bank restoration site

The Oak Creek Mitigation Bank is a privately managed state and federally authorized wetland mitigation bank in Linn County, south of the city of Lebanon (44^{o} 29' 50" N, 122^{o} 54' 00" W). The wetland is ~36 hectares of forested, scrub-shrub and emergent wetland on the eastern margin of the Willamette Valley at an elevation of 112 m (Novitzke, personal communication). On the northeast portion of the property Oak Creek drains from the Cascade Range into the Calapooia River, a tributary of the Willamette River. The property is surrounded by grass seed farm fields and rural residential development.

The wet prairie had been farmed for perennial grass seed for more than 50 years and burned roughly every five years to remove grass residue after harvest (Novitzke, personal communication). The restoration process began in 1998 when berms along Oak Creek were removed to restore the hydrology and exotic plant species were excavated (Novitzke, personal communication). The wetland was burned in September of 2005, just after field work for this study was completed.

The soil classification for the wetland prairie study sites in the southwest corner of the wetland is "Bashaw silty clay" which is classified as a hydric soil (NRCS, 2005c).

Field methods

The wetland prairie study sites were revisited in July 2005 by relocating vegetation plots using a handheld GPS receiver (max GPS error 10 meters). In the previous study, a 10 x 10 meter (100 m^2) plot had been established in each of the eight wetland prairie sites in late June or early July 2000 as a representative sample of the dominant vegetation community and the plot center coordinates were recorded by GPS (Slane, 2001). Vascular plant species and bare ground cover had been visually estimated to the nearest percent in each 100 m^2 plot. In addition to replicating the 2000 plot design, this study also added 1 m^2 microplots inside and outside of the 100 m^2 plot to determine if GPS signal error would lead to false plant community significance tests. Vegetation percent cover was visually estimated for five 1 x 1 meter (1 m^2) microplots that were randomly located within each 100 m^2 plot. Vegetation percent cover was also estimated in five 1 x 1 meter (1 m^2) plots located outside of the 100 m^2 plot a random distance and direction in a radius between 10 and 20 meters from the plot center. The Balboa site was dropped from the temporal study due to problems locating the 2000 plot location and significant heterogeneity of the topography in the presumed vicinity of the 2000 plot. The location of this plot was also close to where a sinkhole developed in 2001 (Parks and Open Space Division, 2006).

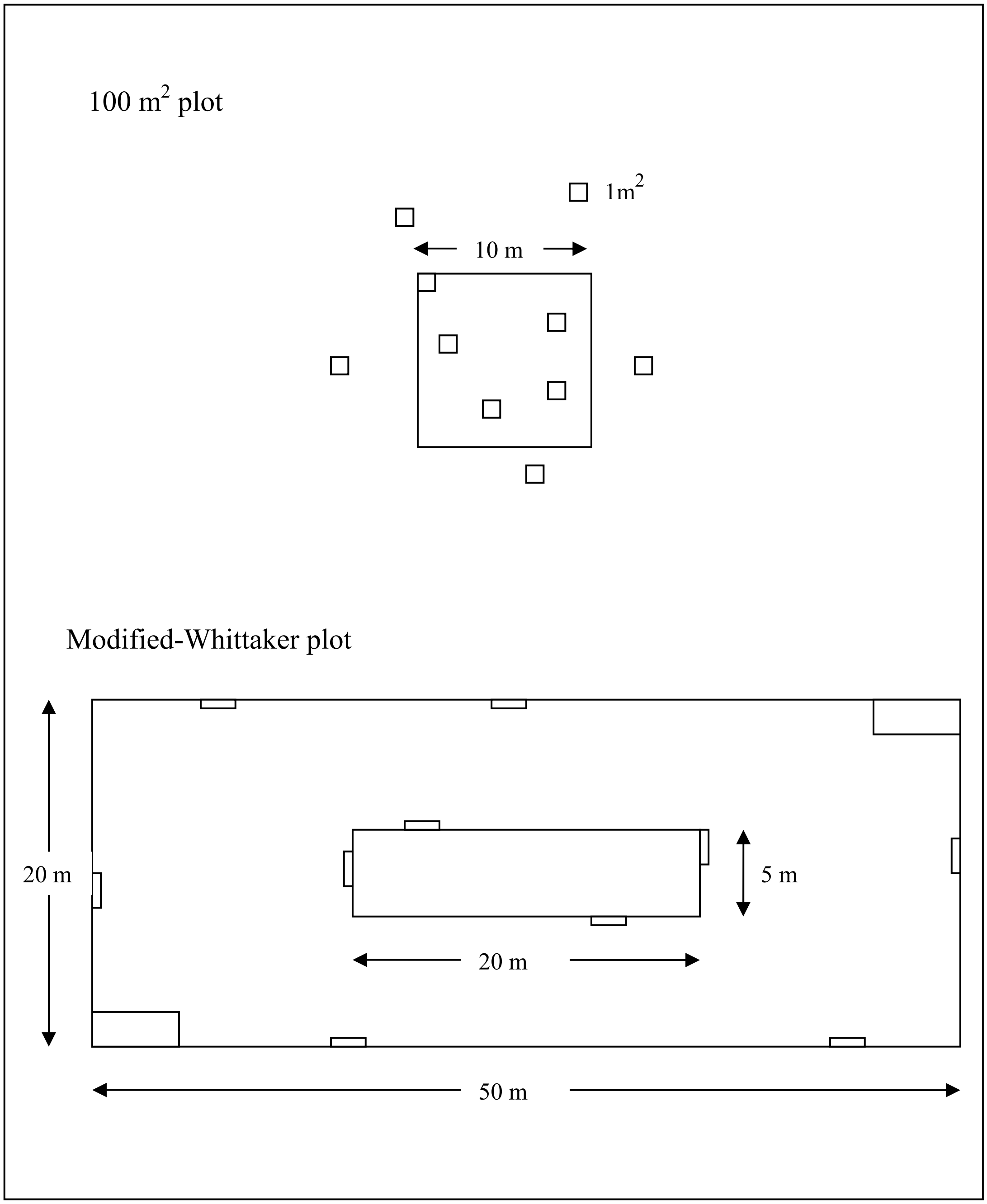
All plant species collected in 2005 were identified and compared to available collections from 2000. The observer from 2000 and I spent a day in the field together before the 2005 field season to cross check abundance measures and these were generally consistent between observers.

In 2005 an additional multi-scale vegetation plot was subjectively located in each wetland prairie site with the long axis running north to south due to lack of apparent moisture gradient in the wetlands. This "modified-Whittaker" plot design allows plant community identification at multiple spatial scales (Stohlgren et al., 1995). The plot consisted of a 20 x 50 meter (1000 m^2) plot with ten 0.5 x 2 m (1 m^2) plots along the inside edge, two 2 x 5 meter (10 m^2) plots at opposite corners, and a central 5 x 20 meter (100 m^2) plot (Figure 3). Vegetation and bare ground cover were estimate to the nearest percent in the 1 m^2 and 10 m^2 plots. Presence/absence was recorded in the 100 m^2 and 1000 m^2 plots.

At Finley Wildlife Refuge one of the modified-Whittaker plots sampled in 2005 overlaid a 25 x 25 meter (625 m^2) permanent vegetation plot last sampled in 1997. Five 1 m^2 plots from the 2005 modified-Whittaker plots were selected that overlapped the permanent plot and vegetation percent cover was averaged. Average percent cover of vegetation in twenty five randomly placed 1 m^2 microplots within the 625 m^2 plot was provided by Frenkel for comparison (personal communication). This allowed the 1997 plot (hereafter called Finley site 2) to be incorporated into the temporal analysis.

Figure 3. Plot layout showing 10x10 m plot and 20x50 m plot.

Plots are in scale to each other but orientation and distance apart not as in field



Data Analysis

Species were characterized by life form (forb, graminoid, shrub, tree, annual or perennial), native or exotic origin, and wetland indicator status. Botanical nomenclature follows Hitchcock and Cronquist (1973) except for *Lythrum hyssopifolium* and *Juncus marginatus.* These two species have a typically southern Oregon distribution and were found in the Jepson Manual (Hickman, 1993). Exotic designation was defined at the state level by the USDA List of Introduced Plants of the U.S. (http://plants.usda.gov/) and cross checked with local floras.

Each species was assigned a wetland indicator code based on published data for the NW region (Reed Jr., 1988; Reed Jr. et al., 1993). Wetland indicator status describes the probability of a plant occurring in a wetland. Wetland indicator status does not suggest the condition of a wetland because exotic species occur in many of the indicator groups and there may be ecotypes within a species that occur in another group (Tiner, 2006). Instead, this measure can suggest whether a wetland supports a diverse assemblage of hydrophytic species when groups of species are combined. In this measure, an obligate (OBL) species has > 99% chance of occurring in a wetland, a facultative wetland (FACW) species has 67-99% chance, a facultative (FAC) species has 34-66% chance, a facultative upland (FACU) species has 1-33% chance, and an obligate upland (UPL) species has >99% chance of occurring in upland habitat.

Wetland species dominants were determined by the 50/20 rule to determine if the plots met criteria for hydrophytic vegetation (Environmental Laboratory, 1997). The plots in this study were only a small fraction of each wetland so this measure merely suggests how the individual plots changed over time, rather than demonstrating qualitative differences in the wetlands. In this procedure, species were separated into herb and shrub groups, and then dominants were determined by calculating relative cover of each species within that group. The most abundant species in each group with combined cover over 50% cover, and additional species with over 20% relative cover were considered dominants. The percentage of species with obligate, facultative wetland, and facultative cover out of all dominants in both groups were calculated to determine whether the community was comprised primarily of hydrophytes.

Characterizations of plant communities, successional change, and significance tests between remnant and restored wetland prairie groups were performed using PC-ORD software (McCune and Mefford, 2006) and SPSS software (SPSS, 2005). Significance of all tests was determined at the $p \leq 0.05$ level. Species abundance data for the 100 m^2 plots was log transformed due to the presence of outliers and heterogeneity of the plant community variance between sites. The transformation preserved the original order of magnitude of the data and preserved zeros by subtracting a constant based on the minimum non-zero value in the data (McCune and Grace, 2002). For the temporal analysis, data collected at Finley Wildlife Refuge in 1997 was grouped with 2000 data for all analyses. Coleman rarefaction curves were computed for the Finley 1997 data using EstimateS software to indicate the species richness that would be found from five microplots instead of the complete twenty-five (Colwell, 2005; Colwell et al., 2004). Balboa was not included in within-year significance tests for the 100 m^2 plot comparisons due to previously mentioned plot location problems.

Within- year community composition

The GPS plot vicinity heterogeneity for the ten 1 m^2 plots in and around the 100 m^2 plot and the statistical validity of within-year plant community differences was determined using a multi-response permutation procedure (MRPP) in PC-ORD software with a Sorensen proportional city-block distance measure (McCune and Grace, 2002). MRPP is a non-parametric statistical method that does not require multivariate normality of the data (Biondini et al., 1988). This method tests for the difference between a priori groups by comparing all possible combinations of the data under the null hypothesis of no difference (Zimmerman et al., 1985). This procedure also provides a value of within-group homogeneity (A) compared to random expectation. A=1 indicates that all items are identical within groups while A=0 indicates heterogeneity between groups is the same as expected by chance (McCune and Grace, 2002). Univariate comparisons were tested with ANOVA using SPSS software.

Two Way Cluster Analysis using Sorensen (Bray-Curtis) distance measure was used to create dendrograms that visually indicated how group average species abundance separated the different wetland prairies by restored and remnant groups. Indicator species analysis was used to determine if any species had affinity to remnant or restored wetland prairie groups (Dufrene and Legendre, 1997). This test contrasts species abundance in two a priori groups to differentiate how much affinity a species has to that group.

Between- year community composition

Statistical differences between the two sample years were tested with repeated measures analysis of variance (RM-ANOVA) using SPSS software (SPSS, 2005). This test was used to satisfy issues of pseudoreplication due to repeat measurements at a single location. A Huynh-Feldt correction parameter that alters the degrees of freedom was used to adjust for sphericity violations (Taylor, 1999). Sphericity, an assumption of repeat measure ANOVA tests, refers to the requirement of equality of variance between the factor levels.

Plant community trajectory

Ordination to model the trajectory of vegetation abundance between years was done by nonmetric multidimensional scaling (NMS) with a Sorensen (Bray-Curtis) distance measure (Mather, 1976). This method uses ranked distances to find the best positions of plots based on patterns of species composition (McCune and Grace, 2002). Multivariate analysis of variance (MANOVA) was used to test the significance of the rate and direction of community compositional change.

Wetland community heterogeneity

The species richness and functional group abundances from the 2005 modified-Whittaker plots were compared between remnant and restored sites and then compared to the results from the 100 m^2 plots. Richness, abundance, and wetland indicator species were compared in the same manner as the 100 m^2 plot method though values were averaged across the ten microplots.

Plant community heterogeneity of species composition within each plot was measured by Sorensen (Bray-Curtis) distance measure. In this method, a distance (dissimilarity) index was calculated between the 10 microplots resulting in 45 dissimilarity measurements for each plot. For example, microplot 1 was compared to microplots 2-10 and microplot 2 was compared to microplots 3-10 etc. The coefficient of variation was calculated for each plot (Baer et al., 2004). This dimensionless number is the standard deviation of the dissimilarity values divided by the mean dissimilarity. Within plot distance for each plot was compared between remnant and restored groups for statistical significance using ANOVA.

Species area relationship

Species area curves were constructed to show the relationship of vascular plant richness (S) to cumulative area in the 2005 modified-Whittaker 1, 10, 100, and 1000 m^2 plots. Species from the ten 1 m^2 and two 10 m^2 plots were averaged across the plot. Because the smaller subplots were nested within the 1000 m^2 plot, the species richness was not independent within plots. Independence became less of a factor when the means were averaged across multiple sites (Keeley, 2003). The slope fit was compared between remnant and restored wetland prairie sites and tested for significance with ANOVA.

Data analysis summary

Table 2 shows which sites and specific plots were involved in the analyses described previously. N=8 for every analysis.

Table 2. Summary of plots involved in analyses.

* = Restoration

Site	Plot m^2	Within/ Between Year	Trajectory	Wetland Community Heterogeneity	Species Area Relationship
Finley 1	100	✓	✓		
	1000				
Finley 2 (1997 permanent)	100				
	1000	✓	✓	✓	✓
Fisher Butte	100	✓	✓		
	1000			✓	✓
Jackson Frazier	100	✓	✓		
	1000			✓	✓
Rose Prairie	100	✓	✓		
	1000			✓	✓
Balboa *	100				
	1000			✓	✓
Greenhill Prairie *	100	✓	✓		
	1000			✓	✓
Marys River *	100	✓	✓		
	1000			✓	✓
Oak Creek *	100	✓	✓		
	1000			✓	✓

RESULTS

GPS variance

When the 100 m^2 plots were relocated in 2005 using a GPS unit, random error in GPS signal strength led to up to a 10 meter error in UTM coordinates around each plot center. I found no statistical difference in species composition in year 2005 between the five microplots within the 100 m^2 plot and the five outside the 100 m^2 plot for each wetland. Therefore, I could not reject the null hypothesis of no difference between microplot groups for the plots (MRPP Finley site 1: A=0.039, p =0.179; Fisher Butte: A=0.006, p =0.374; Greenhill Prairie: A=-0.030, p =0.820; Jackson Frazier: A=0.002, p =0.427; Marys River: A=0.045, p =0.074; Oak Creek: A=0.090, p =0.067; Rose Prairie: A=0.071, p =0.097). The results indicated that there was not sufficient evidence to suggest that the variance component in the GPS measurement would effect the plot placement. The chance corrected within-group agreement (A) values indicated that the plant community heterogeneity between groups of microplots within a wetland was about equal to that expected by chance.

Within- and between-year community composition

Species diversity

A total of 130 species were found between all the 100 m^2 wetland plots over all years and, with the exception of the Marys River and Oak Creek plots, all sites had higher native species richness than exotic richness within the same year (see Appendix 1 for list of all species). Richness, the total number of species within each 100 m^2 plot, was variable between sites (Table 3). The most species were found in both a remnant (43 species) and a restored wetland prairie plot (35 species). These two sites were represented mostly by native species in the remnant wetland at Finley in 1997 and by introduced species in the restoration at Marys River in 2005. Rarefaction curves for the Finley 1997 plot indicated that the species richness that would be found from five microplots instead of all twenty-five microplots was 27.6

with a standard deviation of 2.4. This was still higher than the other sites but much more in line with the other remnant sites. Oak Creek had the lowest richness over both sample years (10 and 15 species). The number of exotic species as a proportion of the total number of species within a plot was highest in the restored Marys River plot over both years and increased from 57% in 2000 to 69% in 2005 (Table 3). Oak Creek was split equally between native and exotic species in 2000 but exotic richness decreased in 2005 to 40% of the total species. Greenhill Prairie and the Balboa 2000 plot, which were also restoration sites, had comparable exotic species richness to remnant sites. Greenhill also showed a comparable increase in exotic species compared to remnant plots. The wetlands were not completely inventoried for floristic diversity so the species found in this study were only a sample of the total wetland richness.

Native species richness was significantly different between the restored and remnant sites in 2000 but not in 2005 (ANOVA 2000: p=0.018; 2005: p=0.259). This was likely due to the very few native species found at Oak Creek in 2000 (5 species) compared to the significantly greater number found at Finley in 1997 (25 species). Exotic species richness was not significantly different between restored and remnant plots for within year comparisons (ANOVA 2000: p=0.821; 2005: p=0.131). A test of the change in exotic species richness between 2000 and 2005 was not significant between restored and remnant sites (RM-ANOVA p=0.082). Therefore I could not reject the null hypothesis of no change in exotic richness between these remnant and restored wetland prairies plots for within year comparisons and between 2000 and 2005.

The Shannon-Wiener diversity index, summarized in Table 3, incorporates richness and abundance of species present in a sample (Whittaker, 1972). The 1997 Finley permanent plot and the 2005 Rose Prairie plot had the highest diversity with this measurement. Similarly to the richness metric, Oak Creek again had the lowest diversity in 2000 but in 2005 Jackson Frazier had the lowest diversity according to this index due to numerous species occurring in trace amounts.

Table 3. Community diversity summary including Shannon-Wiener diversity index and total richness divided into proportion by native and introduced species by year.

H= Shannon diversity index
S= Richness (species per sample unit)
STotal=total number of species found
SNative and SIntroduced are proportion of STotal
* = Restored site

Site	H		S_{Total}		% S_{Native}		% $S_{Introduced}$	
	2000	2005	2000	2005	2000	2005	2000	2005
Finley 1	1.79	1.27	20	23	65	61	35	39
Finley 2 (1997 permanent)	2.36	1.50	43	19	64	61	36	39
Fisher Butte	1.70	1.32	25	21	75	81	25	19
Jackson Frazier	2.09	1.09	23	18	86	88	14	12
Rose Prairie	1.59	1.86	22	29	68	64	32	36
Balboa * (not included in analysis)	2.12	na	24	na	68	na	32	na
Greenhill Prairie *	1.59	1.51	22	28	63	57	37	43
Marys River *	1.19	1.52	15	35	43	31	57	69
Oak Creek *	0.83	1.30	10	15	50	60	50	40

Species abundance

Each wetland prairie plot had one to several species that were dominant based on percent cover, though these species were not dominant across all sites. Table 4 shows the two to three most dominant species in each plot by year based on the highest percent cover values. *Deschampsia cespitosa* was present in six of the seven plots, excluding Oak Creek (though *D. cespitosa* was observed at all the sites in 2005), in both 2000 and 2005, but its cover ranged from 1% at Marys River in 2000 to 65% at Greenhill Prairie in 2005. Less dominant species such as

Centaurium umbellatum, *Holcus lanatus*, and *Juncus tenuis* were present in almost all of the sites at low abundances in all years. There was no distinct north/south geographic breakdown in the most abundant species as these were found equally in both northern and southern plots.

Table 4. Dominant species abundance (percent cover of plot) in 100 m^2 plots by year.

* = Restored site

Site	Dominants (2000)	%	Dominants (2005)	%
	Agrostis tenuis	50	*Agrostis microphylla*	50
	Deschampsia cespitosa	15	*Rosa nutkana*	35
Finley 1	*Rosa sp.*	15	*Deschampsia cespitosa*	10
Finley 2	*Rosa* sp.	38	*Rosa* sp.	39
(1997 permanent)	*Agrostis tenuis*	28	*Deschampsia cespitosa*	31
	Deschampsia cespitosa	50	*Deschampsia cespitosa*	50
Fisher Butte	*Juncus nevadensis*	10	*Mentha pulegium*	30
	Eleocharis palustris	60	*Eleocharis palustris*	60
Jackson Frazier	*Carex unilateralis*	10	*Deschampsia cespitosa*	5
	Panicum occidentalis	40	*Vaccinium caespitosum*	30
	Anthoxanthum odoratum	20	*Hypochaeris radicata*	25
Rose Prairie	*Deschampsia cespitosa*	20		
Balboa *	*Deschampsia cespitosa*	40		
(not included in analysis)	*Juncus tenuis*	15	na	na
	Anthoxanthum odoratum	30	*Deschampsia cespitosa*	65
Greenhill Prairie*	*Deschampsia cespitosa*	25	*Hypericum perforatum*	5
	Deschampsia cespitosa	50	*Madia glomerata*	50
Marys River *	*Agrostis tenuis*	30	*Anthemis cotula*	30
	Agrostis exarata	55	*Agrostis exarata*	80
Oak Creek *	*Alopecurus geniculatus*	40	*Alopecurus geniculatus*	30

When plant community composition was compared within years, the difference in percent cover of all species was not significant between remnant and restored wetland prairies plots (MRPP 2000: A=0.018, p= 0.209; 2005: A=0.141, p= 0.227). The chance corrected within-group agreement (A) indicated that the plant community heterogeneity between the two wetland prairie groups was about equal to that expected by chance. This suggested that within each group there was enough species variation so that the wetland communities were not identical but also that there were some similarities in species composition across sites.

Bare ground cover was not measured for statistical significance because it had not been measured in all the plots. Bare ground did decrease in all the plots indicating vegetation and thatch increased cover (Table 5). The Oak Creek and Marys River restoration sites had significant thatch and no bare ground cover in 2005 but this was similar to Jackson Frazier where a layer of thatch was visible.

Table 5. Total abundance (percent cover of plot) of bare ground and vegetative growth forms in 100 m^2 plots by year.

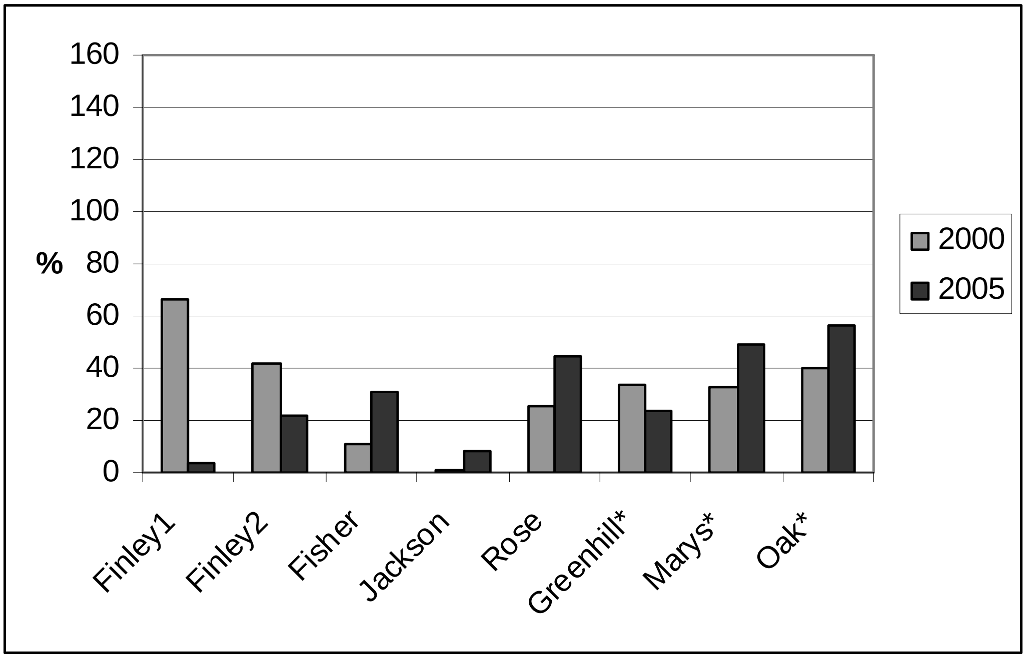
* = Restored site

Site	% Cover Bare		% Cover Graminoid		% Cover Forb		% Cover Shrub	
	2000	2005	2000	2005	2000	2005	2000	2005
Finley 1	15	0	84	63	7	4	25	35
Finley 2 (1997 permanent)	na	3	72	53	31	8	39	38
Fisher Butte	25	7	78	51	8	54	6	1
Jackson Frazier	2	0	108	68	22	54	1	0.1
Rose Prairie	10	6	88	13	1	43	10	31
Balboa * (not included in analysis)	na	na	89	na	16	na	0	na
Greenhill Prairie *	20	2	68	69	17	30	0	0.1
Marys River *	2	0	91	6	4	94	0	1
Oak Creek *	2	0	97	133	1	7	0	1

Graminoid cover decreased in all the sites but increased at Oak Creek. Forb cover generally increased in all the sites but decreased at both Finley plots. Shrubs were not abundant in the restoration sites at all and were not abundant in the restoration plots. Finley had high shrub abundance in both plots and shrubs were visible in most of the wetland.

Greenhill Prairie was the only restoration site to have a decrease in exotic cover between 2000 and 2005 (Figure 4). This was due to a decrease in the graminoid *Anthoxanthum odoratum*. There were mixed results in the remnant prairies with the Finley sites decreasing their exotic cover and Fisher Butte, Jackson Frazier, and Rose Prairie increasing exotic cover. Because of these mixed results both native and exotic species total cover were not significantly different within each year between remnant and restored sites (native ANOVA 2000: p= 0.267; 2005: p= 0.873; exotic ANOVA 2000: p= 0.703; 2005: p= 0.137). These groups also did not have significantly different total cover between 2000 and 2005 (native RM-ANOVA p= 0.457; exotic RM-ANOVA p= 0.517). I could not reject the null hypothesis of no difference in exotic species cover in remnant and restored wetland prairies.

Figure 4. Exotic species abundance (percent cover of plot) in 100 m^2 plot by year.
* = Restored site



Perennials were the most abundant species in all sites except Finley site 1 in 2005 which was dominated by an annual grass, *Agrostis microphylla*, and the 2005 Marys River plot which was dominated by an annual forb, *Madia glomerata*. Perennial graminoids made up the majority of the cover in all sites. These species were both native and introduced. *Agrostis exarata*, a native species that was second in overall cover behind *D. cespitosa*, was most abundant in the restored sites. *Agrostis tenuis*, an introduced species, was most abundant in the remnant wetland prairies sites. While there were some dramatic changes in perennial and graminoid cover, these changes occurred in both remnant and restored plots which tended to balance the results (Figures 5 and 6).

Figure 5. Perennial abundance (percent cover of plot) in 100 m^2 plot by year.

* = Restored site

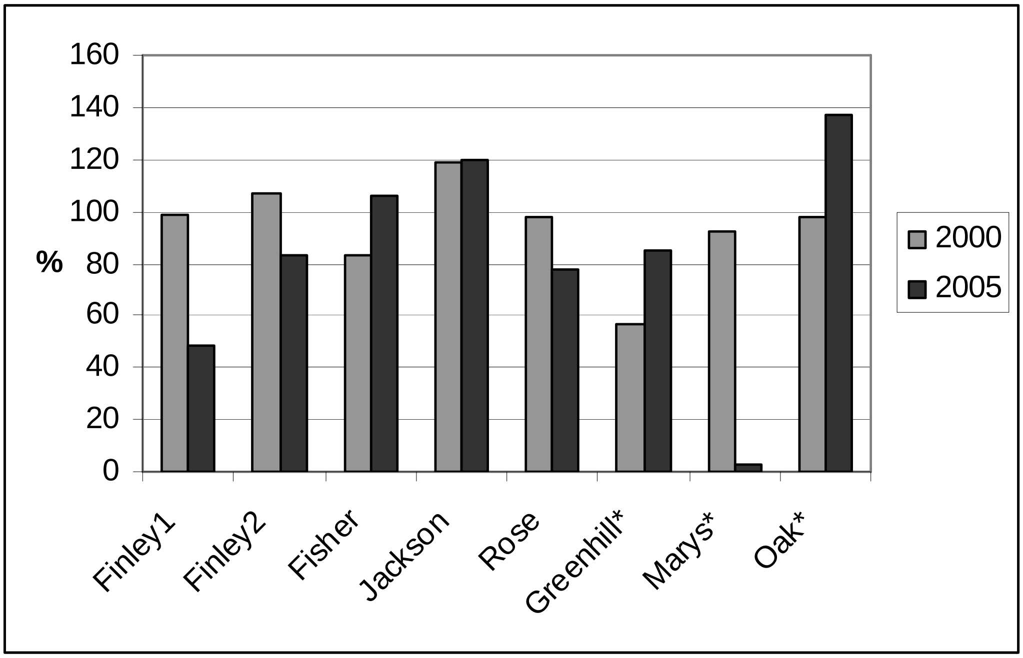
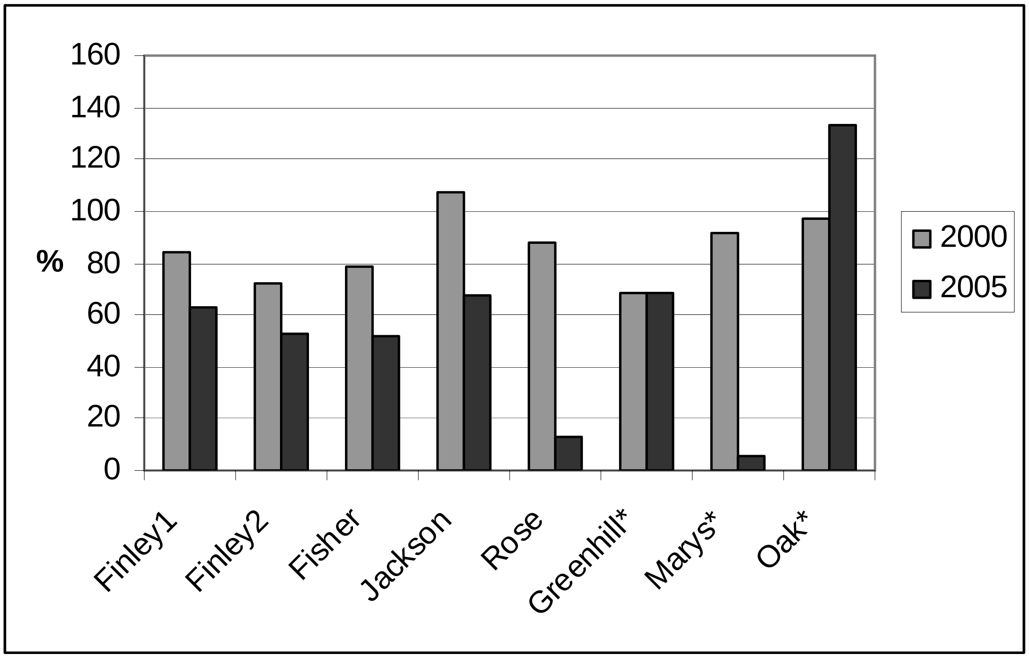


Figure 6. Graminoid abundance (percent cover of plot) in 100 m^2 plot by year.

* = Restored site



Total perennial cover was not significantly different between the restored and remnant sites within years and did not significantly change between 2000 and 2005 (ANOVA 2000: p=0.172; 2005: p=0.732. RM-ANOVA: p=0.842). The difference in graminoid cover was not significant between restored and remnant wetland prairie sites within years or between 2000 and 2005 (gram ANOVA 2000: p=0.980; 2005: p=0.537; RM-ANOVA: p=0.528). Based on these findings I could not reject the null hypothesis of no difference in total perennial or graminoid abundance between these remnant and restored wetland prairie sites.

A two-way cluster analysis of the remnant and restored wetland prairie plots based on group average species abundance shows how the different wetland prairie sites grouped together. In 2000, Oak Creek and Jackson Frazier shared very little species abundance similarity to the other wetland prairie sites (Figure 7). Jackson Frazier was dominated by *Eleocharis palustris*, a native perennial graminoid species that only occurred in trace amounts in other sites. Oak Creek was dominated by *A. exarata* and *Alopecurus geniculatus*, an exotic perennial graminoid. The 1997 Finley site was also outside the main cluster of sites due to high cover of *Rosa*. Finley site 1 and Fisher Butte showed the highest species abundance affinity due to high cover of *Juncus* sp. and *Rosa eglanteria,* an exotic shrub. Finley site 1 and Finley site 2 (1997) only had 40% affinity of similar species abundance. In 2005 the cluster analysis grouped Jackson Frazier and Oak Creek again (Figure 8). The Marys River site seemed to be an outlier, with few shared species with the main group cluster due to high cover of *M. glomerata*. Finley site 1 and Greenhill showed the highest affinity. The Finley sites were more similar in 2005 with about 87% species similarity. Indicator species analysis found a single species, *M. glomerata*, weakly indicative of restored sites (p=0.048).

Figure 7. Two way cluster dendrogram of restored and remnant 100 m^2 study sites in 2000. 0=remnant, 1=restored.

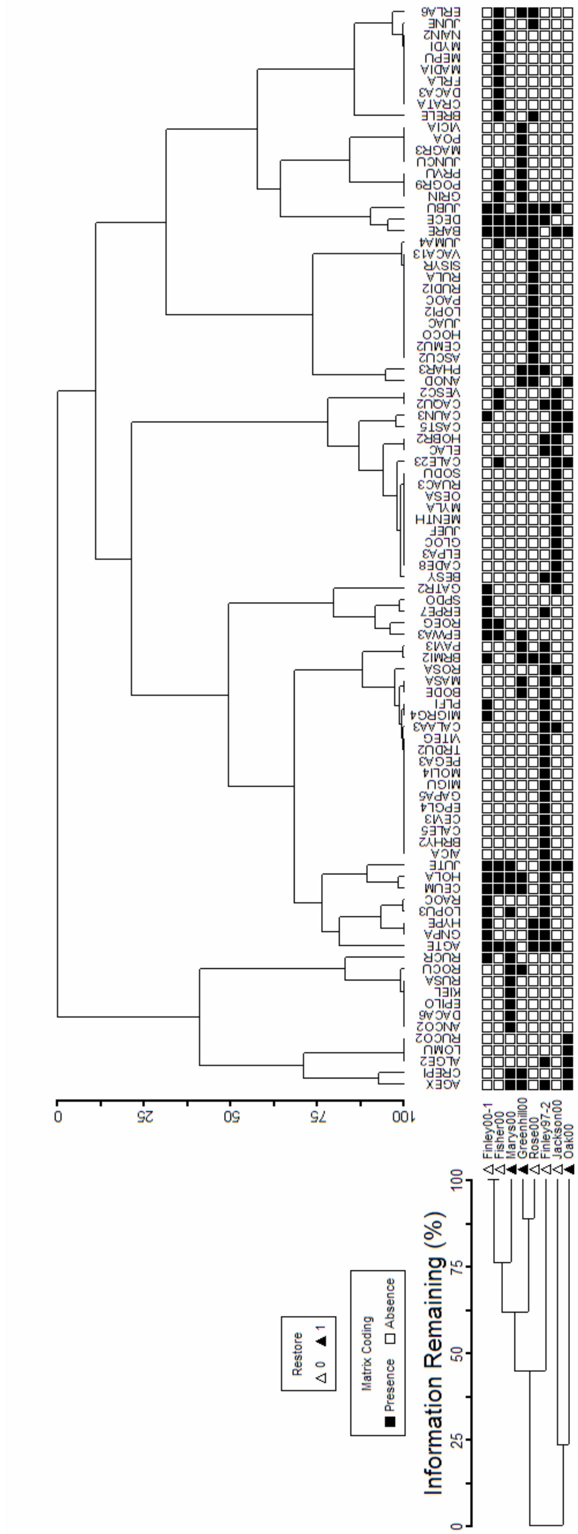
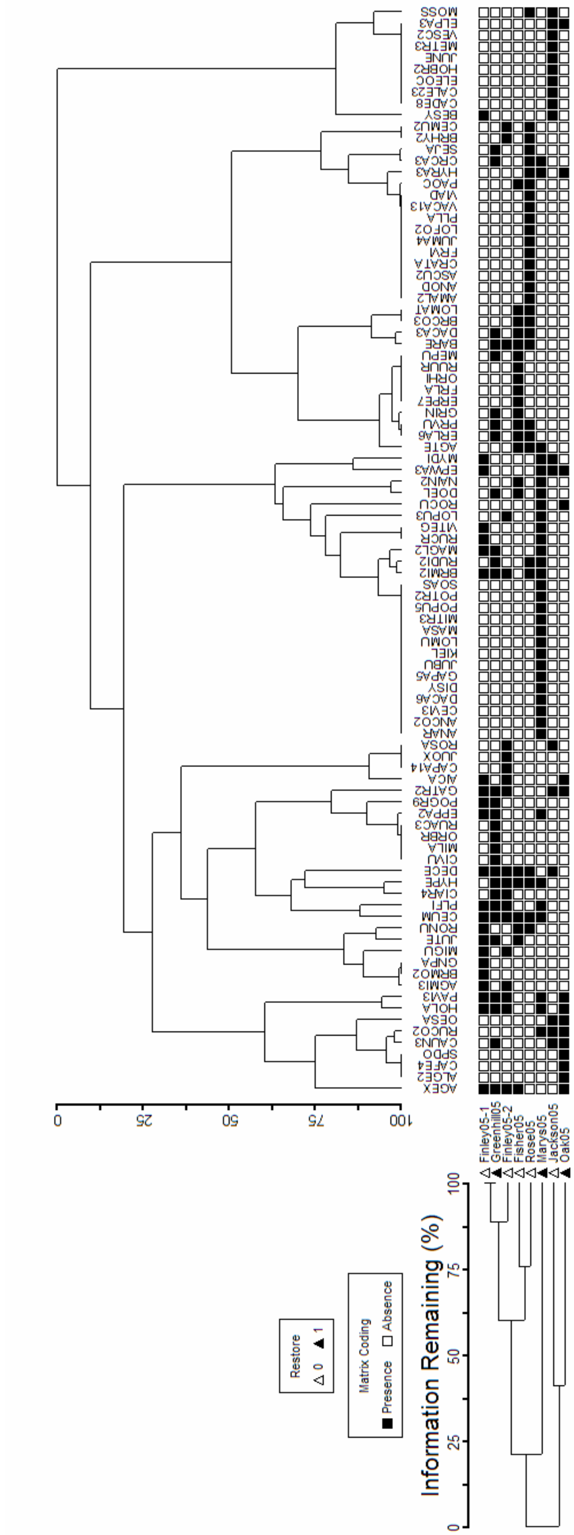


Figure 8. Two way cluster dendrogram of remnant and restored 100 m^2 study sites in 2005. 0=remnant, 1=restored.



Wetland indicator species

Hydrophytic plant species, represented by obligate (OBL), facultative wetland (FACW), and facultative (FAC) indicator species, represented the dominant cover in most of the plots. Following the 50/20 rule all sites were represented by greater than 50% hydrophytic dominant plant species, except the Marys River 2005 plot and the Rose Prairie 2005 plot. The Marys River plot was dominated by facultative upland forbs and the Rose Prairie plot was dominated by both *Vaccinium caespitosum* (FAC) and facultative upland exotic forbs *Hypochaeris radicata* (FACU) and *Crepis capillaris* (FACU).

The most abundant plant species in the plots were facultative wetland species (Table 6). There were very few upland species found in the wetland sites and none were abundant though *Galium parisiense* had the highest cover at the Finley permanent plot in 1997. Obligate wetland species were found in most of the plots though these species were generally less abundant. Jackson Frazier was the only site with visible standing water in July 2005 and this plot also had high obligate wetland indicator species cover in both years which would suggest this plot is consistently wet. Fisher Butte showed the largest gain in obligate cover mainly due to an increase in exotic *Mentha pulegium* from 2000 to 2005.

Table 6. Total abundance (percent cover of plot) of wetland indicator species groups in 100 m^2 plots by year.

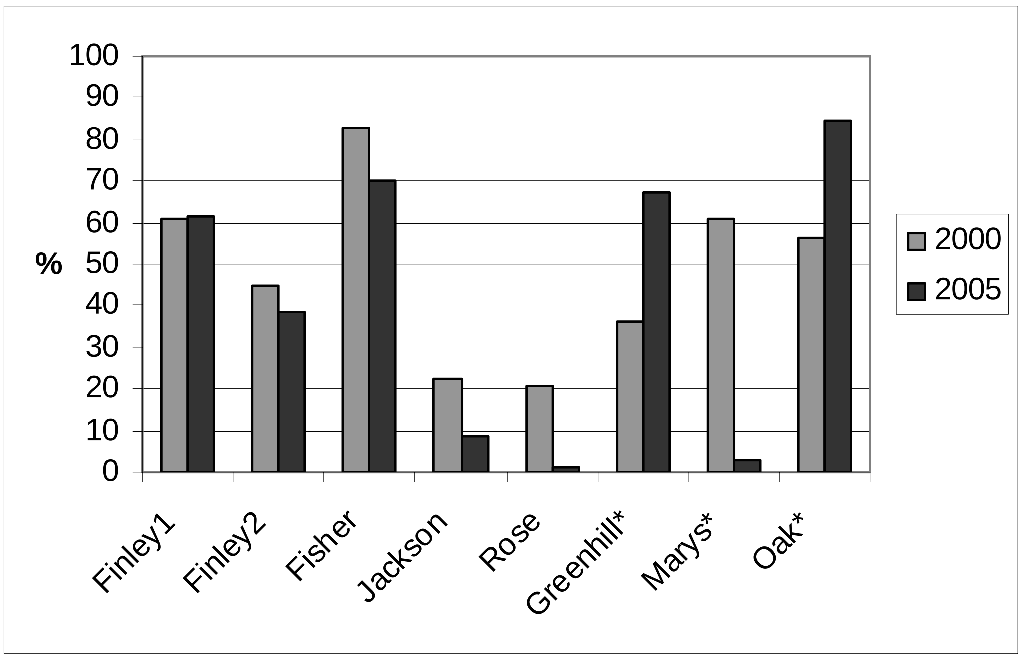
See Data Analysis section for complete description of wetland indicator classes. OBL=obligate, FACW=Facultative wetland, FAC=Facultative, FACU=Facultative upland, UPL=upland.
* = Restored site
0.1% cover indicated trace amount

Site	OBL %		FACW %		FAC %		FACU %		UPL %	
	2000	2005	2000	2005	2000	2005	2000	2005	2000	2005
Finley 1	1.0	0.2	61.1	61.5	51.5	39.4	0.1	0.1	0	0.2
Finley 2 (1997 permanent)	12.6	0.1	44.6	38.5	76.7	38.4	1.3	0.2	3.8	0
Fisher Butte	5.1	30.2	82.5	70.4	1.3	2.2	2.2	2.3	0	0
Jackson Frazier	94.3	62.5	22.3	8.6	7.0	0.1	2.0	0	0	0
Rose Prairie	0.1	0	20.5	1.2	55.2	36.5	20.3	42.7	0	0
Balboa * (not included in analysis)	22.0	na	74.1	na	2.2	na	3.0	na	1.0	na
Greenhill Prairie *	0.1	0.2	36.4	67.4	3.3	13.1	30.1	10.6	0	3.0
Marys River *	1.0	0.4	61.1	2.6	30.3	13.4	1.0	81.3	0.1	1.3
Oak Creek *	41.0	32.2	56.3	84.2	0	23.0	0.2	1.0	0	0

Facultative wetland species were mainly native perennial graminoids such as *Deschampsia cespitosa* and *Agrostis exarata*. The 2000 Finley site 1 plot had the most facultative wetland species (13) while the Marys River site in 2000 and Rose Prairie 2005 site had the least (5). The Marys River site showed a striking increase in facultative upland species abundance along with a decrease in facultative wetland species abundance between 2000 and 2005 (Figure 9). This change was mainly due to a loss of *D. cespitosa* (FACW) and a gain in *Madia glomerata* (FACU). Even with this dramatic gain, the other sites showed more stability in facultative wetland species, therefore there was no significant difference in facultative wetland species abundance within year or between year for the remnant and restored wetland prairie groups (FACW ANOVA 2000: p= 0.771; 2005: p=0.574. RM-ANOVA: p=0.655).

Figure 9. Facultative wetland species abundance (percent cover of plot) in the 100 m^2 plots by year.

* = Restored site



Facultative upland species varied in origin and form with the most abundant being native forbs and shrubs such as *Madia glomerata* and *Vaccinium caespitosum*, and exotic graminoids such as *Anthoxanthum odoratum*. In 2005, Rose Prairie and Greenhill Prairie had the most facultative upland species (11 and 9) while most other sites had between one and six species. The majority of facultative upland species were exotic species such as *Cirsium vulgare* that occurred in trace amounts. Rose Prairie and Marys River site had the most change in facultative upland species abundance between 2000 and 2005 (Figure 10). Greenhill decreased facultative upland abundance due to a lack of *A. odoratum* found in 2005. The other plots tended to be stable so that overall there was also no significant difference within or between years (FACU ANOVA 2000: p= 0.572; 2005: p=0.350. RM-ANOVA: p=0.498). Facultative species were also variable in origin and form though the most abundant were graminoids and shrubs such as *A. tenuis*, *Panicum occidentale*, and *Vaccinium caespitosum*. Finley site 2 (permanent plot) showed the largest loss in facultative species due to lack of *Agrostis tenuis* found in 2005. The facultative cover showed more variability between sites but also was not significant (FAC ANOVA 2000: p= 0.238; 2005: p=0.600. RM-ANOVA: p=0.150). Due to these findings I could not reject the null hypothesis of no difference in wetland indicator status species between the restored and remnant plots.

Figure 10. Facultative upland species abundance (percent cover of plot) in the 100 m^2 plots by year.

* = Restored site

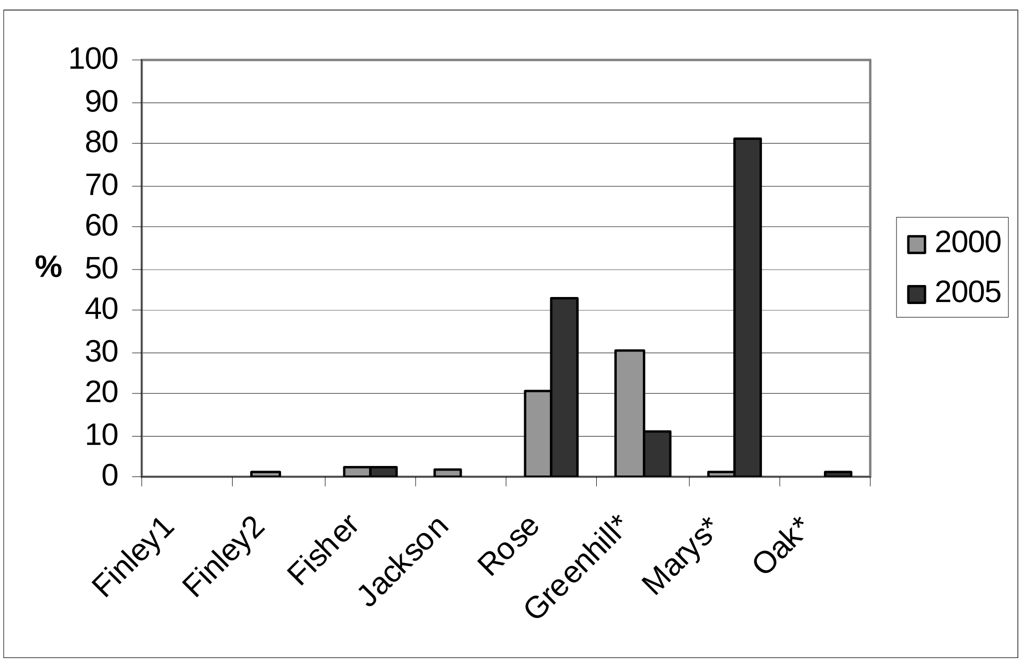
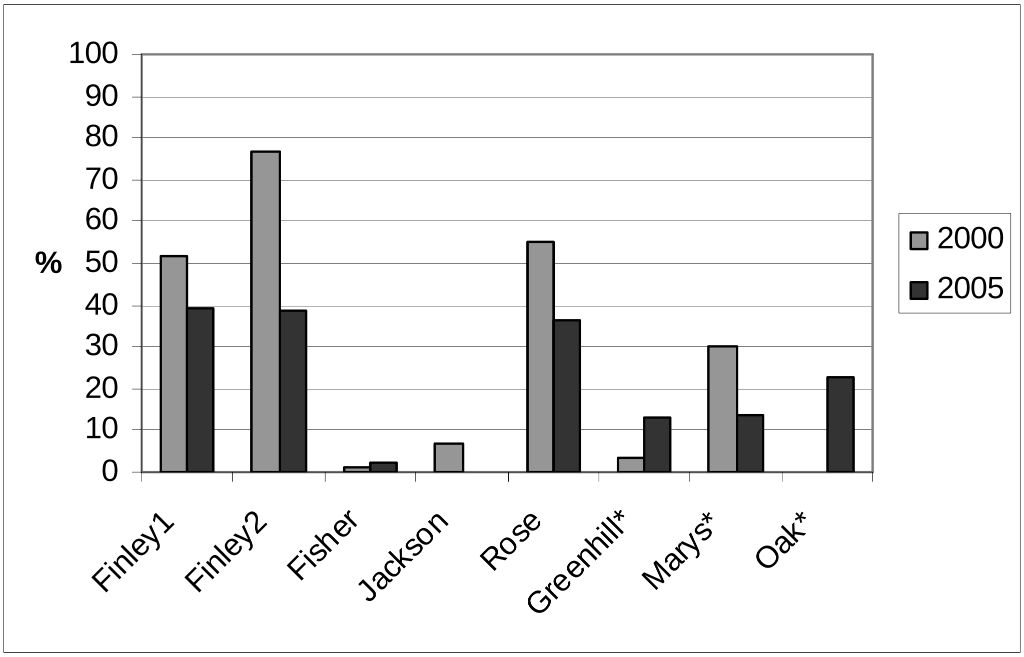


Figure 11. Facultative species abundance (percent cover of plot) in 100 m^2 plot by year.

* = Restored site

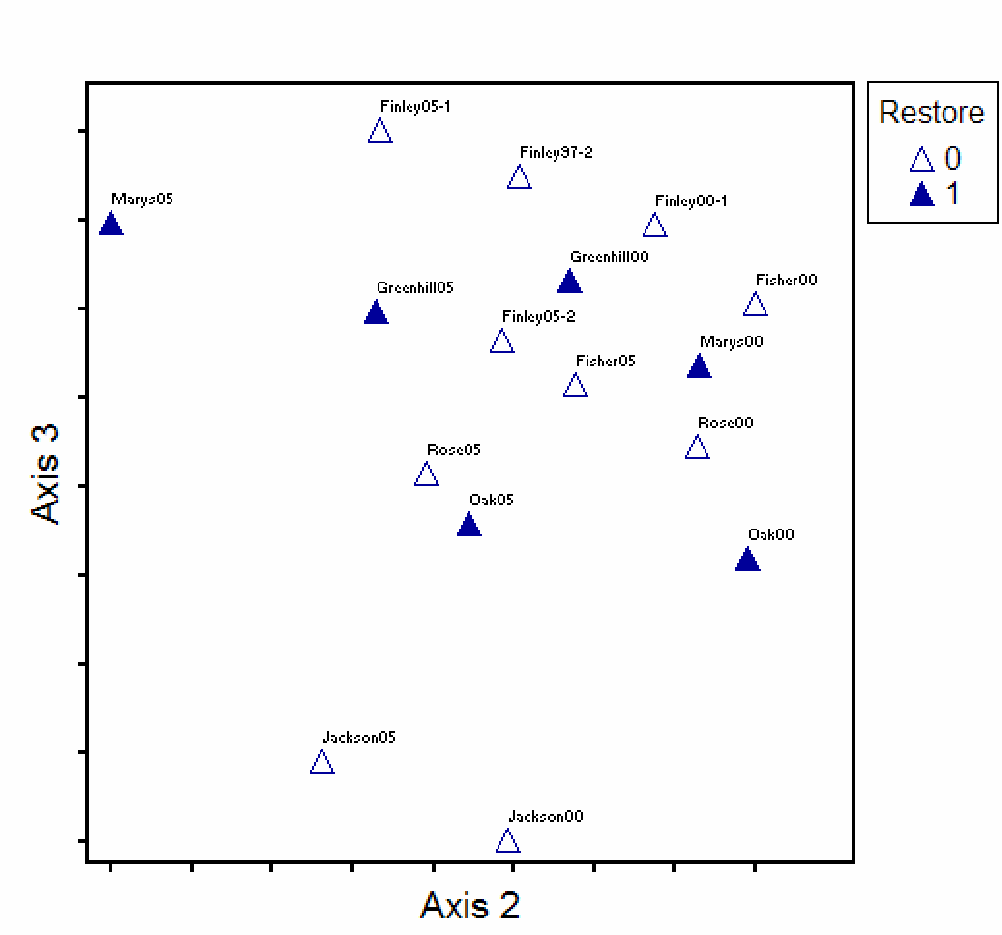


Plant community trajectory

Wetland prairie plots generally were clustered by site in the NMS ordination of sample units in species space (Figure 12). Autopilot mode suggested a three-dimensional solution which was accepted. The final solution used 207 iterations for a final stress of 11.5 (final instability <0.00001). The wetland prairie sites closest together in the ordination space were more similar in species assemblages which indicated that most of the sites were similar between the two sample years. There was no grouping between the restored and remnant wetland prairie sites which visually confirmed the MRPP group test of no significance between group species assemblages. Jackson Frazier, Oak Creek, and the Marys River 2005 site also looked like outliers from the main group which confirmed the two way cluster analysis.

Figure 12. Wetland prairie 100 m^2 plots categorized by restored and remnant wetland groups. Plots are shown in species space from nonmetric multidimensional scaling.

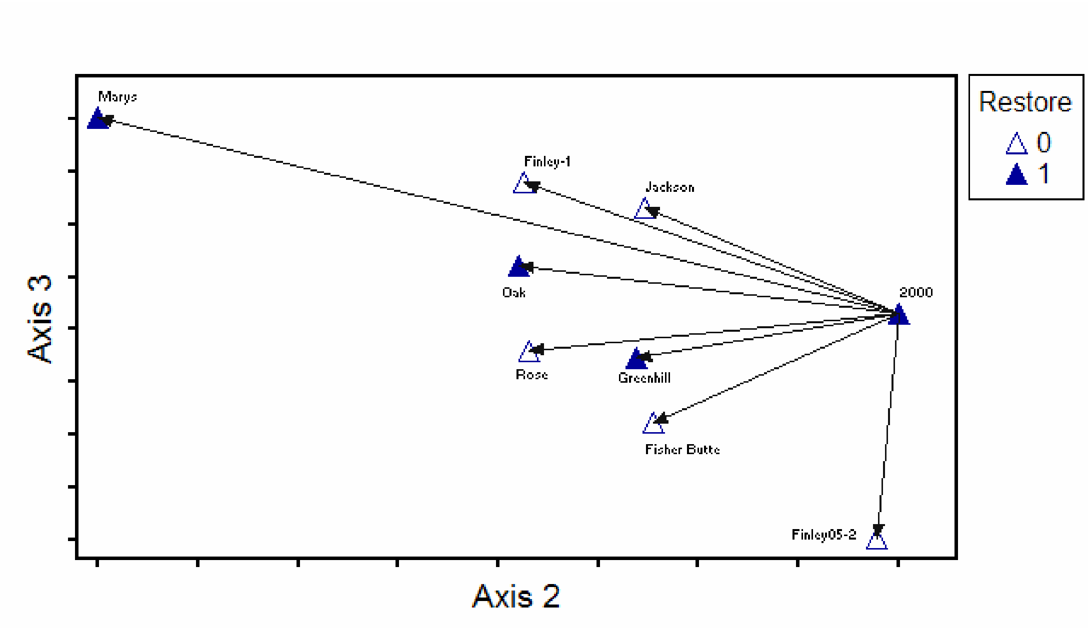
0 = Remnant wetland prairie
1 = Restored wetland prairie



Community composition vectors showing changes in the plant community for each plot indicated that restored wetland prairies did not visually group together in species ordination space (Figure 13). The vectors show how the species composition of the wetland prairie sites changed between the two time periods. The degree of change was generally similar for all the plots except for Marys River which had a major change in community dominants. Time zero position for all the sites was translated to a common origin to show magnitude of change in both rate and direction. The direction of change in most of the sites was very similar except for Finley site 2 which was the permanent plot. The Finley site 2 vector, which indicated change from 1997 to 2005, showed a much different direction of change from the other plots even though the relative abundance of *Rosa* remained the same. This was likely due to the lack of *Agrostis tenuis* in 2005 which had been abundant in 2000. The test for community composition trajectory differences between remnant and restored wetland prairie sites was not significant (MANOVA $p=0.81$). The null hypothesis of no difference in direction and magnitude of change in community composition between remnant and restored wetland prairies could not be rejected.

Figure 13. Combined rate and direction of change in community composition for each 100 m^2 plot by translating time zero to common origin.

0 = Remnant wetland prairie
1 = Restored wetland prairie



Wetland community heterogeneity

The 1000 m^2 modified-Whittaker plots incorporated the Balboa restoration site which was not evaluated in the temporal analysis. This analysis also dropped the Finley site 1 plot from the analysis. With this change, statistical results for the 2005 modified-Whittaker plots only differed from that of the 100 m^2 plots in exotic richness between remnant and restored plots (ANOVA p=0.029) and facultative upland species abundance between remnant and restored plots (ANOVA p=0.028) which hadn't been significant in the previous analysis. Abundance measures were not significant between the remnant and restored groups. A comparison of the plant community composition between the remnant and restored groups was again not significant (MRPP A=0.024, p=0.093). The chance-corrected group abundance (A) indicated the community heterogeneity was about that expected by chance, which was very similar to the 100 m^2 analysis (A=0.018 in 100 m^2 plot analysis).

The change in richness was due to the Balboa plot having high exotic richness even though its native richness (23 species) was among the highest values for all the plots (Table 7). Even though Balboa had high exotic richness, the exotic abundance was very low (11.4% of plot), and the plot was dominated by native perennial graminoids (Table 8). The change in facultative upland significance was due to the new Oak Creek plot having exotic forbs *Hypochaeris radicata* and *Crepis capillaris* which hadn't been found in the 100 m^2 plot and the Marys River plot having much less *Madia glomerata*. The minor differences between analyses of the 100 m^2 plots and 1000 m^2 modified-Whittaker plots suggested that the remnant wetland prairie plot placement did not significantly change the results, but that there was enough heterogeneity in the wetland species abundance in the restoration sites to change statistical significance of the facultative upland values.

Table 7. Community diversity summary including Shannon-Weiner diversity index, Coefficient of Variation of Sorensen dissimilarity, and total richness divided into proportion by native and introduced species in 20 x 50 m^2 plot.

H = Shannon diversity index
S = Richness (species per sample unit)
STotal = Total number of species found
SNative and SIntroduced are proportion of STotal
Distance = 0% is similar, 100% is totally dissimilar
* = Restoration

Site	H	S_{Total}	S_{Native} %	$S_{Introduced}$ %	CV % Dissimilarity
Finley 2 (placed over 1997 permanent plot)	2.2	25	70	30	35
Fisher Butte	2.8	37	63	37	50
Jackson Frazier	2.6	33	74	26	23
Rose Prairie	2.8	30	82	18	35
Balboa *	3.2	44	53	47	35
Greenhill Prairie *	2.8	32	60	40	41
Marys River *	2.9	37	40	60	28
Oak Creek *	2.6	28	50	50	45

The coefficients of variation for within plot plant community heterogeneity were not significant between the remnant and restored wetland prairie (ANOVA $p=0.746$). This indicated that the plant community compositional change throughout the plots was similar between remnant and restored plots and there was no distinct grouping of species. Jackson Frazier had the lowest dissimilarity across the plot due to consistent cover of *Mentha pulegium* and *Myosotis discolor*. Marys River site was also relatively spatially homogeneous due to consistent *Daucus carota* cover over the plot. None of the restoration plots had consistent cover of *Deschampsia cespitosa* over the plot though Balboa had 50% of the microplots with high abundance of *D. cespitosa* and the other 50% mostly bare with obligate wetland species. Based on these results I could not reject the null hypothesis of no difference in species compositional heterogeneity between remnant and restored wetland prairies.

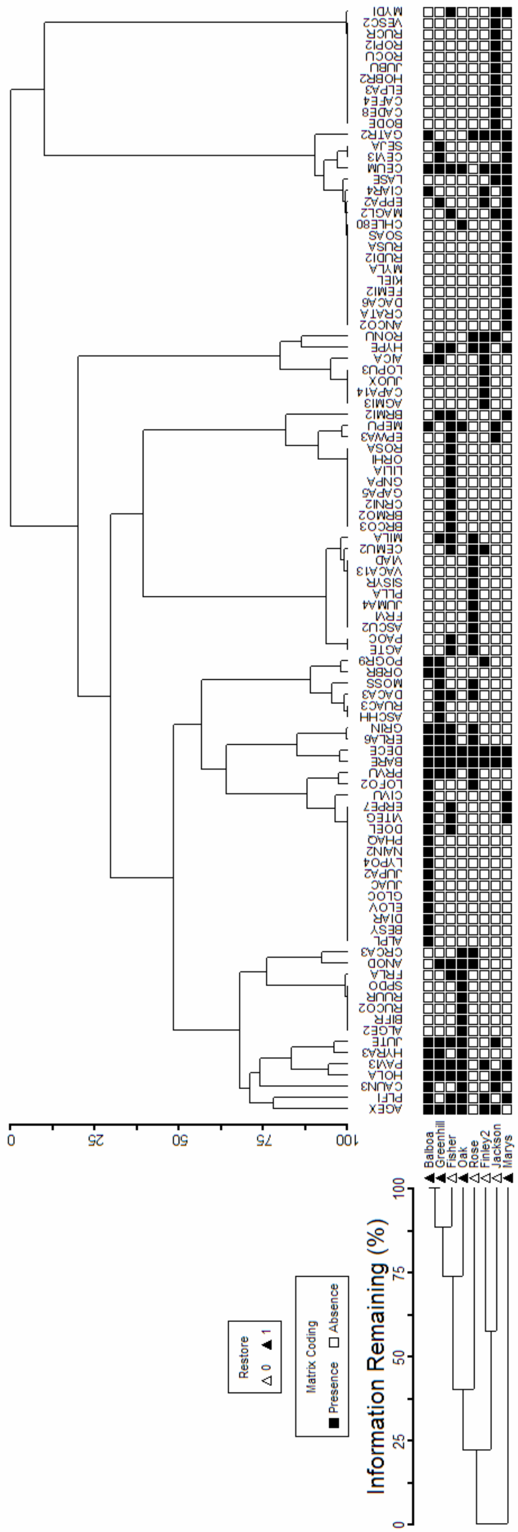
Table 8. Functional group abundance (percent cover of plot) for perennials, introduced species, graminoids, and wetland indicator species averaged over ten 1 m^2 microplots within 1000 m^2 plot in 2005.

See Data Analysis section for complete description of wetland indicator classes. OBL=obligate, FACW=Facultative wetland, FAC=Facultative, FACU=Facultative upland, UPL=upland.
* = Restoration
0.1% indicated trace amount

Site	Perennial %	Int %	Gram %	OBL %	FACW %	FAC %	FACU %
Finley 2 (placed over 1997 permanent plot)	77	26	44	0	28	39	0
Fisher Butte	59	21	36	18	30	9	0.3
Jackson Frazier	48	22	22	17	29	22	0.1
Rose Prairie	62	8	38	0	5	50	7
Balboa *	53	11	40	11	41	1	3
Greenhill Prairie *	73	31	40	0	36	8	27
Marys River *	43	41	7	0	15	3	21
Oak Creek *	76	80	68	8	16	54	17

The two-way cluster analysis of the remnant and restored wetland prairie plots based on group average species abundance shows how the different wetland prairie sites grouped together based on the new plots (Figure 14). Balboa and Greenhill had the highest affinity in species abundance, which made sense because these sites were likely historically from the same wetland complex and were similarly managed. Rose Prairie and Fisher Butte were within the same cluster as Balboa and Greenhill. However, it was surprising that Oak Creek shared affinity with this group. This was likely due to the presence of *Agrostis exarata* and *Anthoxanthum odoratum*. The Marys River site was again an outlier due to the higher percentage of facultative upland species such as *Anthemis cotula* and *Rubus discolor*.

Figure 14. Two way cluster dendrogram of restored and remnant 1000 m^2 modified-Whittaker plots in 2005. 0=remnant, 1=restored.



Species area relationship

Both remnant and restored wetland prairie sites fit a power model ($S=cA^z$) for species richness to area. This model has been proposed for ecosystems in which several species share high abundance (Keeley, 2003). The slope (z) ranged from 0.44 at Rose Prairie to 1.08 at Balboa (Table 9). The fit of the curve to the remnant plots was $R^2=0.74$ while the fit of the curve to the restored plots was $R^2=0.83$ (Figure 15). There was no statistical difference in the slopes when plots were compared by groups of remnant and restored sites (ANOVA p=0.063). Individual sites showed varying fit to the curve. Rose Prairie and Oak Creek had low species richness at the 100 m^2 scale (Figure 16 and Figure 17).

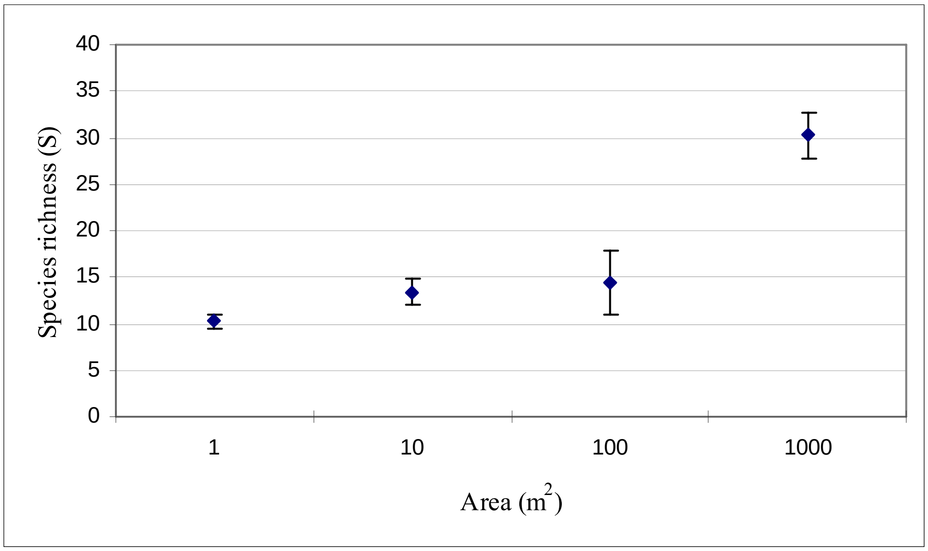
Table 9. Summary of species area curve slope (z), fit (R^2), and richness by area for modified-Whittaker plots in 2005.

S = Species richness; averaged over plot for 1 m^2 and 10 m^2 microplots
* = Restoration

Site	Slope (z)	R^2	S 1 m^2	S 10 m^2	S 100 m^2	S 1000 m^2
Finley 2 (placed over 1997 permanent plot)	0.62	0.61	8.2	10	10	24
Fisher Butte	0.68	0.75	11.9	16	17	36
Jackson Frazier	0.82	0.86	10.4	12	23	32
Rose Prairie	0.44	0.23	10.5	15.5	8	29
Balboa *	1.08	0.83	8.6	11	19	43
Greenhill Prairie *	0.77	0.87	9.6	13	17	31
Marys River *	0.84	0.92	10.4	15	21	36
Oak Creek *	0.82	0.55	6.6	7.5	8	27

Figure 15. Species area curves for a) remnant wetland prairie, n=4 sites b) restored wetland prairie sites, n=4 sites; with means and standard error bars.

a)



b)

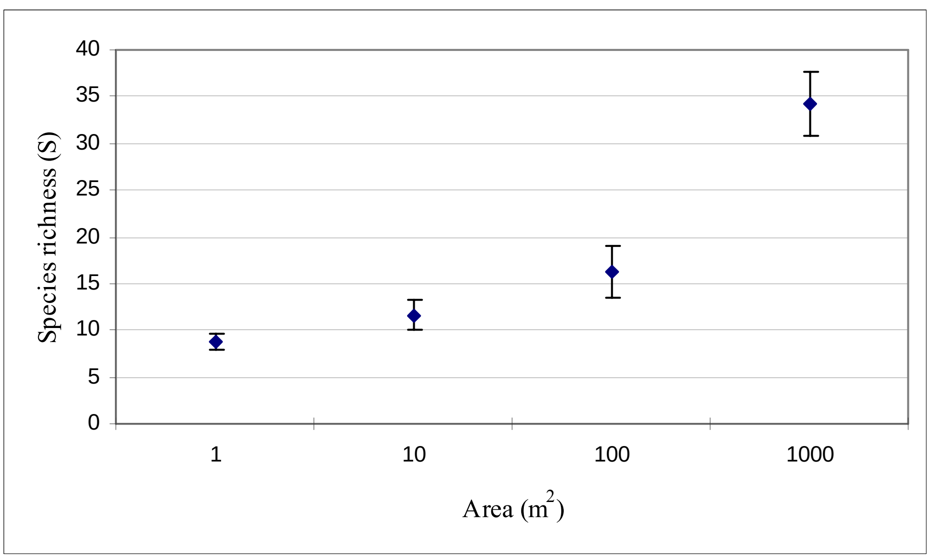


Figure 16. Remnant wetland prairie species area curve.

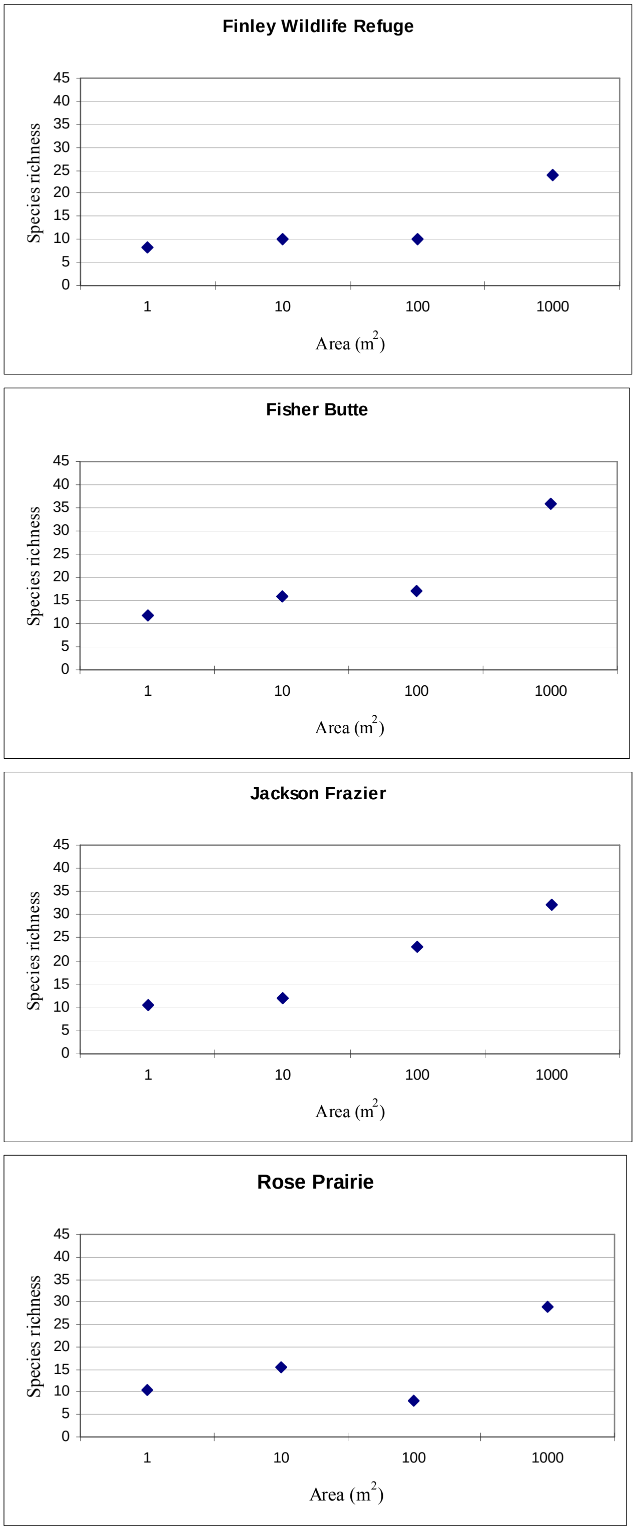
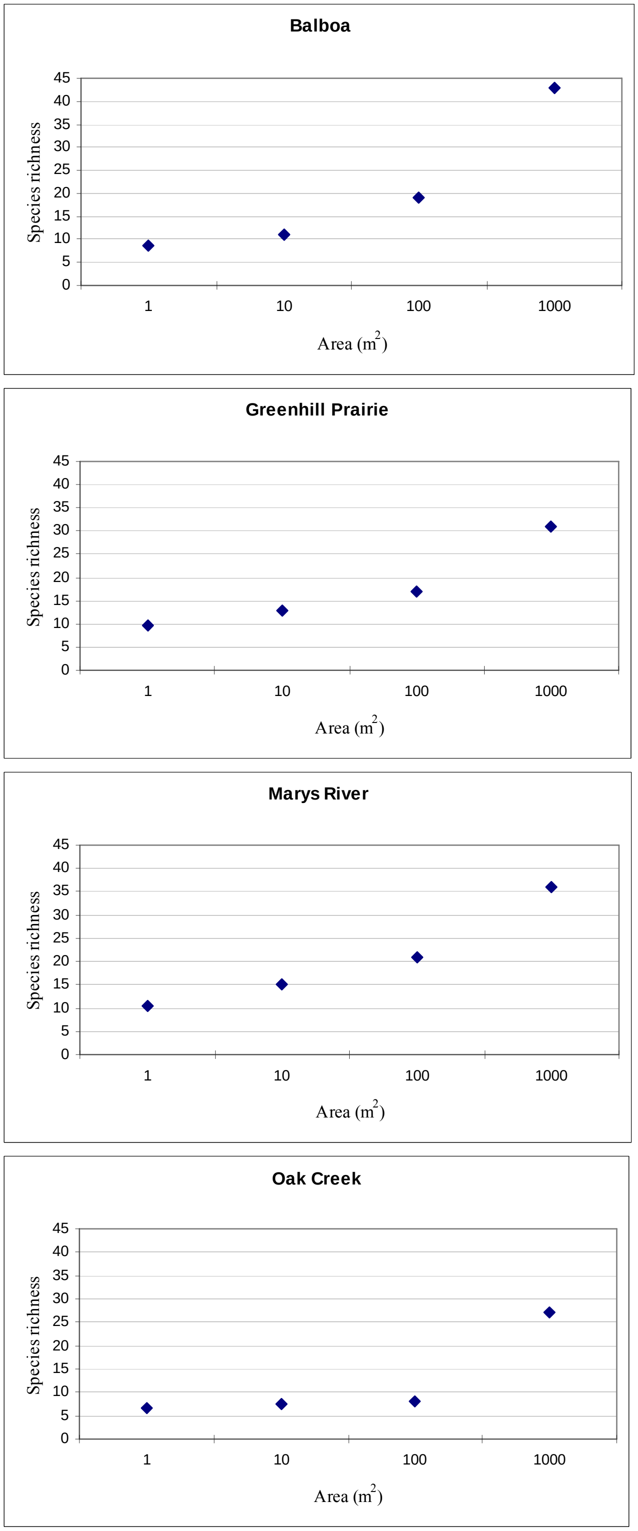


Figure 17. Restored wetland prairie species area curve.



DISCUSSION

Are plant communities less diverse and are exotic species more abundant in restored wetland prairie sites relative to remnant wetland prairie sites?

There were enough similarities between the wetlands in exotic species richness and abundance that there was no statistical difference found between the remnant and restored plots. These findings conflict with other studies of restored wet prairies which have found much higher exotic richness than comparable remnant wet prairies (Galatowitsch and van der Valk, 1996a; Seabloom and van der Valk, 2003b). The results of this study were more similar to research that has found that planted restorations do resemble native prairies after several years (Baer et al., 2004; Kellogg and Bridgham, 2002). In this study, exotic species were generally equal in abundance between restored sites and remnant sites. Overall diversity in terms of native and exotic richness was more complex, and was likely influenced by species area bias from the larger Finley permanent plot in 1997. In 2005 there was no difference in richness between the remnant and restored plots, but the 2005 Finley plot was a size comparable to the other 100 m^2 plots. This result is different from studies in other regions which have found much higher diversity in remnant sites (Martin et al., 2005).

Exotic, perennial graminoids might be expected to be much more abundant in restored wetland prairies, since many of these sites had been farmed for perennial grass seed before restoration. But *Agrostis tenuis*, a species commonly grown for turf seed, was abundant in both remnant and restored plots, especially Finley 1997 (28% cover) and Marys River 2000 (30% cover). *Anthoxanthum odoratum* and to a lesser extent *Holcus lanatus* were also abundant in both remnant and restored sites. This suggests that there was no dispersal limitation for these species, especially since grass seed fields were commonly found next to the wetland prairie sites. Most of the remnant sites had been grazed or hayed, thus grazing animals or tractor tires could have been vectors for introduced seeds. Also, most of the remnant sites had public access, which could also bring in exotic propagules.

Phalaris arundinacea, generally considered a noxious weed, was not common among the sites and was only found in trace amounts in 2000 at Rose Prairie, Greenhill Prairie, and Balboa and in 2005 at Oak Creek. Most of the sites had some obligate wetland species present but do not appear wet enough to provide flooding conditions that enable larger colonies of *P. arundinacea* to establish in the wetland prairies. Introduced annual graminoids were generally not abundant in any of the plots except at Finley, where *Aira caryophyllea* (14% cover in 1997) and *Briza minor* (5% cover in 1997) were abundant. These species were also found in the restoration sites, however.

Exotic perennial forbs were generally not abundant in the plots. The species with the highest abundance were generally found in the remnant sites. *Hypochaeris radicata*, *Hypericum perforatum*, and *Mentha pulegium* were problem species at Rose Prairie, Fisher Butte and Finley. These sites had the most pronounced microtopography and mounds which likely provided a refuge to these species in microsites that fit their hydrologic requirements. In 2005, the Greenhill Prairie 1000 m^2 plot also had high cover of *H. radicata* (25% cover) which was evenly distributed between the microplots. This plot only had a trace of *Hypericum perforatum* and *Mentha pulegium.* There was no pronounced microtopography at Greenhill Prairie so it was not clear if the site was generally a drier habitat for this facultative upland species. Greenhill did have the highest facultative upland species abundance of all the 1000 m^2 plots, possibly due to a slight moisture gradient downhill from west to east. *H. radicata* likely has few dispersal barriers, due to its wind dispersed seed, so it was interesting that it was not found at Finley.

Introduced annual forbs were generally sparse (except at Marys River). These species occurred in all the sites, indicating that they had no dispersal limitation or at least remained in the seedbank a long time. These species usually occurred at low abundance in both remnant and restored sites.

Native species richness was lower in the restoration plots (especially Oak Creek which had low species richness) but this trend was not statistically significant. Native annual forbs were generally not abundant (except at the Marys River site) and were almost non-existent in the plots at Rose Prairie. These results were likely influenced by the mid-summer sampling period which missed ephemeral species. Native perennial forb richness and abundance was higher than annual forb abundance in all the sites. The lowest native forb abundance was in Jackson Frazier, Oak Creek, and the Marys River sites. Higher native forb richness had been expected in the remnant sites because of management for diverse plant species. Jackson Frazier had been mowed but not burned which may have accounted for the lower native forb abundance. Mowing may not be an effective management treatment because it can increase exotic forbs (Clark and Wilson, 2001).

Do restored wetland prairies have a rapid change in plant community composition compared to remnant wetland prairies?

There was surprisingly little change in species composition between groups of sites over the two years. For example, in 2000 *Deschampsia cespitosa* was present in 6 sites with an average cover of 29% while *Agrostis exarata* was present in 5 sites with an average cover of 18%. In 2005, *D. cespitosa* was present in 6 sites with an average cover of 27% while *A. exarata* was present in 4 sites with average cover of 17%. Dominant species remained dominant in most of the sites. At the time of the 2000 survey, these restoration sites had been in the 2^{nd} to 3^{rd} year after restoration and the rapid development of abundant perennial graminoid cover seen here was consistent with successional studies in upland grassland habitats (Camill et al., 2004).

There was no statistical difference in the community composition change over time between remnant and restored sites, but all the sites changed in species abundance. Some species composition change is inevitable, and this study exhibited the complex successional community change which has been found in other grassland systems (Collins, 1990). But the direction of change was remarkably similar between all the sites (Figure 13). This result differs significantly from other studies of ecological succession in restored wetlands that have found no convergence of community composition to remnant sites (Seabloom and van der Valk, 2003b). Species such as *D. cespitosa*, *A. tenuis*, *A. exarata*, and *Juncus tenuis* were consistently found in most of the sites and these species contributed to the similarity in species composition.

The change in native species abundance was variable between the remnant and restored sites, and did not provide a clear indication of dispersal limitations to native species. Native forb change was especially confounded by the increase of *M. glomerata* at the Marys River site.

The Finley permanent plot seemed to have a different directional change from the other sites but this alone did not change the statistical significance results for the group. Overall, there was no significant difference between the remnant and restored plots. The rate of change at the Marys River site was much greater than that of the other sites and reflected a shift to a new, possibly drier community. This shift would need to be investigated to see if the *M. glomerata* was an ecotype adapted to wetter conditions. A description of the 100 m^2 wetland plots follows and known impacts on each wetland site are summarized in Table 10.

Finley Wildlife Refuge remnant site

Pseudo turnover of species may have been a problem in Finley site 1 because there was a completely new dominant species, *Agrostis microphylla*, which had not been found at all in 2000. There was also a trace of this species present in the 2005 plot that overlaid the 1997 permanent plot. This species had not been found in 1997. The Finley site 1 plot may have been disturbed after 2000 by road and viewing platform construction (Beall, personal communication). *A. microphylla* may have been present in very low amounts prior to 2000 and then responded to disturbance. This species is a native annual graminoid often found in thinner rocky soils in

California (Hickman, 1993). *A. microphylla* may have responded to gravelly fill that was still regularly flooded, since it is a facultative wetland species. Future surveys should keep in mind that this species looks very similar to other Agrostis' and may be overlooked.

The permanent plot at Finley was interesting in how much it had changed. The plot had been burned in 2000 and 2002 and showed consistent *Rosa* cover in 1997 and 2005, 39% and 38% respectively. But the graminoid community changed quite a bit. *Deschampsia cespitosa* increased from 12% to 31% cover, while exotic *Agrostis tenuis* was not found in 2005 at all. In 1997 only a trace of *Aira caryophyllea*, an exotic graminoid, had been found but was 14% cover in 2005. Native *A. exarata* cover remained similar at 4% in 1997 and 6% in 2005. Streatfeild had found a negative effect of burning on *D. cespitosa* and an increase in exotics several years after burning (Streatfeild, 1995). With two full growing seasons between the burn in 2002 and this survey in 2005, *Deschampsia* cover may have recovered. Pendergrass found that *D. cespitosa* cover rebounded to preburn levels by the 2nd year after the burn (Pendergrass, 1995). A confounding factor was that the 1997 Finley plot was especially high in diversity compared to all the other plots which may reflect species area bias due to uneven sample size of 25 averaged microplots vs. 7 averaged microplots in 2005. This difference could have effected the assessment of change.

Fisher Butte remnant site

The Fisher Butte community had consistent *D. cespitosa* cover (50% in both years) but the biggest change was the cover of *Mentha pulegium*, an exotic perennial forb. The plot had been burned in 2001 and *M. pulegium* had three growing seasons to rebound. Pendergrass had found that *M. pulegium* increased after fire (Pendergrass, 1995). Generally this community was consistent between both sample years. It was interesting to see *H. lanatus* (FAC) colonizing the *D. cespitosa* (FACW) tussocks in 2005, suggesting that this species was finding a slightly drier microsite.

Jackson Frazier remnant site

The Jackson Frazier plot was wetter than the other sites. Standing water was seen in July here, while all the other plots had dry and cracked soil. At the time of this study, the two foot wide tire track depressions from the previous landowner's tractor were still evident in the wet prairie. These depressions were filled with emergent vegetation. There was a consistent vegetation community between the sampling years, though *Carex* species abundance had declined and *D. cespitosa* cover had increased from 0% to 5% between 2000 and 2005. Between January and June of 2000 there had been 61 cm of rain vs. 42 cm of rain in 2005 (Oregon Climate Service, 2005). This may have contributed to a community with fewer facultative wetland and obligate species in 2005.

Rose Prairie remnant site

The Rose Prairie plot had experienced an increase in the native shrub *Vaccinium caespitosum* from 10% to 30%, and a decrease in exotic graminoid *Panicum occidentalis* from 40% to 7%. This area had not been burned since 1998. Pendergrass had found an increase in the frequency of *P. occidentalis* both after burning and in non-burned control plots (Pendergrass, 1995) The high cover found in 2000 was consistent with the burn. But the decrease in *P. occidentalis* was interesting and could suggest competitive exclusion from *V. caespitosum*.

Greenhill Prairie restoration site

At the Greenhill Prairie plot, *D. cespitosa* (FACW) increased from 25% to 65% between 2000 and 2005 while *Anthoxanthum odoratum* (FACU) decreased from 30% cover to 0%. This site had been tilled to remove *M. pulegium* and the lack of this species was evident in 2005. Native forb cover decreased slightly from 16% to 10%, possibly the result of the high *D. cespitosa* cover. Facultative wetland species cover had increased from 37% to 67%, primarily due to increasing *D. cespitosa*.

Marys River Natural Area restoration site

In 2005, *D. cespitosa* was more abundant on the southern portion of the wetland prairie than the northern half. There was a consistent pattern of dead *D. cespitosa* clumps through the northern portion of the site, indicating that initially the plantings had been growing, but were now dead. This was consistent with the change in percent cover found in the plot. In 2000, *D. cespitosa* (FACW) covered 50% of the plot while in 2005 there were only dead clumps. *Madia glomerata* (FACU), a native forb, had not been found in 2000 but now covered 50% of the plot. *Anthemis cotula* (FACU), an exotic forb, was 1% of the plot cover in 2000 but in 2005 covered 30% of the plot. The change in community composition was reflected in a shift from facultative wetland species to facultative upland species. Based on the 50/20 dominant wetland species delineation rule, this plot would not meet wetland criteria in 2005. It would be interesting to assess the hydrology of the site to determine if the drainage ditch was moving water from the site too quickly and allowing it to dry out. *D. cespitosa* was seen in the lower elevation areas in the southern and eastern portion of the wetland where water would stand into the growing season and *P. arundinacea* was seen along the drainage ditch. The plant community at this site least resembled the remnant wetland prairies even in the wettest portions.

Oak Creek Mitigation Bank restoration site

This site had a significant increase in cover of the native graminoid *Agrostis exarata* (55% in 2000 to 80% in 2005) but also an increase in the cover of the exotic graminoid *Holcus lanatus* (0% in 2000 to 20% in 2005). The abundance of *H. lanatus* was consistent with an unpublished survey at the site in 1999 that found 6-25% cover. This suggests that *H. lanatus* was spreading through the wetland between 2000 and 2005. *Alopecurus geniculatus*, an exotic graminoid, remained consistent between 2000 and 2005 (40% and 30% cover, respectively). This site had not been actively managed between 2000 and 2005. Burning would likely not have decreased *H. lanatus*, since other studies have found no response by this species to burning (Streatfeild, 1995; Taylor, 1999). This site had the least active management but still had an increase in native grasses.

Table 10. Summary of known impacts on-site and adjacent to the wetland prairie sites both prior to this study and up to the summer of 2005.

* = Restoration

Impacts	Finley		Fisher Butte		Jackson Frazier		Rose Prairie		Balboa*		Greenhill Prairie*		Marys River*		Oak Creek*	
On-site	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005
Burning	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓	
Grass seed farming											✓		✓		✓	
Grazing	✓				✓		✓									
Site compaction									✓							
Off-site	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005	<2000	2000-2005
Development					✓	✓			✓	✓			✓	✓	✓	✓
Roads/ hydrology	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grass seed farming	✓	✓					✓	✓					✓	✓	✓	✓

Does the heterogeneity of the plant community indicate a range of microsites available for a diverse plant community?

Spatial heterogeneity at the wetland level was not adequately sampled through this study design but there was an indication of the heterogeneity at the plot level in the 1000 m^2 plots. Plant species composition was heterogeneous through the plots, and there was no difference in plant community heterogeneity between the remnant and restored wetland prairies. This indicated that compositional change across the 1000 m^2 plot was similar between the two groups. This result was interesting, because some planted restorations can have very high cover of a single species such as *D. cespitosa*, and the results here indicate that there was no monoculture formed by seeding and planting native species. These results were similar to experimental plots in upland prairie that exhibited similar structural composition to remnant prairies, though that study found strong differential response to resource availability which was not quantified in this study (Baer et al., 2004).

Fisher Butte had the lowest compositional change across the plot but had high richness and abundance. There was a consistent diversity of species across the plot. In contrast, Balboa had the highest dissimilarity measure across the microplots, but also high diversity. There was high diversity in areas of the plot with D. cespitosa but several patches of bare ground without *D. cespitosa.* These patches were generally very wet (based on obligate wetland species cover) but had low diversity. This trend was consistent in the other restored sites. There were bare wet patches with low diversity and drier patches with higher diversity. Some of this may have been due to restoration practices, where some areas were excavated to create diverse habitat. These excavated low patches were mainly colonized by exotic *Mentha pulegium*.

None of the restorations had visible vertical microtopography so any change in hydrology would likely affect all species in the plot. This appears to be what happened at the Marys River site. The hydrology was not able to support hydrophytic vegetation and a facultative upland species was able to dominate the community, leading to turnover in the dominant species.

Species area curves graphed for each site indicated that species were distributed in random unequal patches. The gradual slope of the curves between 1 m^2 and 10 m^2 suggested that groups of common species were distributed evenly across the landscape. The increase in richness at the 1000 m^2 scale indicated that rare species were more likely to be encountered at this scale due to random distribution across the plot.

Rose Prairie was an outlier in the remnant prairie group due to very low richness in the 100 m^2 plot. Species abundance was not collected at this scale so there is no information on likely topographic patterns that could explain the few species. It is likely that there was a drier area towards the middle of the plot since there was *Rosa nutkana*, *Anthoxanthum odoratum*, and *Hypericum perforatum*. Oak Creek also had a jump in species at 1000 m^2 again suggesting that species were not distributed evenly across the plot. Species area curves did not show significant differences between remnant and restored plots but individual plots did show homogeneous community characteristics at smaller spatial scales.

Study evaluation

There were several reasons why this study may have failed to detect significant differences between the remnant and restored plots. The plot placement in 2000 was constrained by the very long transects required for mammal trapping and therefore could not be randomly placed within the wetlands. The 2000 study was designed to give a general indication of the plant community vegetation and physiognomy, and therefore was not a comprehensive look at floristic diversity in each wetland (Slane, 2001). A single plot in each community likely did not capture the diversity of species across moisture gradients. The statistical results may have been biased due to an uneven and small sample and non-parametric statistical methods, which reduced the power in detecting differences between communities.

Smaller samples need a large effect for statistical significance (McCune and Grace, 2002). Small sample size may have led to a type II error of rejecting a valid hypothesis. The additional 1000 m^2 plots provided an indication of heterogeneity between the wetland sites but were not able to provide a picture of the community change along microtopographic elevation gradients. But I felt that the 1000 m^2 plots did capture a representative sample of each wetland site. There was also uncertainty in the GPS plot placement which could have contributed to differences in the community between years. Finally, there are less than 1% of historic wetland prairies remaining in the Willamette Valley and these may not be a representative sample of historic plant communities. Local conditions such as soil and moisture may have produced unique plant communities at different sites in the Willamette Valley and these differences could be expressed in the plant communities at restored sites. There may not be an idealized wetland prairie to compare restorations against.

Overall, the wetland prairie sites compared for this project had a higher native component than expected and the restored sites as a whole were developing native plant communities. The restored sites that were actively managed and part of historic wetland complexes were in much better shape than the isolated wetland prairies. Future sites with the highest potential for restoration will likely be those with the least hydrologic impacts.

CONCLUSION

Restoration and mitigation of human-impacted landscapes is clearly important for increasing native plant diversity in the Willamette Valley of Oregon. Wetland loss is so extreme that any restoration project has the potential to increase habitat for wetland prairie species. Since much of the Willamette Valley has not been converted from farmland to industrial or urban use, there are many opportunities to restore areas that were historically wetland prairie. In 2005, the combined grass seeds fields in Benton, Lane and Linn counties covered an estimated 105,000 hectares (Oregon Seed Extension Program, 2005). Incentive programs could provide many opportunities for interested owners to enroll in state and federal restoration programs in the southern Willamette Valley. With eight mitigation banks in the Willamette Valley and several more pending approvals, it is important to understand how plant communities may change over time, and if exotic plant species impact the native plant community.

This research did not show group differences in diversity and exotic species change between remnant and restored wetland prairies in the Willamette Valley. Exotic species increases did not necessarily decrease native species richness. The wetland prairies included in this study shared both native and exotic species, but were also dissimilar enough to make comparisons difficult. Exotic species abundance was likely confounded by extrinsic factors for which this study was unable to take into account. It is likely that different disturbance regimes, hydrology, soil and initial site conditions were interacting with the plant communities in complex ways. Management was also a major factor in the plant communities but it was difficult to analyze the species response to the different treatments. These results suggest that differences between restored and remnant wetland prairie sites were not generalizable at the landscape scale and were more dependent on site specific management and local barriers to colonization.

Restoring hydrology and planting native species at the onset of restoration are the most important components of mitigation besides consistent monitoring. The restoration sites included in this study showed native species abundance that was comparable to remnant wetland prairies. These sites also did not show higher exotic species abundance than remnant wetland prairies. Restoration sites had all developed graminoid cover at the time of the initial study in 2000, which was within two to three years after restoration was initiated. All sites were equally likely to contain exotic species. Exotic species common across all sites included *Centaurium umbellatum*, *Holcus lanatus*, and *Hypericum perforatum*. Native species common across sites included *Deschampsia cespitosa*, *Danthonia californica* and *Juncus tenuis*. Consistent occurrence of exotic species across all wetland prairie groups reflects the overall difficulty of managing these complex wetland ecosystems.

Comparing this study to studies of restored and remnant sites in different ecosystems is difficult because wetland prairies in Oregon do not have a broad range of moisture gradients like Mid-West U.S. prairie potholes and are not directly comparable to upland grassland ecosystems. Additional research is needed to confirm that restored Willamette Valley wetland prairies are developing stable native plant communities. It is likely that five years is not long enough to determine whether plant communities in restorations share similar successional trajectories to remnant sites, especially when some species have dispersal limitations. But the results from this study indicate that while these restored Willamette Valley wetland prairies do not necessarily contain rare species, they do share the most common wetland prairie species with the few remaining remnant sites and had increased species diversity and habitat.

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APPENDIX

Appendix 1. Plant species occurring in all plots by year.

Annual (a), Biennial (b), Perennial (p), N=Native, I=Introduced.
Wetland status is the probability of plant occurring in a wetland - OBL: >99%; FACW: 67-99%; FAC: 34-66%; FACU: 1-33% UPL: <1%
NI: Insufficient information; NA: No agreement
x = Present only in 2005 modified-Whittaker plot

Scientific name	Common name	Origin	Wet status	Balboa		Finley			Fisher		Greenhill		Jackson		Marys		Oak		Rose	
				00	05	97	00	05	00	05	00	05	00	05	00	05	00	05	00	05
Trees																				
Fraxinus latifolia	Oregon ash	N	FACW						✓	✓										
Shrubs																				
Amelanchier alnifolia	Western serviceberry	N	FACU																	✓
Crataegus sp.	Hawthorn							x						x		x				✓
Rosa eglanteria	Sweetbriar rose	I	FACW				✓		✓											
Rosa nutkana	Nootka rose	N	FAC					✓	✓	✓				x					✓	✓
Rosa pisocarpa	Clustered rose	N	FAC										✓	x					✓	
Rosa sp.	Rose					✓		✓		x				✓						
Rubus discolor	Himalayan blackberry	I	FACU	✓								✓				✓			✓	✓
Rubus laciniatus	Cutleaf blackberry	I	FACU																✓	
Rubus ursinus	Pacific blackberry	N	FACU							✓		x						x		✓
Spiraea douglasii	Rose spiraea	N	FACW				✓	✓	✓	✓								x		
Symphoricarpos albus	Common snowberry	N	FACU					x												
Vaccinium caespitosum	Dwarf huckleberry	N	FAC																✓	✓

Scientific name	Common name	Origin	Wet status	Balboa		Finley			Fisher		Greenhill		Jackson		Marys		Oak		Rose	
				00	05	97	00	05	00	05	00	05	00	05	00	05	00	05	00	05
Graminoids																				
Agrostis alba var. stolonifera (p)	Creeping bentgrass	I	FAC				✓													
Agrostis exarata (p)	Spike bentgrass	N	FACW	✓	x	✓		✓		✓	✓	✓	✓	✓	✓		✓	✓		
Agrostis microphylla (a)	Small-leaf bentgrass	N	FACW				✓	✓												
Agrostis tenuis (p)	Colonial bentgrass	I	FAC			✓	✓		✓	✓					✓	✓		x	✓	✓
Aira caryophyllea (a)	Silver hairgrass	I	NI		x	✓	✓	✓				x						✓		
Alopecurus geniculatus (p)	Water foxtail	I	OBL			✓											✓	✓		
Anthoxanthum odoratum (p)	Sweet vernalgrass	I	FACU	✓						x	✓	x					✓	x	✓	✓
Beckmannia syzigachne (a)	American sloughgrass	N	OBL	✓	x	✓	✓	✓					✓	✓						
Briza minor (a)	Little quaking-grass	I	FAC		x	✓	✓	✓		x	✓	✓				✓			✓	✓
Bromus mollis (a)	Soft brome	I	UPL				✓	✓		x										
Carex aurea (p)	Golden sedge	N	FACW																✓	
Carex densa (p)	Dense sedge	N	OBL	✓									✓	✓						
Carex feta (p)	Greensheathed sedge	N	FACW				✓											✓		
Carex lanuginosa (p)	Wooly sedge	N	OBL			✓								✓						
Carex leporina (p)	Hare sedge	N	FACW	✓					✓				✓	✓			✓	x		
Carex pachystachya (p)	Thick-headed sedge	N	FAC					✓												
Carex stipata (p)	Sawbeak sedge	N	OBL														✓			
Carex unilateralis (p)	One-sided sedge	N	FACW	✓	x		✓					✓	✓	✓		✓	✓	✓		
Carex sp.	Carex			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Danthonia californica (p)	California oatgrass	N	FACU	✓					✓	✓	✓	✓							✓	✓
Deschampsia cespitosa (p)	Tufted hairgrass	N	FACW	✓	x	✓	✓	✓	✓	✓	✓	✓		✓	✓	x		x	✓	✓
Eleocharis acicularis (p)	Needle spikerush	N	OBL			✓							✓							
Eleocharis ovata (a)	Ovate spikerush	N	OBL		x															

Scientific name	Common name	Origin	Wet status	Balboa		Finley			Fisher		Greenhill		Jackson		Marys		Oak		Rose	
				00	05	97	00	05	00	05	00	05	00	05	00	05	00	05	00	05
Eleocharis palustris (p)	Creeping spikerush	N	OBL	✓	x									✓				✓		
Festuca arundinacea (p)	Tall fescue	I	FAC	✓																
Festuca microstachys (a)	small fescue	N	NI													x				
Festuca myuros (a)	Rat-tail fescue	I	FAC												✓					
Glyceria occidentalis (p)	Western mannagrass	N	OBL		x															
Holcus lanatus (p)	Common velvetgrass	I	FAC	✓	x	✓	✓	✓	✓	x	✓	✓		x	✓	✓	✓	✓		
Hordeum brachyantherum (p)	Meadow barley	N	FACW			✓	✓						✓	✓						
Juncus acuminatus (p)	Tapered rush	N	OBL		x														✓	
Juncus bufonius (a)	Toad rush	N	FACW			✓	✓	✓	✓		✓			x		✓	✓		✓	
Juncus effusus (p)	Common rush	N	FACW	✓										x						
Juncus ensifolius (p)	Swordleaf rush	N	FACW	✓																
Juncus marginatus (p)	Grassleaf rush	N	NA						✓										✓	✓
Juncus nevadensis (p)	Sierra rush	N	FACW						✓					✓					✓	
Juncus oxymeris (p)	Pointed rush	N	FACW				✓	x												
Juncus patens (p)	Spreading rush	N	FACW	✓	x															
Juncus tenuis (p)	Slender rush	N	FACW	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	x	✓		✓	x	✓	✓
Lolium multiflorum (b)	Italian ryegrass	I	FACU													✓	✓			
Panicum occidentale (p)	Western panicgrass	N	FAC							✓							✓		✓	✓
Phalaris aquatica (p)	Harding grass	I	FACW		x															
Phalaris arundinacea (p)	Reed canarygrass	I	FACW	✓		✓					✓							x	✓	
Poa trivialis (p)	Rough bluegrass	I	FACW										✓		✓	✓				
Forbs																				
Alisma plantago-aquatica (p)	American waterplantain	N	OBL		x								✓							
Anagallis arvensis (a/b)	Scarlet pimpernel	I	FAC													✓				

Scientific name	Common name	Origin	Wet status	Balboa		Finley			Fisher		Greenhill		Jackson		Marys		Oak		Rose	
				00	05	97	00	05	00	05	00	05	00	05	00	05	00	05	00	05
Anthemis cotula (a)	Mayweed chamomile	I	FACU												✓	✓				
Aster chilensis ssp. *hallii* (p)	Hall's aster	N	FAC						✓			x							✓	
Aster curtus (p)	White-top aster	N	NI																✓	✓
Bidens frondosa (a)	Leafy beggar-ticks	N	FACW															x		
Boisduvalia densiflora (a)	Dense spike-primrose	N	FACW			✓					✓			x						
Boisduvalia stricta (a)	Brook willow-herb	N	FACW								✓									
Brodiaea congesta (p)	Northern saitas	N	NI																	x
Brodiaea coronaria (p)	Harvest brodiaea	N	NI						✓	✓										✓
Brodiaea elegans ssp. elegans (p)	Elegant brodiaea	N	FACU				✓		✓										✓	
Brodiaea hyacinthina (p)	Hyacinth brodiaea	N	FACU			✓		✓				x								✓
Camassia leichtlinii (p)	Large camas	N	FACW			✓														
Camassia quamash (p)	Common camas	N	FACW			✓			✓											✓
Centaurium muhlenbergii (a/b)	Muhlenberg's centaury	N	FACW					✓											✓	✓
Centaurium umbellatum (a/b)	European centaury	I	FAC	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓				✓
Cerastium viscosum (a)	Sticky chickweed	I	UPL			✓						✓				✓				
Chrysanthemum leucanthemum (p)	Oxeye daisy	I	NI		x											x		x		
Cirsium arvense (p)	Canada thistle	I	FACU		x	✓		✓				✓				✓				
Cirsium vulgare (b)	Bull thistle	I	FACU									✓								
Convolvulus arvensis (p)	Field bindweed	I	NI		x															
Crepis capillaris (a/b)	Smooth hawksbeard	I	FACU									✓				✓			✓	✓
Crepis nicaeensis (a)	French hawksbeard	I	NI							x										
Daucus carota (p)	Wild carrot	I	NI												✓	✓				
Dianthus armeria (a/b)	Deptford pink	I	NI		x															
Dipsacus sylvestris (b)	Teasel	I	NI	✓												✓				

Scientific name	Common name	Origin	Wet status	Balboa 00	Balboa 05	Finley 97	Finley 00	Finley 05	Fisher 00	Fisher 05	Greenhill 00	Greenhill 05	Jackson 00	Jackson 05	Marys 00	Marys 05	Oak 00	Oak 05	Rose 00	Rose 05
Downingia elegans (a)	Common downingia	N	OBL		x					✓		✓				✓				
Epilobium glandulosum (p)	Fringe willowherb	N	FACW			✓														
Epilobium paniculatum (a)	Tall annual willow-herb	N	UPL	✓				✓				✓		x		✓				
Epilobium watsonii (p)	Watson's willow-herb	N	FACW			✓	✓	✓	✓	x	✓			✓		✓		✓		
Erigeron decumbens v. *decumbens* (p)	Willamette Valley daisy	N	NI																	✓
Eriophyllum lanatum (p)	Wooly sunflower	N	NI		x				✓	✓	✓	✓							✓	✓
Eryngium petiolatum (p)	Coyote-thistle	N	OBL	✓	x	✓	✓			✓						✓				x
Fragaria virginiana (p)	Broad-petal strawberry	N	FACU																	✓
Galium parisiense (a)	Wall bedstraw	I	UPL			✓				x						✓				
Galium trifidum (p)	Small bedstraw	N	FACW	✓	x		✓	✓				✓	✓	✓		x		✓		x
Geranium carolinianum (a)	Carolina geranium	I	NI	✓																
Geranium oreganum (p)	Western geranium	N	NI					✓												
Gnaphalium palustre (a)	Lowland cudweed	N	FAC			✓	✓	✓		x							✓		✓	
Gnaphalium purpureum (a/b)	Purple cudweed	N	NI																	x
Grindelia integrifolia (p)	Willamette Valley gumweed	N	FACW	✓	x			✓	✓	✓	✓	✓								✓
Horkelia congesta (p)	Shaggy horkelia	N	NI																✓	
Hypericum perforatum (p)	Common St. Johnswort	I	NI	✓	x	✓	✓	✓		✓	✓	✓		x		✓		x	✓	✓
Hypochaeris radicata (p)	Hairy cats-ear	I	FACU		x							x				✓		✓		✓
Kickxia elatine (a)	Cancerwort	I	UPL												✓	✓				
Lactuca serriola (a/b)	Prickly lettuce	I	FACU															✓		
Lomatium bradshawii (p)	Bradshaw's lomatium	N	FACW																✓	
Lomatium sp. (p)	Lomatium	N								✓		x								✓
Lotus formosissimus (p)	Seaside lotus	N	FACW		x															✓
Lotus pinnatus (p)	Meadow birdsfoot-trefoil	N	FACW																✓	

Scientific name	Common name	Origin	Wet status	Balboa 00	Balboa 05	Finley 97	Finley 00	Finley 05	Fisher 00	Fisher 05	Greenhill 00	Greenhill 05	Jackson 00	Jackson 05	Marys 00	Marys 05	Oak 00	Oak 05	Rose 00	Rose 05
Lotus purshiana (a)	Spanish clover	N	NI	✓		✓	✓	✓							✓	✓				
Lythrum hyssopifolia (a/b)	Hyssop loosestrife	I	OBL														✓			
Lythrum portula (a)	Spatulaleaf loosestrife	I	NI		x											✓				
Madia glomerata (a)	Mountain tarweed	N	FACU	✓				✓		x		✓		x		✓				
Madia gracilis (a)	Slender tarweed	N	NI								✓									
Madia sativa (a)	Coast tarweed	N	NI			✓					✓					✓				
Mentha pulegium (p)	Pennyroyal	I	OBL	✓	x				✓	✓		✓	✓	x				x		
Menyanthes trifoliata (p)	Buckbean	N	OBL											✓						
Microseris laciniata (p)	Cutleaf microseris	N	NI						✓	x		✓								x
Microsteris gracilis (a)	Slender phlox	N	FACU			✓	✓													
Mimulus guttatus (p)	Yellow monkeyflower	N	OBL			✓	✓	✓												
Mimulus tricolor (a)	Tricolored mimulus	N	OBL													✓				
Montia linearis (a)	Narrowleaved montia	N	NI			✓														
Myosotis discolor (a)	Yellow & blue forget-me-not	I	FACW					✓	✓	x				✓		✓				
Myosotis laxa (a/b)	Small flowered forget-me-not	N	OBL		x															x
Navarretia intertexta (a)	Needleleaf navarretia	N	FACW		x				✓	✓				✓		✓				
Oenanthe sarmentosa (p)	Pacific water-parsley	N	OBL				✓						✓	✓				✓		
Orthocarpus bracteosus (a)	Rosy owl-clover	N	NI		x							✓								
Orthocarpus hispidus (a)	Hairy owl-clover	N	FACU							✓						✓				
Parentucellia viscosa (a)	Yellow parentucellia	I	FAC		x	✓	✓	✓		x	✓	✓		✓		✓		✓		
Perideridia gairdneri (p)	Yampah	N	FAC			x														
Plagiobothrys figuratus (a)	Fragrant popcornflower	N	FACW		x	✓	✓	✓		x		✓		x		✓	✓	x		
Plantago lanceolata (p)	English plantain	I	FAC																	✓
Polygonum punctatum (p)	Dotted smartweed	I	OBL													✓				

Scientific name	Common name	Origin	Wet status	Balboa		Finley			Fisher		Greenhill		Jackson		Marys		Oak		Rose	
				00	05	97	00	05	00	05	00	05	00	05	00	05	00	05	00	05
Potentilla gracilis (p)	Slender cinquefoil	N	FAC		x			✓	✓		✓	✓								
Prunella vulgaris (p)	Selfheal	N	FACU		x				✓	✓	✓	✓				x				✓
Ranunculus occidentalis (p)	Western buttercup	N	FAC			✓	✓			x										
Rorippa curvisiliqua (a/b)	Western yellowcress	N	OBL								✓				✓	✓	✓	✓		
Rumex acetosella (p)	Sheep sorrel	I	FACU									✓	✓							
Rumex conglomeratus (p)	Clustered dock	I	FACW											✓		✓	✓	✓		
Rumex crispus (p)	Curly dock	I	FAC				✓	✓						x	✓	✓				
Rumex salicifolius (p)	Willow dock	N	FACW												✓	x				
Saxifraga oregana (p)	Oregon saxifrage	N	FACW					✓												
Senecio jacobaea (p)	Tansy ragwort	I	FACU									✓				x				✓
Sidalcea virgata (p)	rose checker-mallow	N	NI									x								
Sisyrinchium angustifolium (p)	Blue-eyed grass	N	FACW							✓		✓								
Sisyrinchium sp. (p)		N								x									✓	✓
Sonchus asper (a)	Prickly sow-thistle	I	FAC	✓										x		✓				
Trifolium dubium (a)	Suckling clover	I	UPL			✓														
Typha latifolia (p)	Common cattail	N	OBL										✓	x						
Veronica peregrina (a)	Purslane speedwell	N	OBL			✓										✓				
Veronica scutellata (p)	Skullcap speedwell	N	OBL						✓				✓	✓				x		
Vicia tetrasperma (a)	Slender vetch	I	NI		x	✓		✓								✓				
Viola adunca (p)	Hook violet	N	FAC																	✓