Oregon's Wetland Monitoring and Assessment Program: A Pilot Study

Compiled by Kyle Abraham
Oregon Watershed Enhancement Board
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Executive Summary

Since 1997, the Oregon Watershed Enhancement Board has provided nearly $10 million to wetland restoration projects throughout Oregon. The Oregon Department of State Lands (DSL) regulates the mitigation and enhancement of wetlands throughout the state by a permitting process. Currently, however, there is no comprehensive program for monitoring and assessing the condition and function of restored, enhanced or mitigated wetlands in Oregon.

In 2007, the Environmental Protection Agency (EPA) Region 10 Wetland Program Development Grant provided needed funding and resources to develop and refine wetland monitoring and assessment tools to improve the level of understanding of condition and function of Willamette Valley wetlands. A grant was awarded to OWEB by EPA with a direct link to EPA Strategic Plan Objective 4.3 to "restore and protect ecosystems" and works toward achieving the sub-objective 4.3.1 "by 2011, working with partners, achieve a net increase in wetland acres with additional focus on assessment of wetland condition".

The goals of the program are to:

- Increase wetland acreage and gains in wetland function and/or condition due to improved pre-implementation evaluation of proposed wetland restoration and mitigation sites.
- Increase the effectiveness of wetland restoration projects using enhancement for mitigation by applying new understanding of past project performance during the development of future projects
- Increase use and standardization of biological monitoring tools to assess function and/or condition of wetlands.
- Provide data and information about wetland mitigation and restoration sites in a more widely accessible format and make improvements to accuracy and completeness of such data.

The program developed and refined tools that can increase the ability to report on wetland restoration and mitigation outcomes through the use of three tiers of evaluation and assessment:

- Tier I: Landscape profiling
- Tier II: Oregon Rapid Wetland Assessment Protocol (ORWAP)
- Tier III: Detailed effectiveness monitoring

In addition, the program developed and tested preliminary metrics for a macroinvertebrate bio-assessment tool.

Preliminary results from the invertebrate based bio-assessment show that in 2009 and 2010 invertebrate communities displayed a high level of variability. So much variability was found that rendering a robust, complete Index of Biological Integrity was not feasible. Additional data collection, over a longer time period may be necessary to reduce the variability and provide more certainty for this tool. Data analysis of the wetland invertebrate sampling revealed two different suites of attributes that are significantly different at *most-impaired* versus *least-impaired* sites in natural riverine and natural flats wetlands. In addition, the bio-assessment tool does correlate with the Oregon Rapid Wetland Assessment Protocol for estimating levels of wetland disturbance.

Results from the Oregon Rapid Wetland Assessment Protocol (ORWAP), a level II assessment, suggest that most of the *enhanced* wetlands in this study are wetter than *reference* wetlands and have

higher ORWAP scores indicating more water storage potential than *reference* wetlands. In addition, *restored* wetlands demonstrated a higher percentage of non-native species compared to *reference* wetlands.

Detailed effectiveness monitoring, a level III assessment, provides additional insight into wetland function and condition and specifically the similarity between restored and mitigated wetlands compared to natural or reference wetlands. Relatively few statistically significant differences were found between *enhanced* and *restored* sites. *Enhanced* wetlands did tend to have more surface water, a higher proportion of the sampling area with significant cover of invasive plant species, more soil organic matter, and less soil phosphorus compared to *restored* sites.

Results of a limited landscape profiling exercise focused sampling efforts around riverine and flats type wetlands. Results from this effort may help to establish a probabilistic sample of wetland type in future monitoring efforts. The results will also assist with prioritization of future restoration and mitigation actions.

These findings help demonstrate the need for providing more specific information regarding proposed wetland restoration and mitigation actions. From this effort, it was found that detailed information on pre-existing wetland conditions was lacking in some cases or not easily identified. Additional requirements from grantees/permittees, such as implementing some of the tools developed from this pilot study, may allow for a more complete perspective of current wetland condition and help to define what may be realistically expected for certain wetland types while preserving function and condition. Implementation of these, or similar, tools would allow OWEB to incorporate this information into our grant program to provide additional certainty that baseline conditions are adequately understood and results from monitoring efforts will continue to provide valid, reliable information. Implementation and further use of these tools including the improvements to the mapping and database information systems will allow for the continued tracking of wetland acreage gain and loss including the tracking of wetland condition and function over time. The results from this project shed light on the current state of wetlands as a result of restoration and mitigation practices and helped to identify what areas can be improved to increase the effectiveness of such actions. Current results from this study will be disseminated in different forums and delivered to groups including watershed councils, state and federal agencies, tribes, and professional groups. Other action items included in this project were to improve and increase the capability to report on the effectiveness of past wetland mitigation and enhancement actions, including mapping and database improvements. It is anticipated that this effort will make these data accessible to the public through the use of Oregon Wetland Explorer in the near future, thus providing a more widely accessible venue both for reporting of information and also the prioritization of restoration and mitigation opportunities.

These monitoring and assessment tools are intended for inclusion in an effort recently initiated by DSL to begin a Coordinated Wetland Program Plan for Oregon. The product will be a strategic plan developed in coordination with other agencies, tribes and resource practitioners that will function as a roadmap for mutual wetland protection goals and measuring progress in achieving those goals.

Introduction

Over the past century wetlands have been drained, filled and otherwise impacted to the point that it is a priority to conserve remaining wetlands and restore the condition of existing wetlands. Most of the wetlands in Oregon have seen at least some level of anthropogenic disturbance and the condition of these wetlands likely is impaired.

These compromised conditions may have multiple, unintended impacts because many fish, wildlife and plant species are dependent on wetlands for various parts of their life-cycle. Properly functioning wetlands are crucial to the survival of such species. In addition, properly functioning wetlands provide many key ecological functions, including but not limited to stormwater retention, nutrient capture, sediment deposition, and providing habitat for a diversity of species. These wetland functions result in ecosystem services such as improved water quality, reduced flooding duration and extent, recreational benefits and scenic beauty. Recently, Oregon has begun exploring how to provide ecosystem credits for restoring these services, with the intent of protecting and providing these services for the larger public good while rewarding landowners who practice ecologically beneficial stewardship. It is important to develop a clearer understanding of the current status and condition of wetlands in order to advance the state of knowledge of for protection, restoration, and mitigation of wetland resources.

The state of Oregon has a "no-net loss" of wetlands policy. The policy is meant to describe wetland protection and maintenance requirements from both an acreage calculation perspective and from the maintenance of wetland function and/or condition at present. Since 1997, with the intent of helping achieve this policy, the Oregon Watershed Enhancement Board (OWEB) has provided nearly $10 million to wetland restoration projects throughout Oregon. Wetland restoration represents the sixth largest investment provided by the agency under the Oregon Plan for Salmon and Watersheds. In addition, the Department of State Lands (DSL) is charged with ensuring that wetlands across Oregon which may be impacted by permitted activities are successfully replaced by required wetland mitigation actions and that applicants adhere to the condition stated in the permit. There are other state agencies (e.g., the Oregon Department of Environmental Quality) that regulate water quality in and near wetlands as required under the Clean Water Act.

Currently, however, there is no comprehensive program for monitoring and assessing the condition and function of restored, enhanced or mitigated wetlands in Oregon. As such, there is no definitive method of evaluating if restoration efforts that are occurring across the state, in concert with effects of wetland mitigation actions are maintaining or increasing wetland acreage, condition, and function.

In 2007, the Environmental Protection Agency (EPA) Region 10 Wetland Program Development Grant offering presented an opportunity to develop and refine wetland monitoring and assessment tools that would help improve the level of understanding about the condition and function of select wetlands in the Willamette Valley. A grant was awarded to OWEB by EPA with a direct link to EPA Strategic Plan Objective 4.3 to "restore and protect ecosystems" and works toward achieving the sub-objective 4.3.1 "by 2011, working with partners, achieve a net increase in wetland acres with additional focus on assessment of wetland condition". Through this project, work towards developing and refining monitoring tools such as a preliminary invertebrate index of biological integrity (I-IBI), rapid monitoring techniques, and detailed effectiveness monitoring was developed by project partners including the

Xerces Society for Invertebrate Conservation (Xerces), Adamus Resource Assessment, Inc. (ARA), DSL and OWEB.

The objectives of the Oregon Wetland Monitoring and Assessment Program are to:

- Increase wetland acreage and gains in wetland function and/or condition due to improved pre-implementation evaluation of proposed wetland restoration and mitigation sites.
- Increase the effectiveness of wetland restoration projects using enhancement for mitigation by applying new understanding of past project performance during the development of future projects
- Increase use and standardization of biological monitoring tools to assess function and/or condition of wetlands.
- Provide data and information about wetland mitigation and restoration sites in a more widely accessible format and make improvements to accuracy and completeness of such data.

Monitoring Program Strategy

Over the past few years, strategic investments in improving information regarding wetland locations in relation to broad contexts such as land use, location in the watershed, and wetland type have been implemented. In 2011, OWEB in partnership with others, will have completed an effort to update the National Wetlands Inventory (NWI) maps in Oregon to enable more precise information for wetland location and subsequent restoration and mitigation planning efforts. Results from this effort should allow for an increased understanding of the context of wetlands at multiple spatial scales. This work will also increase consistency in building a common framework for future monitoring and assessment.

Three tiers of assessment and evaluation were used for developing this monitoring program, which is intended to be sensitive to the diversity of wetlands in Oregon. These different levels of intensity are meant to provide a menu of monitoring options based on the specific goals and available resources for monitoring and assessment. The program developed and refined tools that can increase the ability to report on wetland restoration and mitigation outcomes through the use of three tiers of evaluation and assessment:

- Tier I: Landscape profiling
- Tier II: Oregon Rapid Wetland Assessment Protocol (ORWAP)
- Tier III: Detailed effectiveness monitoring

In addition, the program developed and tested preliminary metrics for a macroinvertebrate bio-assessment tool.

Project partners were able to establish, initiate, and test these techniques through this pilot project to begin to addressing overall programmatic objectives and develop preliminary tools for wetland monitoring and assessment.

<u>Tier I:</u> Landscape profiling involves assessing wetlands and predicting the wetland condition based on remote sensing methods. For example, a wetland that is in closer proximity to an urban area may be more likely to be impacted by hydrologic changes, increased nutrient runoff and higher percentages of invasive species as opposed to a wetland in a more remote area. The advantages of this method are that it can be done, for the most part, with existing data and it can be performed in an office environment at any time of the year. Disadvantages include the detail of information about wetlands is

limited to the data that are currently available (e.g., not all wetlands are accurately mapped) and strong GIS skills are required. A limited landscape profiling approach was used for this project for identifying potential sites for evaluation.

Tier II: Rapid wetland monitoring techniques have been developed and refined over the years in an effort to provide more robust and standardized set of assessment tools. Rapid techniques are designed to provide more detail than a landscape profiling exercise and also allow the user to complete the assessment in less than one day. In 2009, the Department of State Lands adopted the Oregon Rapid Wetland Assessment Protocol (ORWAP) as its formal, standardized protocol for wetlands assessment. One unique feature of ORWAP is that it can compare wetlands of different types and report the function and condition of those wetlands in a common format. For this pilot study ORWAP provides a Level II assessment of wetlands, allows for additional testing opportunities of ORWAP, and additionally determines how well rapid techniques align with other methods of wetland assessment (Landscape profiling, detailed effectiveness monitoring, and preliminary invertebrate bio-assessments).

Tier III: Detailed effectiveness monitoring is designed to fall into level III assessment and provide additional insight into wetland function and condition and specifically how well do the restored and mitigated wetland functions and conditions compare with natural or reference wetlands. This allows groups who are actively performing restoration actions to determine the effects of restored wetlands and if restoration is achieving the function and condition that was planned for.

Developing and refining methods to assess the relative health of stream and riverine systems have provided robust and transferable tools that can evaluate the trajectory of whether streams are improving or declining in health. One of these monitoring tools is an Index of Biological Integrity (IBI). Unfortunately, an IBI does not exist to assess the health and biotic condition of wetlands in Oregon. It is important to develop this Invertebrate Index of Biological Integrity (I-IBI) in the framework for an Oregon Wetland Monitoring and Assessment Strategy to evaluate the potential for further refinement and useful context of this tool.

Results from multiple components of this project are listed in summary fashion in this report and final reports from project partners are available in Appendices. It is the intention of the project participants that the methods developed under this project will be further enhanced and refined so increasingly robust measurement of the relative health of wetlands is possible in the future.

Methods

Invertebrate Based Bio-Assessment

Site selection

Fifty wetlands in the Willamette Valley ecoregion were sampled per year in 2009 and 2010, from a pool consisting of 33 riverine and 19 flats-type wetlands, as determined by the hydrogeomorphic (HGM) classification system (Brinson 1993, Adamus 2001). Roughly half the sites were riverine wetlands sampled by Xerces during previous studies on wetland invertebrates in 2007 & 2008; these sites had been selected to represent a gradient of human impact levels, from most-impaired to least-impaired by anthropogenic activity. The remaining sites were chosen to add the *flats* category of wetlands to the study, and to incorporate restored (10 total) and enhanced (24 total) wetlands into the study in addition

to natural (reference) sites (18 total). Additional site characteristics such as ease of accessibility and willingness of owners and/or land managers to allow access were also considered in final site selection. It should be noted that HGM category (riverine vs. flats) and/or management status (natural vs. enhanced or restored) category was re-assigned for several sites during the course of the study, based on changing information from early assessments conducted by DSL, a wetlands assessment meeting conducted prior to the 2009 field season with an EPA wetland specialist (Mary Kentula), the OWEB contractor conducting ORWAP assessments (Paul Adamus), and project partners, as well as data from ORWAP assessments (Adamus *et al*. 2009) conducted in 2009 and 2010. This complicated data analysis to some extent, as it was necessary to examine different HGM types and management classes separately to ascertain differences in macroinvertebrate community characteristics that could be used to generate biological site assessment tools.

Habitat Assessment

Determining the range of anthropogenic stressors currently operating at a given wetland is problematic, particularly in an area with such extensive agricultural and urban development as the Willamette Valley. Rapid wetland assessment techniques have been developed for Oregon (ORWAP; Adamus *et al*. 2009), but these require trained professionals with specialized knowledge, and take several hours to complete. To render basic wetland assessment more accessible to a variety of users, we implemented a wetland Human Disturbance Assessment (HDA) form, modified from a rubric developed by Gernes & Helgen for wetland assessment in Minnesota (in U.S. EPA 2002). HDA components also follow recommendations of Rader & Shiozawa (2001) in developing criteria for defining reference conditions. The HDA assesses five site aspects:

- Buffer landscape disturbance (land use within 50 ft/15 m of wetland)
- Immediate landscape influence (500 ft/150 m of surrounding land)
- Habitat alteration, immediate landscape (500 ft/150 m of surrounding land)
- Hydrologic alteration, immediate landscape (500 ft/150 m of surrounding land)
- Chemical & Sediment Inputs

Each aspect can be rated as Excellent (0 points), Moderate (5 points), Fair (10 points), or Poor (15 points). The site HDA score is calculated by summing the rating for each section. Thus, an utterly pristine site would receive an overall score of 0, while a completely impaired site would receive 75 points. Study sites were ultimately grouped into three classes, based on HDA scores: class 1 (least-impaired, HDA score = 0-22), intermediate disturbance (HDA score = 22.1-42), and most-impaired (HDA = 42.1-75). The lowest HDA score received by any site in any year was 5, and the highest was 65 points. The complete HDA form is presented in Appendix C.

Environmental data

The location of the sampling site within each wetland was recorded using a Garmin Rino 120 GPS unit (NAD 83 datum). The sampling transect was also photographed to allow sampling to be conducted in the same place in the wetland each year. Prior to macroinvertebrate sampling, water quality measurements were taken adjacent to the sampling region, to avoid trampling or disturbing the region from which macroinvertebrates would be netted.

Macroinvertebrate sampling

Two teams consisting of two people each conducted sampling of all sites within the first three weeks of May each year. This index period was used because it is late enough in the spring that most macroinvertebrates will be mature enough to identify to genus and species, while being early enough in the season that there is less risk of losing sampling sites to dry down. One to three sites each year were

too dry to sample by May, but sampling at pre-selected back-up sites enabled us to sample a total of 50 wetlands each year.

All samples were delivered to the taxonomic lab (ABR, Inc., Forest Grove, OR) by June 1st of each year for identification. Each composite sample was randomly subsampled to a target count of 500 organisms; if a sample contained fewer than 500 organisms, the entire sample was picked, counted, and identified. For samples with more than 500 organisms total, "large and rare" invertebrates were also picked and identified after the target subsample was reached. Organisms were identified to the lowest taxonomic level possible, usually genus.

Rapid Assessment and Detailed Effectiveness Monitoring

In a series of Willamette Valley wetlands, standardized protocols, including ORWAP and a protocol developed for this project, were used in 2009 and 2010 to primarily assess: (a) vegetation species composition; and, (b) relative levels of ecosystem services. Of the 60 total wetlands visited, 34 were classified as riverine and 26 as flats (see Table 1 for definitions). Of the 34 riverine wetlands, 21 are believed to be restored or enhanced. Of the 26 flats wetlands, 20 are believed to be restored or enhanced. Also, 13 different riverine and 6 different flats wetlands were visited to provide reference data since, to our knowledge, they have not been recently restored or enhanced. Sites chosen as *reference* or *natural* were used for comparison purposes from other wetlands that may have higher levels of disturbance. To meet aquatic macroinvertebrate sampling needs, all the surveyed wetlands had a significant area of surface water that persisted at least through early June.

Protocols were applied during a single visit each year. Additionally, and in 2009 only, selected compounds in the soil from each site were analyzed. During both years, incidental detections of birds and amphibians were also recorded. Between one and three wetlands were assessed per sampling day, depending on their size and proximity.

Table 1. Definitions of selected technical terms

Term	Definition as Used in This Section
Ecological Condition	The quality or integrity of a site as reflected partly by the similarity of its biological communities to those in areas not significantly impacted by human activities
Co-dominants	Species that comprise 10% or more of a sampling unit
Dominants	Species that comprise more than 50% of a sampling unit
Ecosystem Services	The functions of an ecosystem and the values placed on them partly due to their context in the landscape
Enhancement	Management actions undertaken to change wetland condition and/or functions to a state more preferred by a landowner, agencies, or others.
Facultatives	Plant species almost equally associated with wetlands and uplands as indicated in 1996 list from USFWS
Flats	Wetlands in flat terrain that receive a significant portion of their water from direct precipitation, and secondarily from groundwater and runoff. They usually lack natural outlets.
Forbs	Leafy herbaceous plants, including wildflowers, ferns, and others
Functions	The things that wetlands do, such as store and purify water, provide habitat
Graminoids	Grasslike plants such as sedges, rushes, and grasses

Term	Definition as Used in This Section
Indicators	Measured variables that are useful for informing about particular conditions or functions.
Invasives	For this study, plant species listed as invasive in this region in Adamus *et al*. (2009a)
Metrics	Indices calculated from indicator data that summarize condition or functions
Non-Native Birds	For this study, includes the following species that were encountered: European starling, house sparrow, California quail, and ring-necked pheasant
Nonnatives	For this study, plant species listed as non-native in this region in Adamus *et al*. (2009a)
Obligates	Plant species strongly associated with wetlands as indicated in 1996 list from USFWS
Restoration	Management actions undertaken to change wetland condition and/or functions to something closer to its original state
Richness	The number of species or other taxa per unit area
Riverine	Wetlands with unidirectional flow that occurs at least once every two years. Includes most impounded and excavated channels and ditches, as well as stream riparian areas and river floodplains.
Stressors	Factors that are likely to cause wetland conditions to exceed natural levels of variation; usually applied in the context of human actions
Wetland Birds	Species which in this region are believed to occur disproportionately in wetlands and were found during this study. Includes all waterfowl, shorebirds, 2 raptors (osprey, northern harrier), and the following passerines: belted kingfisher, willow flycatcher, tree swallow, marsh wren, warbling vireo, common yellowthroat, yellow warbler, red-winged blackbird.

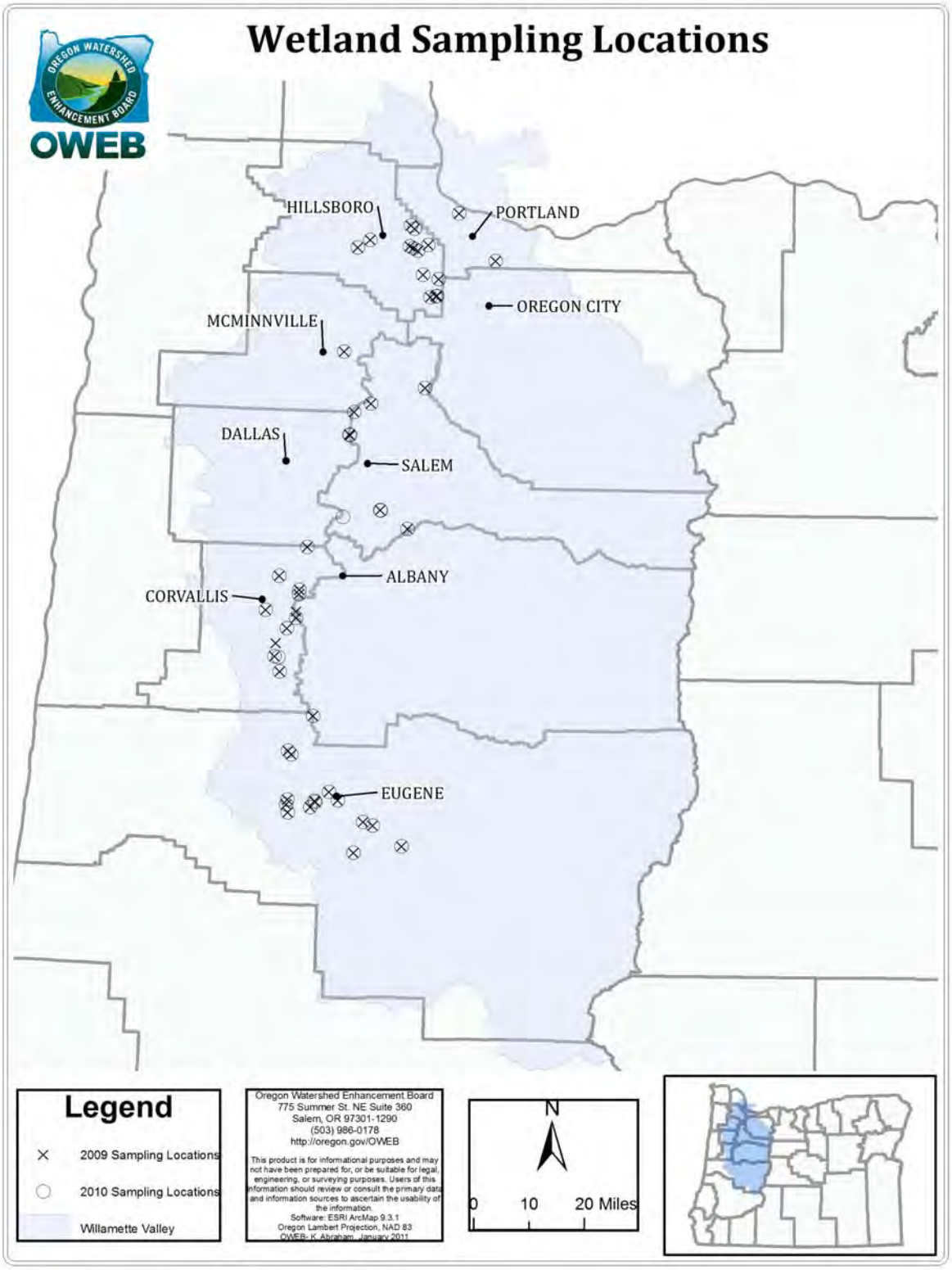

Figure 1. Locations of wetlands sampled for this study.

Rapid Assessment

The relative levels of 16 potential wetland functions and values (i.e., ecosystem services) were assessed by applying the Oregon Wetland Rapid Assessment Protocol (ORWAP, Adamus *et al*. 2009a) at each site. ORWAP provides scores ranging from 0 (low effectiveness) to 10 (high effectiveness) for each of the 16 wetland functions. In addition, ORWAP provides scores for a wetland's ecological condition, human stressors, relative sensitivity, and contextual value of each of its functions. ORWAP is the wetland assessment method recommended for most applications by DSL, US Army Corps of Engineers, Natural Resources Conservation Service, and several other agencies and groups in Oregon.

For this study, ORWAP questions were answered in the context of the entire wetland, rather than just the immediate area in which vegetation and soils were sampled. The "entire wetland" was delimited visually based on topographic and hydrologic similarity as described in the procedures of the ORWAP manual (Adamus *et al*. 2009b). When an entire wetland could not be accessed for inspection, interpretation of aerial imagery was used to augment ground-level observations from the accessible parts.

Much of the information needed for the "office" component of each assessment was compiled first by trained OWEB staff using internet data sources. Landowners and managers also were contacted (by phone, email, or in person) about wintertime hydrologic conditions and the type, date, and location of enhancement activities at many of the sites. To answer the one ORWAP indicator question pertaining to wetland soils, surplus material remaining in the composited soil sample collected at each site was examined. Physical processing of this soil by the laboratory had broken up larger aggregates but no chemicals had been added. All such samples were examined on a single day using the ORWAP soils protocol, ensuring optimal consistency in applying the procedures for texturing the soils (e.g., similar moisture among all samples).

Detailed Effectiveness Monitoring

Soil Sampling and Analysis

Hand-sized samples of soil were taken from the upper 3 inches of a soil pit after removing large organic matter (duff) from each wetland. Four samples were taken approximately at opposite corners of the wetland plus one near the center, after determining that each location contained indicators of wetland conditions. No samples were collected from areas inundated at the time of sampling. The five samples from each wetland were composited into a single sample of about 150 g and then transported to the Central Analytical Laboratory at Oregon State University for analysis within one week of collection. The following parameters were measured: pH, extractable bases (Ca, Mg, Na, K), organic matter (LOI), total Kjeldahl phosphorus, nitrate nitrogen, and heavy metals (Cu, Zn, Mn, Fe). Soils were not analyzed from three wetlands that were substituted in 2010.

Vegetation

The vegetation protocol was designed so that an average of one wetland per day could be surveyed by one person. In each wetland, all plants were identified to species where possible in the field, and their absolute percent cover was estimated to the nearest 5% within 20 (during 2009) or 10 (during 2010) square quadrats of dimension 1 meter x 1 meter, and 1 meter vertically. The number of quadrats per site was halved in 2010 after preliminary analysis of the 2009 data on mean percent cover of non-native plants indicated that stable estimates of this variable could be obtained from 10 evenly-spaced quadrats per wetland. In general, sampling during the earlier parts of each field season focused on wetlands without seasonally persistent water levels (e.g., flats) because their flora often matures earlier.

Sampling of persistently flooded wetlands later in the season enabled better access as their deeper waters receded.

Quadrats were spaced as evenly as possible to cover the entire accessible wetland, rather than randomly or in a manner intended to represent all major cover types apparently present, or sections of a wetland suspected of having undergone management actions. In every wetland at least one quadrat was placed at or near the location where aquatic invertebrates and water quality were sampled, and was so labeled in the database. However, no quadrats were placed in water deeper than about 2 feet at the time of vegetation sampling. Where wetlands consisted entirely of a ponded area surrounded by a fringe of wetland vegetation, quadrats were positioned evenly around the "shoreline." Due to access difficulty, vegetation was not sampled in portions of wetlands dominated by extensive areas of dense brush (e.g., snowberry, *Rubus* spp.).

Geographic coordinates were recorded for every quadrat location. Consideration was given to using rebar or flagging to mark quadrat locations so they could be relocated in subsequent years, but this was not done because of the additional time required and because of the high potential for marker loss as a consequence of many of the wetlands being used extensively by the public. Nonetheless, when resampling the same wetlands in the second year, attempts were made to place the quadrats at approximately the same locations, by referring to their coordinates from the prior year. Because the number of quadrats was halved in year 2, only the odd-numbered quadrat locations from year 1 were revisited.

In addition to recording each plant species, in each quadrat the percent cover of "Water" and "Bare/Litter" was estimated as it existed beneath any overhanging vegetation. For example, if surface water covered an entire quadrat, Water was recorded as 100% despite it containing both emergent and submergent plants. Similarly, if the ground was almost entirely bare beneath a canopy of (for example) reed canary grass that filled the entire quadrat, then Bare/Litter was recorded as 90% as well as reed canary grass being recorded as 100%. When areas with less than about 20 percent cover of emergent plants were encountered, quadrat locations were shifted to locations with more vegetation. Every quadrat was photographed from both vertical and horizontal aspects during 2009, and these photos have been labeled and archived for possible future reference.

Plants that could not be identified in the field to species were collected, pressed, and examined later under a dissecting scope if any potentially diagnostic parts were present. Use of the XID taxonomic keys in Flora ID Northwest (2009) software allowed many immature and partial specimens to be identified with confidence. Besides consulting many standard regional references for wetland plant identification (Hitchcock & Cronquist 1973, Guard 1995, Cooke 1997, Wilson *et al*. 2008), the investigator frequently consulted the extensive collection of photos at the Oregon Flora web site (oregonflora.org). Taxonomic nomenclature from the USDA Plants web site (plants.usda.gov) was used. A large amount of time was dedicated to plant identification and required a high degree of previous plant identification knowledge.

A "confidence rating" was assigned to every identification in the database with "1" indicating high certainty that identification to species was correct, "2" that identification to genus was probably correct but species (if reported) was less certain, "3" that only the identification to taxonomic family was likely to be correct and/or that genus-level identification was uncertain, and "4" indicating plants that could only be identified as "forb" or "graminoid," which in most cases was due to the poor physical condition of available specimens (e.g., not yet flowering or fruiting, or too long past that time). Of the 9238 plants individually examined for this project, 97% had either a "high" or "probable" certainty rating and

3% had a rating of "likely" or" unknown". In only 9% of all quadrats did plants with a certainty level less than "1" comprise more than half the absolute cover within the quadrat. These quadrats were often dominated by *Agrostis* which is difficult to identify to species. The identity of many collected and pressed specimens was resolved under a 10X dissecting scope. Voucher specimens were preserved for most species.

Birds and Other Wildlife

As noted earlier, wildlife species were not surveyed systematically or using standardized protocols and equipment. This was primarily because of seasonal and diurnal constraints (the optimal times for surveying amphibians and birds do not match well the best times for plants) and the inability to make repeated visits during a relatively short period of time as needed for effective surveys. Nonetheless, the investigator is skilled in auditory recognition of all breeding bird and frog species of the Willamette Valley so the number of detections was fairly large, especially when wetlands were visited early in the season and early in the day. Nearly all detections were auditory. From these alone it is not possible to determine with certainty which records were from individuals located within a visited wetland as opposed to being from upland habitats immediately surrounding a wetland.

Analysis

Invertebrate Based Bio-Assessment

This study spanned only two field seasons (2009 & 2010), but it represented a continuation of wetland bio-assessment work done by Xerces in 2007 and 2008, and almost half of the wetlands sampled in the course of this study were also sampled by Xerces in the previous field seasons. By the end of the 2010 field season, 23 sites had been sampled for two consecutive years, 17 sites had been sampled across three years, and seven sites had been sampled across four years. An important consideration in developing a bio-assessment tool is the degree of annual variation that occurs in the target biological community, as this will affect the reliability and predictive power of indicator taxa and/or community composition metrics. Therefore, to better examine the variation in macroinvertebrate community composition at the same site in different years, and to select indicator taxa or attributes with the best predictive power, macroinvertebrate community data from the 2009 and 2010 field seasons was considered separately as well as in combination with data from previous years of study.

The PRIMER v6 software package (Clarke & Gorley 2006) was used to examine invertebrate community structure. Data from 2009 & 2010 were examined together, and in combination with data from sites also sampled in 2007 and 2008. Geometric class plots were drawn in PRIMER to investigate species abundance distributions among different wetland categories. This is a recommended method for detecting pollution-induced changes in sensitive species in benthic communities (Gray & Pearson 1982). The plots show the number of species represented by only 1 individual in the sample set (geometric class 1), 2-3 individuals (geometric class 2), 4-7 individuals (geometric class 3), 8-15 individuals (geometric class 4), etc.

Linear regression analysis was done in Excel to assess the relationship between selected invertebrate community attributes and site disturbance levels. Data from 2009 and 2010 were analyzed separately, as a pooled dataset, and in conjunction with site data from 2007 and 2008, where possible. Community attributes were plotted against individual site HDA scores and the R^2 value was determined.

The same attributes were also plotted against disturbance class (class 1= least-impaired, class 2 = intermediate disturbance, class 3 = most-impaired) and ORWAP stressor score. Unpaired t-tests were done to assess whether attribute mean values differed significantly ($P < 0.05$) between class 1 and class 3 natural wetland sites. Table 2 lists all invertebrate community attributes calculated for each site.

Our goal was to identify community characteristics and/or taxa that differed substantially and reliably between:

1. natural wetlands experiencing different levels of human disturbance, especially class 1 vs. class 3;
2. wetlands experiencing different management techniques, especially natural vs. restored.

Table 2. Wetland invertebrate community attributes, 2009 & 2010.

Abundance	**Richness (Total # of taxa**
# of highly tolerant taxa (MHBI 8-10)[a]	# of predator taxa
% diversity highly tolerant (MHBI 8-10) [a]	% diversity predator
% abundance highly tolerant (MHBI 8-10) [a]	% abundance predator
# genera in *Chironomini*	# genera *Gastropoda*
% diversity *Chironomini*	% diversity *Gastropoda*
% abundance *Chironomini*	% abundance *Gastropoda*
# taxa *Tanytarsini*	# taxa collector/gatherers
% div *Tanytarsini* of *Chironomidae*	% diversity collector/gatherers
% abundance *Tanytarsini* of *Chironomidae*	% abundance collector/gatherers
# taxa ETSD[b]	% diversity ET[c]
% diversity ETSD[b]	# taxa ET[c]
% abundance ETSD[b]	% abundance ET[c]
# taxa *Coleoptera*	# taxa *Orthocladiinae*
% diversity *Coleoptera*	% diversity *Orthocladiinae*
% abundance *Coleoptera*	% abundance *Orthocladiinae*
# taxa *Chironomidae*	% abundance top dominant taxon
% abundance *Chironomus*	% abundance top 3 dominant taxa
% *Chironomus* of total *Chironomidae*	% abundance mites
MHBI [a], unweighted mean	# of non-insect taxa
MHBI [a], weighted mean	# rare taxa (<1% abundance at site)
# taxa (*Crustacea* + *Mollusca*)	% diversity rare taxa (<1% abundance at site)
% diversity (*Crustacea* + *Mollusca*)	% diversity *Crustacea*
% abundance (*Crustacea* + *Mollusca*)	% abundance *Crustacea*
# taxa sensitive (MHBI 1-4) [a]	% abundance *microcrustacea*
% diversity sensitive (MHBI 1-4) [a]	% abundance *Caecidotea*
% abundance sensitive (MHBI 1-4) [a]	% abundance (*Amphipoda* + *Isopoda*)
% abundance *Sphaeriidae*	% abundance (*Amphipoda* + *Isopoda*) of total *Crustacea*

[a] MHBI = modified Hilsenhoff Biotic Index
[b] ETSD = *Ephemeroptera*, *Trichoptera*, *Sphaeriidae*, dragonflies
[c] ET = *Ephemeroptera*, *Trichoptera*

Rapid Assessment and Detailed Effectiveness Monitoring

Metrics and indicators pertaining to vegetation, invertebrates, birds, and all chemical and physical characteristics were merged into a single database for each of the two sampling years. Because of the statistical non-normality of most of the data, Spearman (rather than Pearson) rank correlation coefficients were computed for each of the approximately 66,290 pairs of numeric indicators or metrics, separately by year. Of those pairs, a total of 16,538 (~25%) were determined to be statistically significant ($p<0.05$) during one or both years. Inference about potential ecological relationships may be considered to be stronger when the same metrics correlate during successive years across all sites. Even then, ecological causality should not be inferred only from the statistical correlations reported herein.

The other statistical analysis involved performing Mann-Whitney U tests, which are similar to two-sample T-tests but are used with statistically non-normal data. For each year's data, a statistical determination was made whether differences in the medians for riverine vs. flats wetlands were significant for every metric and indicator. Separately, a statistical determination was made whether differences in the medians of each of the following site management categories were significant for every metric and indicator: Enhanced vs. Reference, Restored vs. Reference, Enhanced vs. Restored.

Before running the Spearman rank correlations and Mann-Whitney tests, raw field data were compiled mathematically into metrics. For example, from a file containing a list of all plants identified by quadrat and wetland metrics such as the following were computed and reported:

- number of species per plot and per site (richness);
- proportion of a site's plots that contained invasive plants (frequency);
- cumulative dominance per quadrat of species that were less-common among all sites (constancy)[1];
- wetland bird species as a percentage of all bird species detected per site;
- average and maximum percent-cover of graminoids among all of a site's quadrats;
- number of species considered dominant by virtue of having >50% cover per quadrat;
- cumulative dominance per quadrat of species that were less-common among all sites;
- and many others described in the Data Dictionary (see Adamus full report, 2010).

Dozens more could have been computed from the raw data and examined for correlation with invertebrates, birds, soil chemistry, and other variables. These particular ones were chosen both for conceptual reasons and because they have shown promise as descriptors or definers of wetland condition in studies of wetland restoration elsewhere in the world.

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[1] This metric was computed as follows: 1) Calculate each species' frequency of occurrence among all sites,both years together; include only native wetland indicator species that had been identified fully to species. 2) Divide each species' frequency by 289 (the maximum frequency among all species across all quadrats), then subtract from 1. This is the U coefficient. Species that occurred less frequently among all plots have higher values for U. 3) For every occurrence of a species, multiply its U coefficient by its percent cover. Then divide by the sum of all percent cover for native wetland species in the plot, to give the average U within each plot, weighted by percent cover. 4) For each site, calculate average of the plot averages (UbiqWetNtvAvg), and maximum for whole site (UbiqWetNtvMx).

Results

Invertebrate Based Bio-Assessment

Consistency and replication

Because one goal of this project was to create a biological wetland assessment tool accessible to a variety of users, it was important to determine the consistency and reliability of both the macroinvertebrate sampling technique and the HDA assessment form. Even with standardized protocols and trained users, practitioner-related differences are a matter of concern in bioassessment studies, so it is important to examine the robustness of the technique. To determine the consistency of the invertebrate sampling technique, duplicate samples were taken at two sites each year. In each year, analysis of site assemblages showed the greatest degree of similarity between duplicate sample pairs, indicating reliability in sampling technique. Overall, the sampling protocol was very consistent among users.

Development of a bio-assessment tool requires identifying biological community attributes that change predictably along a gradient of human impairment. Therefore, a critical part of this study was the performance of the simple rubric used to assess human-induced site disturbance. The HDA form was designed to be accessible to users with little experience in wetland assessment, and may be subject to a degree of subjective judgment by different users. The project assessed the reliability of the HDA score in reflecting the degree of anthropogenic impact at a site, and to determine the consistency of site HDA scoring among different users of the rubric.

HDA assessment was implemented at existing sites (25 riverine wetlands) in 2008, and it was conducted at all sites in 2009 and 2010. About half of the sites each year were sampled by a different trained sampling team, and HDA assessment was done on each site each year at sampling time. Linear regression analysis showed a positive correlation between site HDA score and the more comprehensive ORWAP stressor score (R^2 = 0.4734 for all natural sites sampled in 2010; R^2 = 0.428 across all sites sampled); this relationship was slightly stronger for riverine vs. flats wetlands (R^2 = 0.5939 for all riverine natural sites; R^2 = 0.4787 for all flat natural sites). A similar relationship was seen for site HDA scores in 2009, although less strong for natural flat sites (R^2 = 0.3424 across all sites; R^2 = 0.5585 for natural riverine sites; R^2 = 0.2822 for all natural flat sites). This consistent correlation with the much more detailed stressor score, which is comprised of a wide range of different site aspects evaluated during ORWAP assessment, indicates that raw HDA score and the associated scaled HDA classes (least-impaired (1), intermediate-impaired (2), or most-impaired (3)) provide a realistic reflection of the level of anthropogenic impact at a site.

For sites that were sampled across multiple years, the overall HDA score was generally not identical for the same site in different years (Figures 2-4). However, the magnitude of the change was small enough that the overall classification of a site as least-impaired, intermediate-impaired, or most-impaired changed for only four sites, which were at the upper or lower score limit for a given impairment class. These results indicate that the parameters of the HDA assessment process are laid out clearly enough that consistent results regarding site impairment level can be obtained by different trained users.

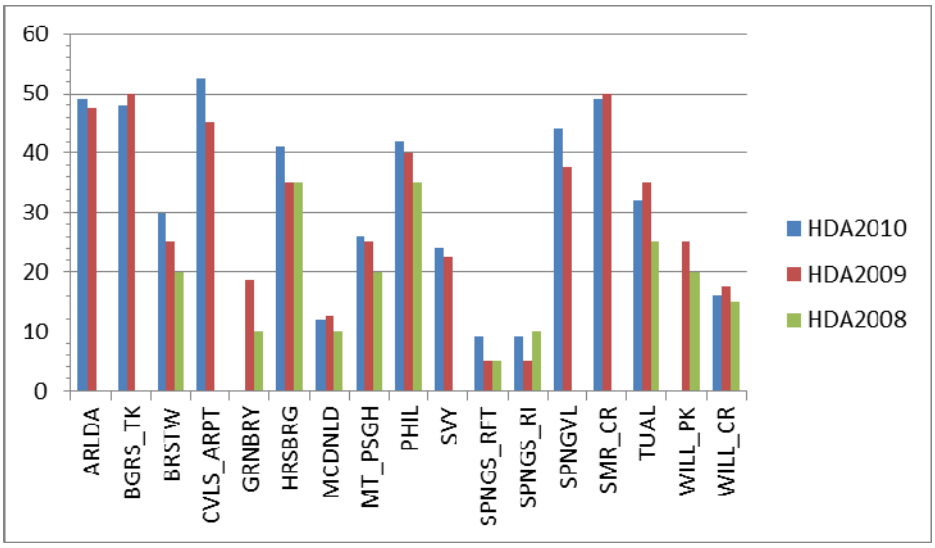


Figure 2. Annual variation in HDA rubric scoring for *natural* wetlands.

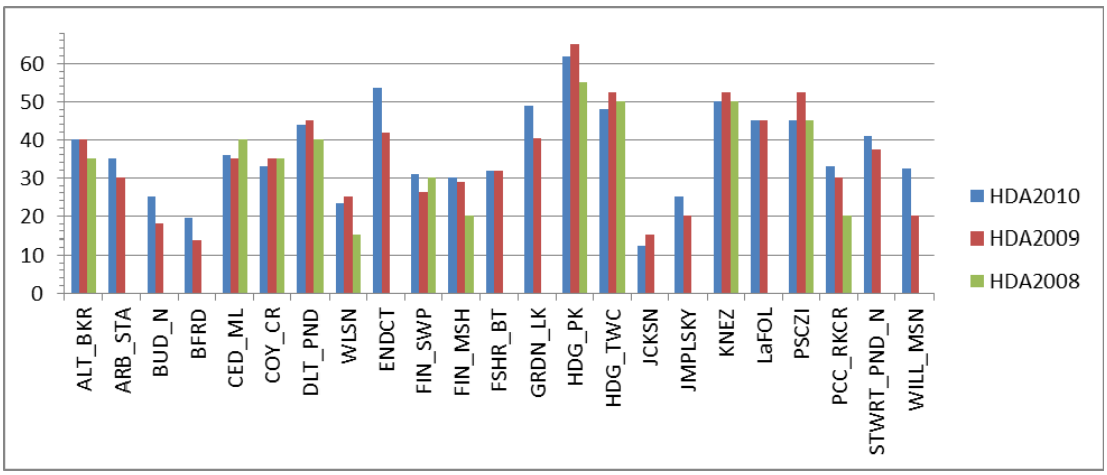


Figure 3. Annual variation in HDA rubric scoring for *enhanced* wetlands.

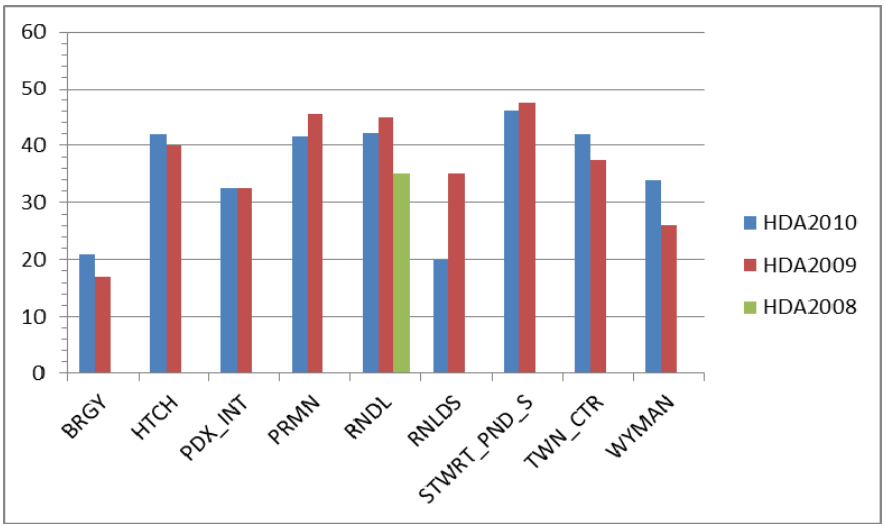


Figure 4. Annual variation in HDA rubric scoring for *restored* wetlands.

Wetland macroinvertebrate taxa

Additional taxa were collected among the complete set of sampling sites in each year this project was conducted. The 2008 dataset contained 169 wetland macroinvertebrate taxa collected among 25 riverine sites, expanding the list considerably from 2007, when 92 taxa were found among 11 riverine sites. The complete taxa list, comprised of organisms sampled at 50 wetlands in both the riverine and flats HGM categories, increased to 231 taxa following the 2009 and 2010 field seasons. This increase was due both to sampling at greater number of additional types of wetlands, as well as the fact that the taxonomic lab that performed specimen identification in 2009 and 2010 identified many groups to genus or species level that had been left at family or genus in previous years, including aquatic mites and multiple families of aquatic beetles.

The number of unique taxa per site among all riverine wetlands ranged from 17 to 51 in 2010 (mean richness = 30.3 $\pm$ 7.76), and from 12 to 42 in 2009 (mean richness = 28.6 $\pm$ 6.96). The most abundant, ubiquitous taxa among all riverine sites were common and tolerant groups including nematodes, oligochaete worms, chironomid midges, fingernail clams, snails, microcrustacea, and crustaceans (mainly scuds and aquatic sowbugs). Corixid bugs and ceratopogonid midges were also common among riverine sites.

The number of unique taxa per site at all flats wetlands was slightly lower than for riverine sites, ranging from 10 to 43 in 2010 (mean richness = 27.5 $\pm$ 7.97), and from 12 to 40 in 2009 (mean richness = 25.9 $\pm$ 8.61). Many of the common taxa groups at riverine sites were also among the most common at flats sites, including oligochaete worms, chironomid midges, snails, microcrustacea, and crustaceans. Other common groups at flats sites included corixid bugs and dytiscid beetles.

Eleven taxa in the complete taxa list were entirely absent from all riverine sites in all years; of these, eight were represented by other genera in the same family (aeshnid dragonflies, planorbid snails, dytiscid beetles, haliplid beetles, and tipulid flies), and only three (*Conchostraca* [clam shrimp], *Microveliidae* [short-legged water striders], and *Polycentropidae* [trumpetnet caddisflies]) were completely unrepresented among all riverine sites. Flat sites had a much more restricted community, with 91 of the taxa found among all sites during all years absent from any flats site. Over half of these absent taxa (51) were represented by other genera in the same families (tipulid flies, chironomid midges, haliplid beetles); the remaining missing taxa were comprised largely of groups that require colder, faster-moving water, including all stoneflies, elmid beetles, and blackflies, and the majority of mayflies and caddisflies. This difference is not unexpected, as the nature of ephemeral flats wetlands is such that the water levels are generally lower, warmer, contain less dissolved oxygen, and are much more lentic compared to riverine wetlands. It is interesting to note that while the community at all flats sites included abundant numbers of multiple taxa of chironomid midges, 33 of the 66 genera of *Chironomidae* found among all sites did not occur at any flats site; in contrast, none of the chironomid genera were lacking among all of the riverine sites in this study.

Environmental data

Basic water chemistry data were collected each year prior to sampling. Conductivity, pH, and DO were measured from 2007 through 2010; total Kjeldahl nitrogen (N), total phosphorus (P), and chloride (Cl) were measured in 2008-2010. Natural riverine and flats wetlands exhibited a similar range of values across all years for pH, P, Cl, conductivity, and DO. The range for N levels was about three times higher among natural flats sites compared to natural riverine sites.

Values for all water chemistry parameters sampled varied substantially from year to year at the same site for both riverine and flats sites. For riverine wetlands, the magnitude of this change from year to year did not appear to be related to the level of human disturbance (HDA class) at the site; among flats sites, the magnitude of annual change in N and P levels was lowest at least-impaired sites.

The observed variation across time at the same sites for water chemistry parameters may explain the overall lack of strong correlation between individual water chemistry parameters and site HDA scores. In 2009, higher N and P levels showed a moderate to weak correlation with increased impairment at natural riverine sites (R^2 = 0.294 and 0.2187, respectively). Data for the same sites in 2010 showed weak correlation with increased site impairment and higher levels of N (R^2 = 0.2169), P (R^2 = 0.107) and higher conductivity (R^2 = 0.1606). The water chemistry dataset among all years of sampling for natural riverine sites revealed a weak correlation between site impairment and higher levels of N (R^2 = 0.1773), P (R^2 = 0.1057), and higher conductivity (R^2 = 0.1196).

More and slightly stronger correlations between water chemistry and site impairment were seen for natural flats sites, which may be a reflection of the lower magnitude of annual variation among sites observed for some parameters. In 2009, higher N levels and increased conductivity showed a moderate to strong correlation with increased impairment at natural flats sites (R^2=0.4641 and 0.3797, respectively). In 2010, data from these same sites indicated correlation with increasing site impairment for higher pH (R^2=0.108), Cl (R^2=0.4848), N (R^2=0.1539), P (R^2=0.2502), conductivity (R^2= 0.9147) and DO (R^2=0.3389). When water chemistry data for natural flats sites was considered across all years, however, many of these relationships disappeared, and weaker correlations with increasing site impairment were seen only for conductivity (R^2=0.1778) and DO (R^2=0.2705).

Water chemistry parameters among restored sites did not differ significantly from those seen at natural sites. T-tests comparing the mean water chemistry values at natural and restored wetlands for riverine and flats sites indicated no significant differences, with the single exception that total N values were significantly higher among restored riverine sites compared to natural riverine sites.

Macroinvertebrate community structure

Patterns in community composition were examined in PRIMER using the CLUSTER and SIMPER routines and MDS ordination, with the goal of identifying taxa and/or taxa groups that merited further investigation for their utility in discriminating between most- vs. least-impaired sites, and/or restored vs. natural wetlands.

CLUSTER analyses run on Bray-Curtis similarity matrices of fourth-root transformed data revealed limited association among sites based on level of human disturbance (HDA class), ecological condition (natural, enhanced, or restored), or HGM class (flats vs. riverine). The most consistent similarity was seen in duplicate site samples, which always clustered together as a pair. Most-impaired sites separated out most frequently into the same clades, although this same level of association was not observed among least-impaired sites (Fig. 5). Limited and inconsistent association was observed among sites in different ecological classes, with a slight suggestion of clustering among restored wetland sites (Fig. 6). Flats sites also appeared slightly more likely to cluster together (Fig. 7). This pattern was true for the data from 2009 and 2010 considered separately and in combination, and for the entire pooled dataset across all years of sampling (2007-2010).

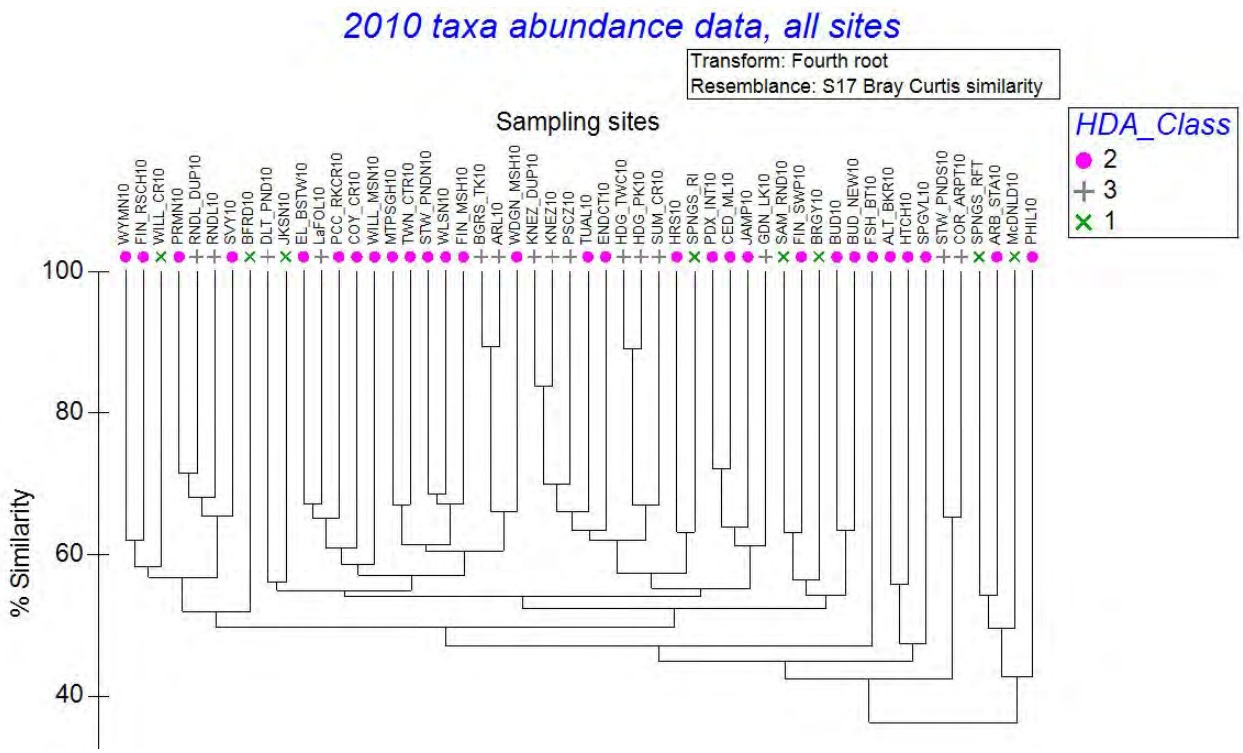


Figure 5. CLUSTER analysis of sampling sites by human disturbance level. Class 1 = least-impaired, class 2 = intermediate disturbance, class 3 = most impaired.

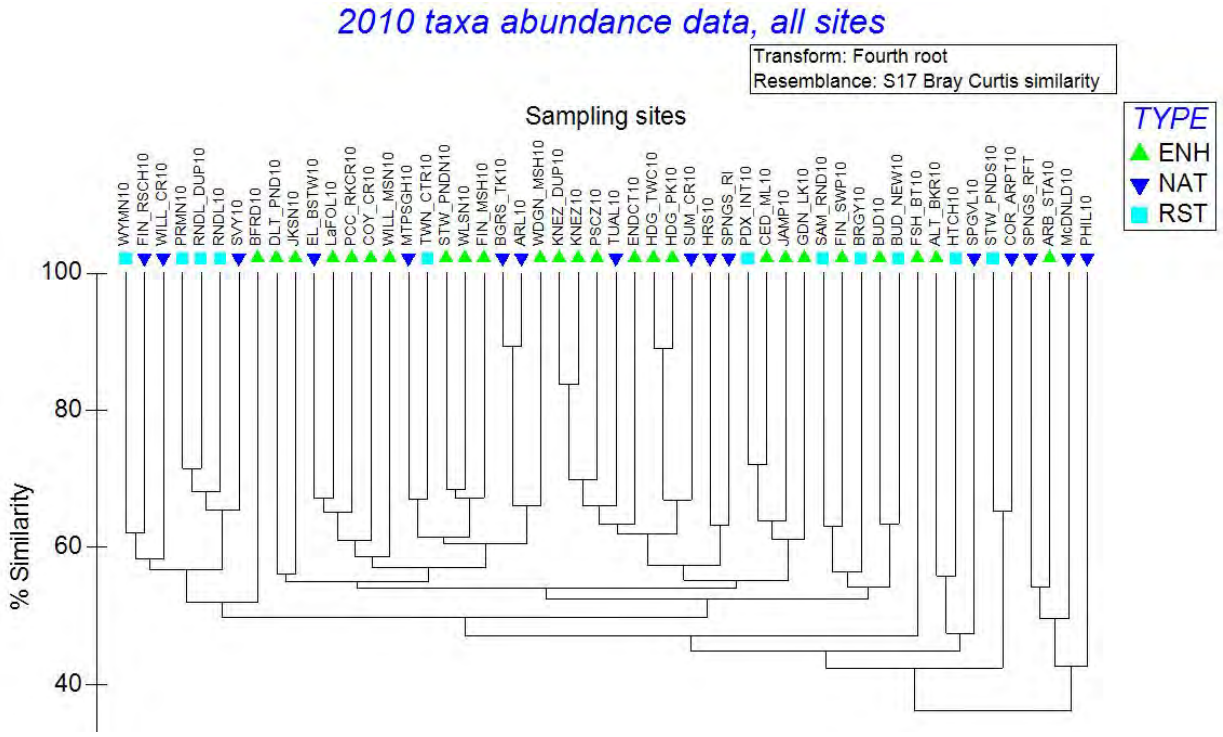


Figure 6. CLUSTER analysis of sampling sites by type (ENH = enhanced; NAT = natural; RST = restored).

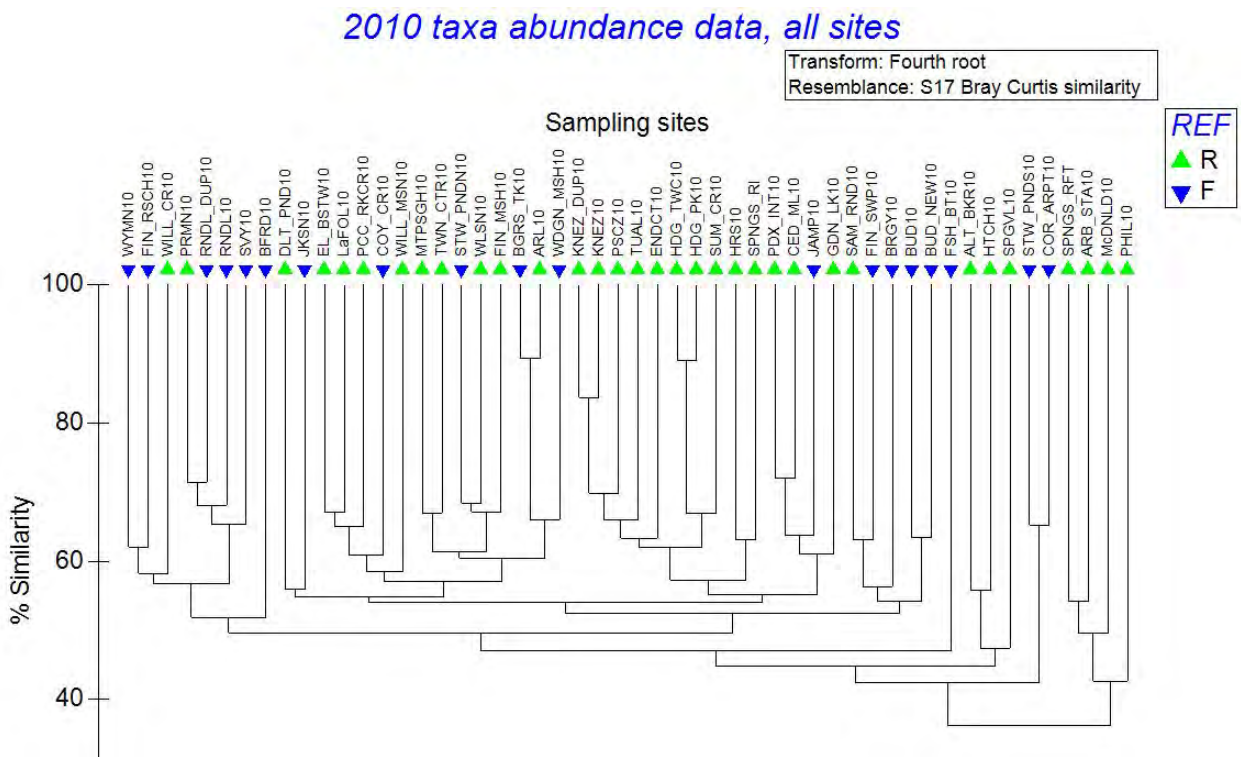


Figure 7. CLUSTER analysis of sampling sites by HGM class (R = riverine, F = flats).

For the purposes of establishing a macroinvertebrate-based assessment tool, it is necessary to determine whether the macroinvertebrate community composition differs among sites according to a gradient of human disturbance. When the macroinvertebrate community was examined across all years among all natural sites, clustering among sites of different HDA classes became more apparent (Figure 8), due in part to the fact that the datasets from the same site sampled across multiple years tended to segregate into the same clade for most of the natural sites. However, the macroinvertebrate community at each site sampled across multiple years differed enough annually that not all of the sampling years for a single site cluster together. Clustering based on HGM class proved less revealing, as there were far fewer natural flats than natural riverine sites (5 natural flats vs. 13 natural riverine). However, MDS ordination of the same data suggested some association among flats sites, even those in different HDA classes, when compared to natural riverine sites (Figure 9).

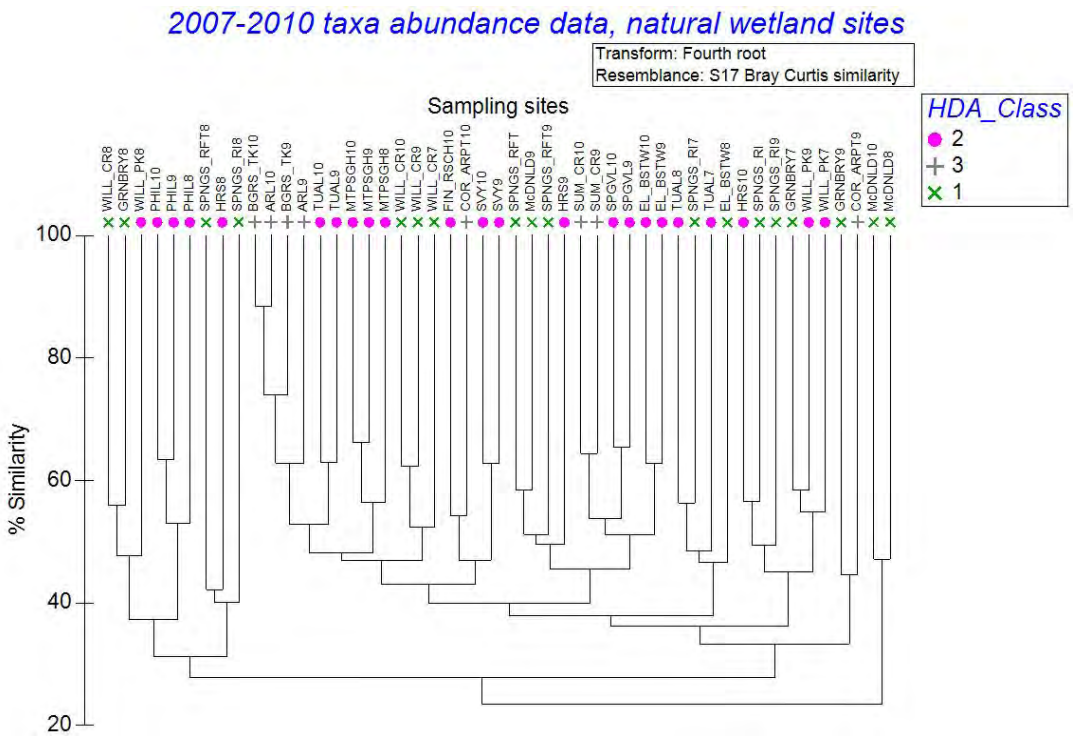


Figure 8. Analysis of macroinvertebrate taxa for all natural wetland sites (2007-2010). The numeral at the end of the site name abbreviation indicates sampling year. Numbers indicate disturbance level (class 1 = least-impaired; class 2 = intermediate disturbance; class 3 = most impaired).

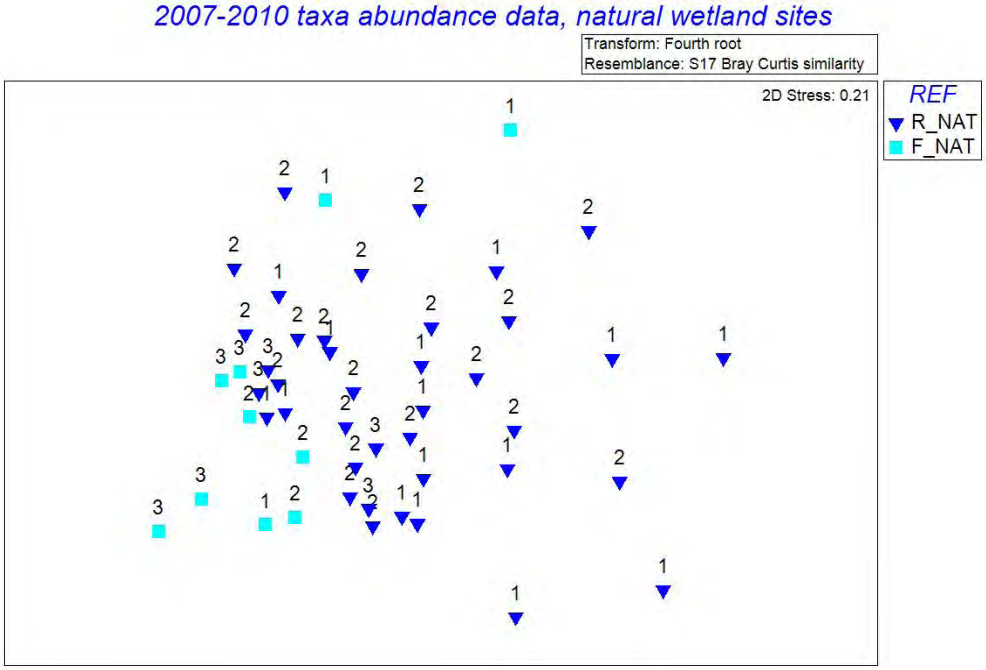


Figure 9. MDS ordination of natural flats and riverine wetland sampling sites. Numbers indicate human disturbance level.

SIMPER analysis of average community similarity of all sites across all years sampled supported the site separation based on HDA class. Although within-group similarity among the different classes was low overall, average similarity in invertebrate community composition increased from least-impaired (32.5% average similarity) through intermediate-impaired (37.1% average similarity) and most-impaired (44.5% average similarity) sites. The taxa that contributed the most to the observed average similarity within each HDA class were the same among all three classes: oligochaete worms, *Chironomus* midges, and copepods. The between-group dissimilarities were similar among all pairwise comparisons (class 1 vs. 2, class 2 vs. 3, class 1 vs. 3), ranging from 62.7% to 68% average dissimilarity, but was highest for class 1 vs. class 3. Each individual taxon contributed only a small percentage to the observed average dissimilarities (3-5%), but the taxa that contributed the most to differences between site classes were the microcrustacea (*Cladocera*, *Copepoda*, *Ostracoda*).

When natural riverine sites sampled across all years were considered separately, most-impaired sites had greater average abundance of *Orthocladius* (chironomid midge genus), *Crangonyx* (scud), and corixid bugs (water boatmen), while least-impaired sites had a greater average abundance of *Ephemeroptera* (mayflies) and non-dytiscid beetles (i.e., aquatic beetle taxa other than the predaceous diving beetle family). Among natural flats wetlands considered across all years, most-impaired sites had greater average abundances of *Culicidae* (mosquitoes), *Pseudosmittia*, *Corynoneura*, and *Psectrocladius* (all three are chironomid midge genera), while least-impaired sites had five taxa groups that were completely absent from most-impaired sites: *Ephemeroptera*, *Sphaeriidae* (fingernail clams), *Menetus* (planorbid snail genus), *Siphlonurus columbianus* (mayfly), and *Chaoborus* (phantom midge).

Community composition did not differ greatly between flat vs. riverine sites, or between natural vs. restored sites. For the dataset across all four years of sampling, restored sites had a higher within-group similarity (40% average similarity) than did natural sites (33% average similarity), while natural and restored sites had 68% average dissimilarity. When considered according to both HGM class and ecological type, restored riverine sites showed slightly higher within-group similarity than was seen among all natural riverine sites (39% vs. 33% average similarity). A similar trend was seen for sites in the flats class, with restored flats having a higher within-group similarity than natural flats sites (38% vs. 33% average similarity, respectively). Overall community composition differed little among different groups, but restored flats had a greater average abundance of odonates and corixid bugs, while natural flats had more non-chironomid *Diptera*.

<u>Annual variation in macroinvertebrate communities</u>

The overall level of variation in the macroinvertebrate community at the same site across multiple years was similar among all the sites examined as a group (mean community similarity across years for all sites = 56.3% $\pm$ 9.4). This mean was virtually identical when the average similarity across years for all sites was examined in relationship to different HGM classes or ecological type. In addition, the mean % similarity across years in community composition was virtually identical for riverine vs. flats wetlands, and for natural vs. enhanced. However, the mean % similarity across years in community composition differed significantly when sites were examined according to HDA class ($p = 0.0282$), with most-impaired sites exhibiting a greater % similarity in community composition from year to year (mean similarity = 59.5% $\pm$ 9.4) than least-impaired sites (mean similarity = 50.0% $\pm$ 8.0).

The same relationship was observed when natural wetlands were considered as a separate group. Among all natural riverine sites sampled across multiple years, the mean % change annually in community composition was the same as that seen for all sites together (56.6% $\pm$ 10.8). However, when the mean % similarity in community composition was examined for natural riverine sites in different

HDA classes, the mean annual % similarity at least-impaired sites was significantly lower than that seen at most-impaired sites (class 1 mean community similarity across years = 47.4% ± 7.7; class 3 mean = 69.3% ± 4.7; p = 0.0395). Similar calculations were not possible for natural flats sites sampled across multiple years, as this subset consisted of only a single least-impaired and two most-impaired sites.

Restored sites examined according to level of human disturbance not did exhibit the same difference in mean community similarity across years. The mean similarity across years for all restored sites was again similar to that seen for all sites in general (57.7% ± 8.7), and while the mean annual community similarity was greater at most-impaired sites (61.1% ± 11.1) vs. least-impaired (55.0% ± 2.8), this difference was not significant (p = 0.5270).

Geometric class plots

The higher degree of community similarity from year to year at most-impaired sites described above suggests that these highly impaired wetlands support a more restricted macroinvertebrate community, one likely more tolerant of disturbance and/or pollution. The higher degree of change annually at class 1 sites, combined with the lower degree of community similarity overall among class 1 as compared to class 3 sites, suggested that least-impaired sites may support a greater diversity of rare species. Because taxa that contributed the most to observed within-site similarity among class 1 sites were common and abundant, it is likely that the rare species these sites support occur at low abundance, and the rare species present may change from year to year. We investigated this further using geometric class plots drawn in PRIMER, to show species abundance distributions among different wetland categories (i.e. HDA class, natural vs. restored, and HGM class). Geometric class plots of individual sites sampled across multiple years reflected the annual changes in community composition seen using SIMPER analysis, with wide variation each year in the proportion of species represented by fewer than 15 individuals (geometric classes 1-4). This change in the distribution of geometric abundance classes from year to year at the same site appears to be true at both least-impaired and most-impaired sites (Figure 10). Multiple sites that had been sampled across several years were examined and the same pattern was seen. These plots also reflect the greater similarity between macroinvertebrate community composition in 2007-2008 compared to 2009-2010, as the curves for 2007 and 2008 follow each other more closely than the curves for the later years, while the curves for 2009 and 2010 follow a similar pattern together.

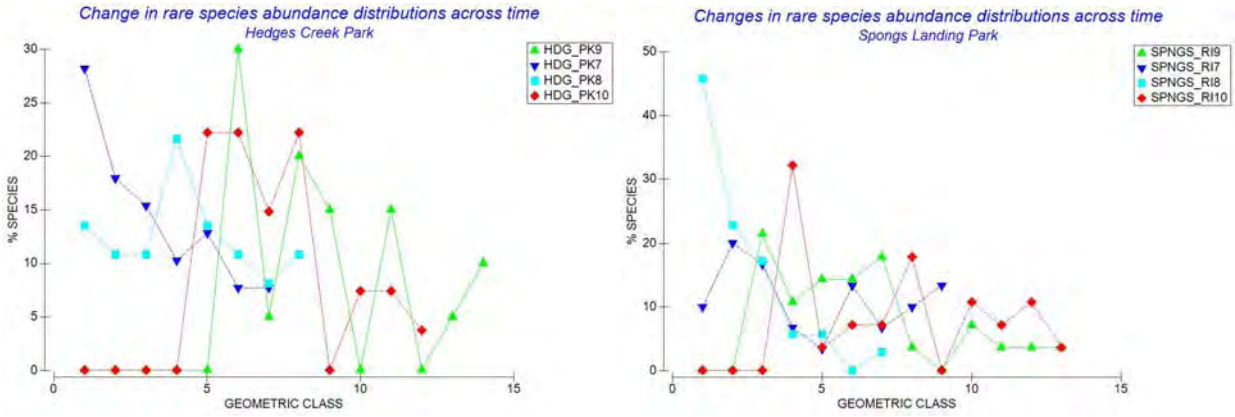
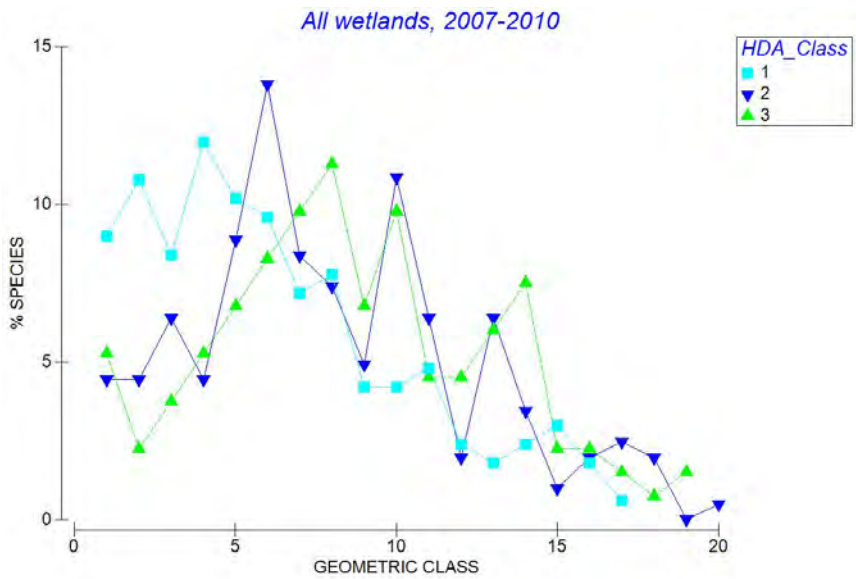
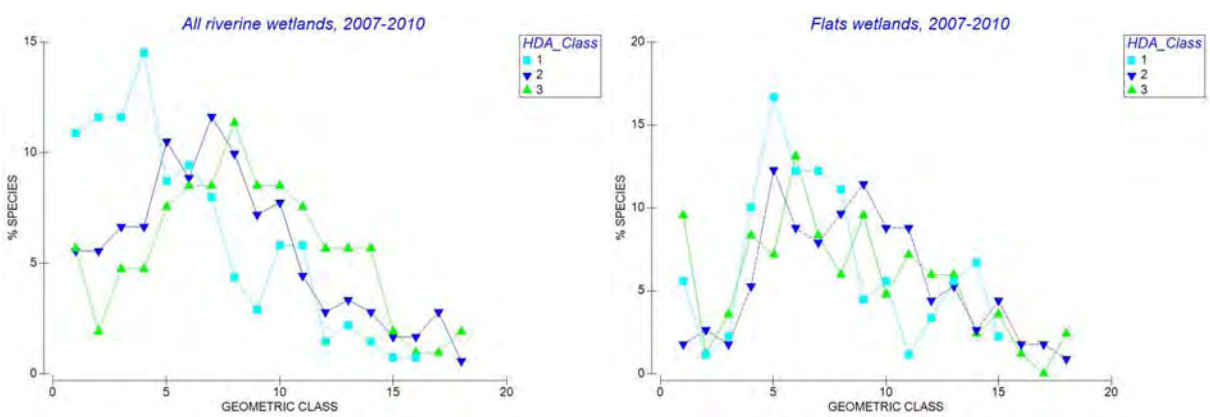


Figure 10. Annual within-site variation in rare species distribution among sampling sites. Plots show the proportion of total species at the sites represented by 1 individual in the sample (geometric class 1), 2-3 individuals (geometric class 2), 4-7 individuals. Hedges Creek Park (most-impaired, enhanced riverine site).and Spongs Landing Park, riverine-impounding (a least-impaired, natural riverine site).

Analysis of all sites sampled across all years showed a greater proportion of species in low geometric classes for least-impaired sites compared to most-impaired sites (Figure 11 A). This same pattern was seen when all riverine sites were examined as a group, with class 1 sites exhibiting greater proportions of rare species (Figure 11 B); however, little to no relationship between rare species abundance and HDA class was observed among all flats sites sampled, and the geometric abundance plot curves were similar for all three HDA classes (Figure 11 B).



A. All sites, all years (2007-2010)

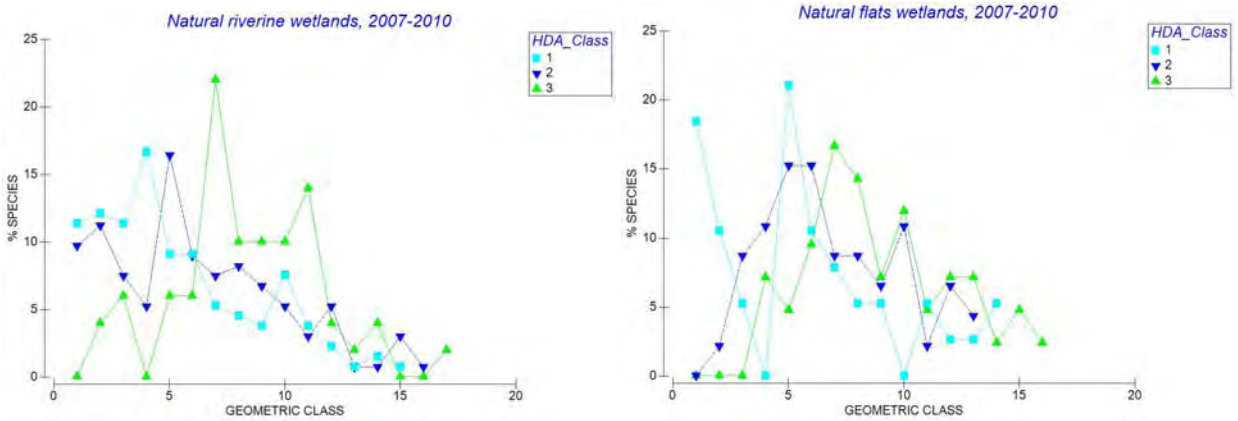


B. Riverine vs. flats sites

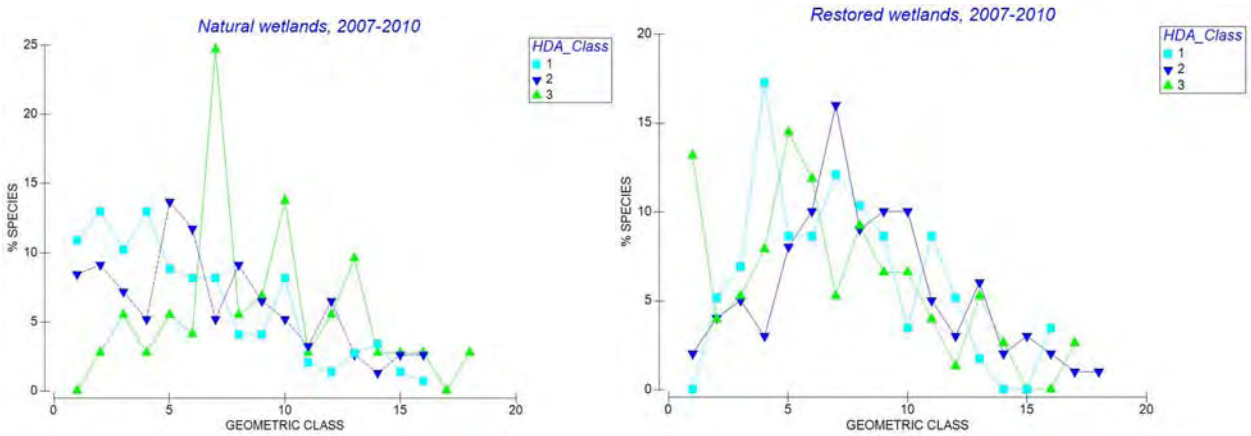
Figure 11. Difference in rare species abundance distributions among wetlands experiencing different levels of human disturbance. Class 1 = least-impaired; class 2 = intermediate impaired; class 3 = most-impaired.

To investigate whether the reduced proportions of rare species among flats wetlands was related to ecological type, we examined rare species distributions for both natural riverine(Figure 12 A) and natural flats sites (Figure 12 A), and compared rare species distributions between natural (Figure 12 B)and restored sites (Figure 12 B). Higher proportions of rare species were present among least-impaired sites

for both natural riverine and flats wetlands, while rare species were either absent or present at a much lower proportion of the total species among most-impaired sites. The situation was quite different among restored wetlands, however, with most-impaired sites exhibiting the highest proportion of species in the lowest abundance classes.



A. Natural and riverine and natural flats sites, all years



B. Natural and restored sites, all years

Figure 12. Relationship between rare species abundance and human disturbance levels among natural and restored wetlands.

<u>Regression analysis of macroinvertebrate community attributes</u>

To develop an invertebrate-based bio-assessment tool, it is necessary to identify macroinvertebrate community attributes that vary consistently and predictably at reference wetlands according to a gradient of human disturbance. Community attributes used as biotic index metrics generally represent different categories including taxonomic richness, taxonomic composition, tolerance/intolerance, and functional feeding group (Barbour *et al*. 1999). The choice of macroinvertebrate community attributes examined in this study (Table 1) was guided by past work done to develop wetland and lake invertebrate IBIs in other states, including New Jersey (Blocksum *et al*. 2002), Michigan (Burton *et al*. 1999, Uzarski *et al*. 2004), and Minnesota (Galatowitsh *et al*. 1999, Helgen & Gernes 2001), and analyses (described above) of wetland invertebrate community data collected by Xerces in 2007-2008 as well as in 2009-2010. Wetlands designated as "natural" served as reference sites throughout the study.

Despite the differences in community characteristics suggested by PRIMER analysis of taxa abundance data, such as taxa contributing to differences between different wetland categories and differences of rare taxa abundances, strong correlations between wetland site disturbance (HDA) score and invertebrate community attributes were generally absent to weak (i.e., R^2 values for attributes that showed correlation ranged only from approximately 0.1 to 0.4). In addition, attributes that correlated with site disturbance among sites from one year of sampling data frequently showed no correlation with data from a different year. The attributes that exhibited consistent correlation with impairment gradient across consecutive years at both riverine and flats reference wetlands included % abundance of highly tolerant taxa, # of predator taxa, and # of *Coleoptera* (beetle) taxa. Attributes that exhibited consistent correlation with impairment gradient across consecutive years in only one HGM class of reference sites included % diversity of highly tolerant taxa (riverine) and 0% abundance *Gastropoda* (flats). However, the strength of correlation for all of these attributes was low to moderate, based on R^2 values.

Regression analysis conducted on all natural riverine and natural flats wetlands across all years of sampling revealed almost no consistent relationships between community attributes and site impairment gradient among riverine sites. R^2 >0.1 was seen for only a single community attribute (abundance), and the strength of the correlation was very weak (R^2 = 0.1072). Total nitrogen, phosphorus, and conductivity also showed a weak correlation with site impairment, and were higher at more impaired sites (R^2 = 0.1773, 0.1057, and 0.1196, respectively). In contrast, many more and much stronger correlations were seen for attribute values among natural flats sites, with 28 macroinvertebrate community attributes varying with site impairment gradient, and with R^2 values ranging from 0.1164 to 0.5618. Conductivity also showed a weak correlation with site impairment gradient, and was higher at more impaired sites (R^2 = 0.1778).

Xerces' pilot studies in wetland bio-assessment were conducted initially in riverine wetlands (2007-2008), and the flats category was added only as the study expanded in 2009-2010. As a result, almost all of the natural riverine wetlands in this study were sampled across three or four consecutive years, while each flat site was sampled across one or two years. We noted earlier that for sites sampled across multiple years, macroinvertebrate community composition is most similar between 2007 & 2008, and between 2009 & 2010. Most natural riverine wetlands were sampled across a longer period of time, and thus the calculated community attributes will be more affected by annual within-site variation. Most natural flat sites were sampled only in 2009 and 2010, and the results of regression analysis do not reflect the level of within-site community variation that is likely to occur across a longer span.

One explanation for the overall poor discriminatory ability of regression analysis lies in the extremely high levels of variation seen among all reference sites experiencing intermediate levels of disturbance (class 2). This variation is not unexpected and may be explained by the intermediate disturbance hypothesis (Connell 1978), which suggests that taxa diversity is greater in systems that experience a moderate level of disturbance than in systems with high or low degrees of disturbance. It is possible that while most-impaired sites experience a level of stress such that more sensitive or intolerant taxa can no longer survive and perhaps do not attempt to colonize, sites experiencing intermediate disturbance may have differential survival of different taxa groups, opening up new niches repeatedly to colonization. PRIMER analyses described above revealed that most-impaired sites had the highest degree of internal community similarity, and that differences in community composition were most pronounced between class 1 and class 3 sites. Therefore, we examined whether there was a significant difference between the mean values of attributes for class 1 and class 3 reference wetlands across all years sampled (2007-2010, but note that some reference sites were only sampled for a subset

of that period). Due to the observed differences in invertebrate community composition, we examined riverine and flats reference wetlands separately (Table 3).

Among natural riverine wetlands, 12 community attributes were significantly different between class 1 and class 3 sites, although three were redundant as they measure aspects of the same group (highly tolerant taxa). Two of these 12 attributes (# of highly tolerant taxa, # of non-insect taxa) were among those selected as potential IBI metrics following analysis of the 2007-2008 dataset. Seven attributes were found to be significantly different among most-impaired and least-impaired natural flats sites, three of which were redundant (all measuring aspects of *Ephemeroptera*, *Trichoptera*, *Sphaeriidae*, dragonflies [ETSD] taxa). Five of these seven attributes also correlated with site impairment gradient in regression analysis, and one was among those selected as potential IBI metrics based on the 2007-2008 data (% diversity collector/gatherers). Only one attribute differed significantly between most- and least-impaired sites among both natural riverine and flats wetlands (% abundance *Sphaeriidae*).

Table 3. Significant differences in means of macroinvertebrate community attributes between least- and most-impaired natural wetlands (*p value <0.05; **p value between 0.05 and 0.1).

Natural riverine wetlands	
Attribute	Mean greater at:
Abundance	class 3*
# of highly tolerant taxa (MHBI 8-10)[a]	class 3*
# of non-insect taxa	class 3**
# genera (*Crustacea* + *Mollusca*)	class 3**
# genera ECOT[b]	class 1*
% diversity highly tolerant (MHBI 8-10) [a]	class 3*
% abundance highly tolerant (MHBI 8-10) [a]	class 3*
% div. *Crustacea*	class 3*
% diversity (*Crustacea* + *Mollusca*)	class 3*
% *Chironomus*[c] of total *Chironomidae*	class 3**
# taxa *Coleoptera*	class 1*
% abundance *Sphaeriidae*[d]	class 3*
Natural flats wetlands	
Attribute	Mean greater at:
% diversity collector/gatherers	Class 3*
% abundance *Chironomini*[e]	Class 3*
# taxa ETSD[f]	Class 1*
% diversity ETSD	Class 1*
% abundance ETSD	Class 1*
% abundance *Chironomus*[c]	Class 3*
% abundance *Sphaeriidae*[d]	Class 1*

[a] MHBI = modified Hilsenhoff Biotic Index
[b] ECOT = *Ephemeroptera*, *Coleoptera*, *Odonata*, and *Trichoptera*
[c] tolerant genus of chironomid midge
[d] fingernail clams
[e] tribe of chironomid midges with many tolerant genera
[f] ETSD = *Ephemeroptera*, *Trichoptera*, *Sphaeriidae*, and dragonflies

Invertebrate-based assessment of wetlands

In 2009, Xerces developed set of preliminary IBI metrics, according to data from riverine wetland reference sites sampled in 2007 and 2008. These preliminary metrics were selected based on three criteria:

- Linear regression against site HDA scores with an R^2 value >0.25
- Significant difference between the means of class 1 vs. class 3 sites ($p < 0.05$)
- Sufficient range within the attribute values that a scoring system could be devised

Because sites were grouped into three main impairment classes, potential metric values from 0 to the 95th percentile were trisected (Karr *et al*. 1986). Values in the top one-third received a score of 1, values in the middle third received a 3, and values in the bottom third received a 5. The trisection method is thought to be best for scoring in regions where conditions are such that nearly all reference sites are thought to be impacted (Gerritsen *et al*., 1988), which is true of wetlands in the Willamette Valley. The trisection system was also used by the Minnesota Pollution Control Agency in developing biological IBIs for wetland assessment (Gernes & Helgen 2002). To be consistent with the HDA score ranking, attribute ranges corresponding to least-impaired condition were assigned an IBI score of 1, and ranges corresponding to more severely impaired conditions were scored as 5.

Table 4. Preliminary invertebrate-based IBI for Willamette Valley riverine wetlands (based on sampling data from 2007-2008). For each metric, the range corresponding to least-impaired sites is given the lowest possible score (1).

Attribute	Metric range	Score	Rationale
# of highly tolerant taxa data range 4-20	0-6 7-12 13-21	1 3 5	Increases with site disturbance
# of predator taxa data range 0-18	0-5 6-11 12-18	1 3 5	Increases with site disturbance
# genera in Chironomini data range 1-8	0-2 3-5 6-8	1 3 5	Increases with site disturbance
% diversity collector/gatherers data range 37-100%	>48% 25.1-48% 0-25%	1 3 5	Decreases with site disturbance
# of non-insect taxa Data range 3-13	0-4 5-9 10-13	1 3 5	Increases with site disturbance
Simpson Index ($1-\lambda$) Data range 0.31-0.93	0-0.31 0.32-0.63 0.64-0.93	1 3 5	probability that 2 randomly chosen individuals will belong to same taxon; increases with site disturbance
Total possible IBI scores			Near-pristine = 6 Severely impaired = 36

In 2009, the macroinvertebrate community composition at all sites differed enough from previous years that the preliminary IBI metrics performed very badly, losing nearly all predictive power. At that point, it was unclear whether the data from the 2009 field season represented an anomaly, due to

differences in winter and spring weather, or if it reflected a true normal level of annual variation in community composition. The preliminary IBI metrics also performed very poorly for the 2010 dataset, which again was shown to be more similar to that of 2009 than to previous years. The data ranges for each attribute in the metric (shown in Table 4) had changed slightly in 2009 and 2010, which may have been responsible for the poor IBI performance in those years. To investigate this, scoring for each metric was recalculated by determining the 95th percentile of each metric based on the 2009-2010 data and trisecting that value. However, the entire IBI still performed badly under the revised scoring system.

Rapid Assessment and Detailed Effectiveness Monitoring

Ecosystem Services (Wetland Functions and Values)

ORWAP results from 60 wetlands, demonstrates that these wetland as a whole are probably most effective for Sediment Retention. Almost equally, they are effective for Organic Matter Export, Resident Fish Habitat, Waterbird Feeding Habitat, and Habitat for Songbirds, Raptors, and Mammals. They are least effective for Anadromous Fish Support, Thermoregulation, and Waterbird Nesting. The potential values of the functions, based mainly on the location of these particular wetlands relative to upslope and downslope potential beneficiaries, are likely greatest for Pollinator Support, Wetland Invertebrate Support, Water Storage & Delay, Songbird Habitat, Plant Diversity, and Public Use.

Comparing these wetlands to a nonrandom set of 221 wetlands assessed statewide (Adamus *et al*. 2009b), these wetlands on the average scored lower with the exception of only one function (Resident Fish Habitat). Although difficult to compare, this may suggest that the wetlands in this study are functioning at a lower level than statewide wetlands. The potential values of their functions was greater than wetlands statewide for Water Storage, all the water quality functions, Resident Fish Habitat, and Pollinator Habitat.

Using ORWAP, no between-year differences could be detected in functions at any of the sites. ORWAP did not detect the briefly wetter conditions in 2010 because, in order to maintain consistency among users, many ORWAP questions are intentionally phrased in terms of what conditions would be like during a normal year rather than conditions at the moment a wetland is visited. ORWAP may nonetheless be capable of detecting changes over longer periods (e.g., 5 years) in many functionally-relevant wetland features that are susceptible to management, such as the category and general pattern of vegetation.

Vegetation Characteristics

A total of 367 plant species were identified from 1546 quadrats and 55 wetland sites. At least 16 (4%) of these species occurred in more than half of the sites, and 138 (38%) were found in more than 10%. Of all the plant species, 40% were non-native and 60% were native or indeterminable; 13% were invasive. Also, 60% were forbs and 58% were species listed officially as wetland indicators. On a per-quadrat basis, the number of species averaged 5.08 (1.84-13.50) of which 2.41 (1.10-7.35) were non-native. Non-native species were found as dominants or co-dominants in an average of 75% (30-100%) of the quadrats per wetland, and invasive species in 57% (5-100%). Overall, invasive species were found in 75% of the quadrats, were co-dominant or dominant in 55% of the quadrats, and were dominant in 27%.

Table 5. Invasive species distribution and abundance

Name	% of Sites	% of Quadrats	Name	% of Sites	% of Quadrats
Phalaris arundinacea	84	37	*Rubus armeniacus*	49	6
Holcus lanatus	60	11	*Mentha pulegium*	42	15
Alopecurus pratensis	49	11	*Lotus corniculatus*	42	8
Solanum dulcamara	47	7			

Where reed canary-grass was present, its percent-cover averaged 42% per quadrat. Native plants comprised more than 80% of the cover in 9% of the wetlands[2] and more than 50% of cover in 56% of the wetlands.

These statistics are but a few of dozens that were calculated or could be calculated from the collected data, in order to describe these wetlands more fully. They are important because along with statistics calculated from other similar accessible databases (e.g., McCain & Christy 2005, Adamus 2001), they help establish normative conditions and thus what may be reasonable to expect as performance standards among Willamette Valley riverine and flats wetlands, both "unmanaged" and ones in various stages of restoration or enhancement.

Birds and Other Wildlife

A total of 114 bird species, averaging about 27 per wetland, were identified from 55 wetland sites over the two summertime field seasons. Four of these were detected in >90% of the sites (American Goldfinch, Barn Swallow, Song Sparrow, Cedar Waxwing), 22 in more than half of the sites, and 58 in more than 10% of the sites. Of all the birds detected, 34 (30%) were species that are clearly wetland obligates, the most frequent being Common Yellowthroat (47 wetlands), Red-winged Blackbird (35), Killdeer (33), and Mallard (27). On a per-site basis, in 2009 the number of bird species averaged 23 (10-39) of which 19% (0-49%) were wetland obligates. In 2010 the total averaged 14 (6-33) per site of which 22% (5-53%) were wetland obligates. As noted earlier, all the bird detections were incidental to other survey activities and no data were collected using standard protocols for bird surveys. Similarly, no standard protocols were used to survey amphibians, but adults of four amphibian species were noted incidentally: American Bullfrog (58% of the wetlands), Pacific Treefrog (27%), Rough-skinned Newt (2 sites), and Northern Red-legged Frog (1 site). Nutria were noted at 11 sites.

Stressors and Management Features

On a scale of 0 to 10, the median value for ORWAP's Stress metric was 5.34 (range 1.41- 7.41), compared with a median of 5.70 from 221 nonrandomly selected wetlands statewide. Sites identified by this metric as having the highest relative levels of potential stress from water level alterations, soil disturbance, polluted runoff, and/or other factors were Knez and Arbor Station. The metric averaged higher for Riverine sites (5.19, range 1.41-7.41) than for Flats (4.86, range= 1.41-6.78). A somewhat analogous metric, the Human Disturbance Assessment index (HDA) which was developed originally by a wetland monitoring project in Minnesota and applied by Xerces, also averaged higher in Riverine wetlands. The sites it identified as having the most actual or potential human disturbance were Hedges Park, Endicott, Corvallis Airport, and Knez. The sites with the least disturbance values were Spongs riverine flow-through, Spongs riverine impoundment, McDonald Forest and Jackson-Frazier.

[2] Jackson-Frazier enhanced, Budeau restored, Tualatin Hills, Willow Creek riverine, and Finley Brown Swamp enhanced.

Soils

In soils collected from 53 wetlands, the median concentration was 3.05 ppm for zinc, 4.00 ppm for copper, and 295 ppm for iron. For the western United States in general, mean concentrations in soil in relatively unimpaired settings are 55 ppm for zinc, 21 ppm for copper, 210 ppm for iron, and 380 ppm for manganese (Shacklette & Boerngen 1984). Among the 53 Willamette wetlands, 9% exceeded this regional mean for zinc, 42% for copper, 72% for iron, and none for manganese. Soil zinc concentrations were significantly higher in Riverine wetlands than in Flats (Mann-Whitney test, $p<0.05$), but no other soil parameter differed significantly by HGM class.

No definitive ecological standards exist for metal concentrations in wetland soils, but a limited review of literature suggests that the levels of zinc, copper, and manganese we measured are unlikely to be toxic to plants in any of the surveyed wetlands. In contrast, in at least half the wetlands, the levels of soil iron might have been toxic to some plant species that otherwise would have been present. Wetlands with the most soil iron were Town Center (Woodburn), Hedges TWC, Summer Creek, and Arbor Station. Wetlands with the least soil iron were Alton Baker, Spongs riverine flow-through and Newton Creek. Highest levels of zinc were at Delta Pond, Garden Lakes, Knez, Summer Creek, Hedges TWC, and Stewart Pond North. Lowest levels of soil zinc were found at Coyote Creek, Wyman and Deer Creek Park. Wetlands with the most copper were Portland Vanport and surprisingly, Buford East and McDonald Forest. Lowest copper amounts were at Hedges TWC, Corvallis Airport and Wyman. And those with the most manganese were Willow Creek, Seavy, and Fisher Butte. Those with the least manganese were Mt. Pisgah Arboretum, Alton Baker and Delta Pond.

Nutrients

Nutrients (mainly phosphorus, nitrate, and potassium) can also influence plants, but their actual effect is difficult to discern without repeated sampling and simultaneous measurement of levels in plant tissues. In soils of these 53 wetlands, the median level of total Kjeldahl phosphorus was 697 ppm (range= 242-2042), nitrate was 3.51 ppm (0.1 – 47.03), and potassium was 143 ppm (63-1041).

Soil organic matter is important to plant growth, soil invertebrates, and the cycling of several elements in wetlands. The median level of soil organic matter was 7.08%, with a range of 1.03 to 18.98%. Sites with the most soil organic matter were Jackson-Frazier, Hedges TWC, and Delta Pond, while those with the least were Spongs Riverine Flow-through, Randall, and Wyman. In previous sampling of 95 wetlands in the Portland area, Shaffer & Ernst (1999) found the mean level of soil organic matter to be 9.75% in Reference wetlands and 5.83% in mitigation wetlands.

Sampling Effects

In 2010, an unusually wet spring lead to overall wetter conditions at many of the sites which may have introduced some differences in vegetative conditions. Reducing the sampling requirement from 20 quadrats to 10 quadrats per site led to less time at each wetland which may have unintentionally influenced the number of avian detections at sites. Sampling dates began on May 20, and May 21 in 2009 and 2010, respectively, and ended on September 5 and September 4 in 2009 and 2010, respectively. Sample sites later in the season tended to occur at wetter sites and may have a correlation with vegetation communities. Differences in plant identification tended to have more unidentifiable plant taxa at sites with persistent water.

Representativeness of Vegetation at the Invertebrate Plot

Data analysis indicated that during both years more than half the vegetation metrics from just the one invertebrate quadrat, which corresponds with the invertebrate samples collected, correlated

significantly with the same metrics compiled from 10-20 vegetation quadrats. This is remarkable, considering that the vegetation quadrats were scattered throughout the entire wetland. It suggests that among-site variation in most of the vegetation metrics was more significant than within-site spatial variation.

Plant-based assessment of wetlands

Data from this study have provided some potentially useful benchmarks for future performance standards in the Willamette Valley. For example, Table 6 shows levels that might be considered for use on a case-by-case basis as realistic performance standards for Willamette Valley wetlands sampled in the same way as this study. In this case, Poor, Fair, Good, and Excellent are defined, respectively, by the 10th, 25th, 75th, and 90th percentiles of the extensive data collected by this study.

Table 6. Examples of possible performance standards for Willamette Valley wetlands derived from plant metrics.

	FLATS				RIVERINE			
Metric	Poor	Fair	Good	Excellent	Poor	Fair	Good	Excellent
Number of plant species per quadrat (RichAllQdAvg)	<3.85	3.85-5.45	8.00-9.95	>9.95	< 4.14	4.14-5.00	7.85-9.46	>9.46
% of quadrats with >9% cover of invasive plants (xFqInvGT9)	>75	51-75	8-20	<8	100	100	55-70	<55
Average percent cover of invasive plants (PCinvQdAv)	>46	28-46	7-12	<7	>74	57-74	16-24	<16

Landscape Profiling

Landscape profiling involves assessing wetlands and predicting the wetland condition based on remote sensing methods. For example, a wetland that is in closer proximity to an urban area may be more likely to be impacted by hydrologic changes, increased nutrient runoff and higher percentages of invasive species as opposed to a wetland in a more remote area. The advantages of this method are that it can be done, for the most part, with existing data and it can be performed in an office environment at any time of the year. Disadvantages include the detail of information about wetlands is limited to the data that are currently available (e.g., not all wetlands are accurately mapped) and strong GIS skills are required. A limited landscape profiling approach was used for this project for identifying potential sites for evaluation. Potential sites needed to represent a range of conditions to fully evaluate the effectiveness of restoration, mitigation, or enhancement projects. Listed below are the variables that were assigned using this approach.

Contact Agency (OWEB, DSL, Xerces)
Site Status
Wetland Name
Prior wetlands activities (voluntary restoration, mitigation, enhancement, none)
Action Description

Detailed Action Description
Action Completion Date
Elevation
Soils Data
Floodplain and flood information
Topographic map / Aerial Photo
Local and National Wetland Inventory Map

Sites were then further filtered by wetland size, current hydrogeomorphic (HGM) classification, historic HGM classification, surrounding land use and location. This landscape profiling approach helped demonstrate the relative abundance of typical vs. atypical wetlands and it also provided additional information about sampling sites and led to improved consistency and accuracy in the site selection process. It is anticipated that future work could refine this approach and develop a base set of parameters which could be further developed in Oregon for predicting wetland condition by HGM sub-class and prioritizing wetland restoration, mitigation or enhancement projects based on a level of condition.

Database and Mapping Improvements

The goal of database and mapping improvements was to review and analyze historic permit file information and to subsequently incorporate project information into the existing geodatabase structure maintained by DSL, including through improved mapping of projects via geographic information systems (GIS) software. This mapping exercise includes information prior to 1999 through 2008 when current mapping and data management standards were institutionalized by the agency. Previous information may have been mapped only to the accuracy of a centroid of a legal or PLS section. In addition, older projects sometimes suffered from having vague or incorrect information provided by permittees. For these projects, information was lacking on any potential wetland loss or gains. This information is critical for determining the state's performance regarding its "no-net-loss" policy. In addition, precise GIS information is important for prioritizing future wetland mitigation and enhancement activities. At the start of this project approximately 2,600 wetland mitigation and restoration projects were preliminarily identified for inclusion in the geodatabase. Information from wetland gains or losses was gleaned from the project files as well. The work was divided into four phases:

- Phase 1 included approximately 475 projects from the time period 1/1/03 to 5/6/08
- Phase 2 included 339 projects from 12/31/99 to 12/31/02
- Phase 3 included 129 projects from 5/6/08 to present

During implementation of phase 4 it was determined that only 985 projects in this time period required mapping, revised downward from about 1600 projects. Reasons for this reduction are that projects did not have enough information to be accurately mapped or were inappropriately categorization initially. There are approximately 265 sites that are not yet completely integrated into the geodatabase maintained by DSL; however DSL remains committed to this process and will work to complete the last remaining projects in a timely manner.

Currently, this information is primarily available through DSL staff, but over time the intent is to make this information readily available for the public. It is anticipated that a GIS database with limited,

relevant attribute information will be made available for posting on the Wetlands Explorer website in the near future once this exercise is completed.

Improvements to DSL's database—the Land Administration System (LAS)–were made with the intent of improving the quality and management of data contained within the wetlands resource gains and losses portion of the database. During development of this project, the partners identified that a more timely and efficient way of reporting the status and condition of wetlands across Oregon could better inform decisions about wetland management and enhancement. LAS was reorganized to allow categorization of resource gains and losses according to the certain program activities. The following program activities were included for categorization: permit applications and enforcement actions, compensatory and voluntary restoration actions, and physical resource gains and losses and ledger (mitigation banks, payment in lieu and fee in lieu) types. These changes allow for more effective queries to extract the data. In addition, LAS is now able to record and track resource gains and losses and can integrate ecological attributes of the resources that are gained or lost. The system also is able to record gains and losses through data emerging from active monitoring. Another added feature from this effort is the allowance of data analysis that can provide up-to-date status of the wetland resource, thus enabling long-term tracking of wetlands in Oregon.

Program improvement includes:

- Preparation of existing data for data migration:
    - DSL monitored more than 300 existing compensatory mitigation sites and updated existing records in preparation of data migration.
- Development of routine monitoring protocols:
    - DSL developed a comprehensive guide to mitigation site monitoring for use by consultants and staff to improve the quality of data related to mitigation site performance.
- Preparation for the implementation of the new database improvements:
    - DSL has created new data entry forms and is in the process of training staff to use the new database components.

Although the LAS improvements listed in this report are complete, the database is still in test format and has not been implemented for use by all DSL staff. DSL will augment other portions of the database, as the highest priority, to accommodate new permit instruments that go into effect on March 1, 2011. These changes will allow DSL to track post-construction monitoring results for all permits with information about project design compliance, area of authorized impact, site restoration of impaired areas and implementation of erosion and sediment control best management practices. Rollout of the improved database with components identified above and augmented with additional capacity provided by DSL is intended to commence on March 1, 2011

The inclusion of the mapping and database improvements in this monitoring strategy is important to provide overall consistency and accuracy on several fronts; for example, when employing a landscape profiling monitoring exercise, when prioritizing locations where restoration and mitigation projects may provide the most benefit with limited resources, and in determining if restoration and mitigation actions are consistent with wetland functions and processes most likely to be anticipated for an area. This information may also provide necessary tools for evaluating the condition of wetlands. Ultimately, the intent of this work is that information collected from multiple types of actions and during all three tiers of wetland monitoring mentioned in this framework can be compiled into a common database for reporting on wetland condition and status in Oregon.

Conclusions

The project partners established broad categories—*Restored, Enhanced, Reference/Natural*—in which to place each of the wetlands sampled. In order to appropriately categorize these wetlands, the history of past conditions and management actions, along with the effects of outside factors (e.g., effects of nearby land management) and the type and quality of restoration or enhancement work being undertaken, must be known. On most sites selected for this study it was difficult to ascertain necessary details, which are listed in general order of descending confidence,

- whether the site was originally a wetland
- types of subsequent alterations
- duration and timing of subsequent alteration
- the exact locations of restorative or enhancing actions implemented within the site

In most cases, grant application or alteration permits lacked descriptive information on the conditions listed above. Current site managers who were interviewed sometimes had only limited knowledge of original conditions. A more thorough investigation involving work plans and site visits with project managers may yield additional insights for these actions. Such issues are common to nearly all published studies that have attempted to examine compensatory wetland mitigation in terms of simple categories, and yet simple categories are what are used to compute mitigation ratios.

Despite these uncertainties, results from this study confirmed and geographically extended the conclusions from previous research in parts of the Willamette Valley region. Key findings are summarized as follows:

- The macroinvertebrate sampling protocols and Human Site Disturbance Assessment (HDA) rubric used in this study are robust, reliable, and consistent among different trained practitioners.

- Based on consistent correlation with ORWAP stressor scores, HDA score provides a relevant reflection of the level of human impairment at a site.

- Multiple years of sampling at 50 wetlands of differing human impairment levels, HGM classes, and ecological types has expanded our knowledge of wetland taxa in the Willamette Valley and enabled building a larger ecoregion-specific dataset that may be used for reference purposes in the future.

- General differences in macroinvertebrate community composition were observed between riverine and flats wetlands.
    - Flats sites exhibit less annual variation in water chemistry parameters than riverine sites.
    - The macroinvertebrate community at flats sites overall is more restricted and composed of more tolerant groups.
    - A different suite of macroinvertebrate community attributes was significantly different among most- vs. least-impaired sites in natural flats and natural riverine wetlands.

- General differences between restored and natural wetlands:
    - Restored sites do not differ in water chemistry parameters compared to natural wetlands.
    - Macroinvertebrate community composition is very similar among restored and natural wetlands sites in the same HGM class.
    - Least-impaired restored wetlands do not have the higher proportions of rare species seen at least-impaired natural wetlands.

- The similarity of community composition among sites within the same class or category compared to sites in different categories renders it difficult to pinpoint indicator taxa whose presence or abundance differs significantly at different types of sites.

- Variation in macroinvertebrate community composition at the same site across consecutive years indicates a high level of dynamism. Because this level of annual variation occurred at sites across all impairment classes, it suggests that even least-impaired sites in the Willamette Valley are experiencing constant anthropogenic stressors that impact invertebrate communities, and that annual variation in invertebrates may naturally be high. It remains to be seen whether the annual variation in invertebrate community composition across time is too great to allow a stable invertebrate bio-assessment tool to be implemented.

- Changes in wetland invertebrate community characteristics are most apparent among natural wetlands experiencing different levels of human disturbance. These differences are mainly apparent when comparing natural wetlands that are highly versus minimally impaired.
    - Most-impaired wetlands having a more restricted and more stable macroinvertebrate community. These differences are apparent in both riverine and flats wetlands.
    - Most-impaired sites have higher levels of total Kjeldahl nitrogen, phosphorus, and higher conductivity than least-impaired.
    - Most-impaired sites have higher within-group invertebrate community similarity, lower annual variation in invertebrate community composition, and a lower proportion of rare (and possibly more sensitive) species compared to least-impaired sites.

    - Community attributes that focus on rare or sensitive species have not shown any predictive power. Attributes relating to highly tolerant taxa have consistently differed significantly between least- and most-impaired sites, especially at riverine wetlands.

- Previously, several researchers (e.g., Gwin *et al*. 1999, Morlan *et al*. 2010) have observed that *enhanced* wetlands in this region tend to contain more open water with longer seasonal duration than *reference* wetlands.
    - This was confirmed by this pilot study. Wetlands categorized as *enhanced* had significantly higher scores for Water Storage and other indicators.
    - Wetlands classified as *restored* were also wetter than *reference*, as indicated by greater number of wetland-obligate species and percent of all species that are wetland obligates.
    - The wetter condition of *enhanced* and *restored* wetlands could be due to management goals.

- No statistically significant evidence was found that wetlands categorized as *enhanced* were in worse or better condition than *reference* wetlands overall.
    - However, enhanced wetlands did have less cover dominance by regionally uncommon plant species, and a relatively few dominant species comprised most of the vegetative cover.
    - Comparing *enhanced* and *reference* wetlands, only three functions differed significantly. Pollinator Habitat and Plant Diversity functions were less in *enhanced* wetlands, but the Water Storage function (as noted above) was greater.
    - Although previous studies (e.g., Shaffer & Ernst 1999) found *Enhanced* wetlands to have generally lower concentrations of soil organic carbon than Reference, no statistically significant difference in this parameter was found between these categories in our study population.

- No statistically significant evidence was found that wetlands categorized as *restored* functioned at a relatively higher or lower level than *reference* wetlands (as estimated using ORWAP).
    - *Restored* wetlands had a greater average and maximum number of non-native (but not necessarily invasive) species among quadrats than *reference* wetlands. This could be due to recentness of some restorations, and might improve naturally if abiotic conditions trend towards stability.

- Relatively few statistically significant differences were found between Enhanced and Restored sites.
    - Enhanced wetlands did tend to have more surface water, a higher proportion of quadrats with significant cover of invasive plant species, more soil organic matter, and less soil phosphorus compared to restored sites.

- If the two stress metrics that were examined (ORWAP's stress metric and the HDA metric) truly represent key factors that may degrade wetland condition, then the relatively simple vegetation metrics used here, which correlated significantly and negatively in many cases with one or both stress metrics, appeared to be sensitive enough to react to those stress factors overall.

- Data analysis found significant correlations between Level II (ORWAP) and Level III (Detailed effectiveness monitoring).
    - Sites with invasive plants in a larger proportion of their quadrats had lower ORWAP scores for Resident Fish Habitat and Invertebrate Habitat.
    - Wetlands with a greater variety of plants happened to rate higher for the Nitrogen Removal but lower for Songbird Habitat functions according to ORWAP.
    - Wetlands with a relatively high soil zinc concentration tended to have a lower score for Invertebrate Habitat function according to ORWAP.

- Data from this study have provided some potentially useful benchmarks for future performance standards in the Willamette Valley. If the same vegetation metrics and protocols used here are used to evaluate performance of other restoration or enhancement sites or mitigation banks in the region, percentiles calculated from collected data could be used.

    - For example, Table 6 shows levels that might be considered for use on a case-by-case basis as realistic performance standards for Willamette Valley wetlands sampled in the same way as this study. In this case, Poor, Fair, Good, and Excellent are defined, respectively, by the 10th, 25th, 75th, and 90th percentiles of the extensive data collected by this study.

<u>Macroinvertebrate community</u>

By the end of this study, with up to four consecutive years of sampling data from some sites, the project partners hoped to identify community attributes that were robust across time, maintaining a predictive value unaffected by annual macroinvertebrate community variation at each site. Because linear regression analysis was largely unrevealing, and because PRIMER analysis did not pinpoint significant taxa differences, a comparison of community attribute means across all years for most- and least-impaired sites was used to find those that were significantly different (Table 2 pg.XX). All of these attributes have values that span a sufficient range across all sites to allow a scoring rubric to be developed (Table 3). However, it is recommended that all the attributes shown to be significantly different between class 1 and class 3 sites at natural wetlands should be investigated further before being incorporated into a formal IBI, for several reasons:

- As described above, several attributes that are significant for both riverine and flats wetlands measure different aspects of the same taxa group. Redundant metrics in an IBI must be avoided, as they artificially weight the final score. Therefore, it would be necessary to arbitrarily select a single attribute relating either to highly tolerant taxa for riverine wetlands, or to ETSD taxa for flats wetlands; however, sufficient data do not exist at this point to judge which among those redundant attributes will have the best predictive value. By selecting one and discarding the rest, the opportunity to examine multiple attributes further for their robustness and predictive power is lost.

- The reliability of the potential indicator attributes developed from natural flats wetlands is even more uncertain at this point, due to the fact that only a small number of reference flats wetlands could be identified for inclusion in this study, thereby resulting in a much smaller pool of reference flats compared to riverine sites, as well as a smaller subset of class 1 and class 3 sites for comparison. In addition, sampling data for flats sites covers only two years, as opposed to three or four years of data from the majority of reference riverine sites, so the continued significance of these attributes in the face of expected annual variation among reference site invertebrate communities is unknown.

- The wide range of values for all attributes among sites experiencing intermediate levels of impairment (class 2) renders use of an IBI problematic, as these sites are more likely to receive an artificially high or low IBI score that does not truly reflect their biological condition.

We therefore recommend that the full collection of attributes continue to be considered as a suite of potential indicators of human-induced wetland impairment, and that continued targeted testing be done to determine their robustness and predictive capabilities.

Recommendations

Additional analysis into classifying sites based on management actions (mowing, flooding, burning, planting, weed control) may provide additional meaningful results about how well or poorly these actions achieve improvements to wetland function or condition. Additional attention should also be paid to documenting information regarding the extent, timing, and location of the management actions.

Effort should also go into developing and conducting baseline monitoring that contains more information about the pre-project conditions at sites scheduled for restoration and mitigation actions. This investment may improve the ability to report on the effectiveness of wetland restoration and mitigation over time.

Although the two metrics intended to summarize stress or threat to wetlands were in general agreement and performed as expected with regard to predicting biological responses, they should be validated in the future by comparing their scores with detailed measurements of land cover using GIS and topographic information.

In summary, as wetland monitoring projects in this and other regions continue to evaluate overall success of restoration, mitigation and enhancement projects, the following steps should be addressed:

- Continue to use, as a criterion for selecting study sites, the amount and specificity (spatial and temporal) of information on the types of past and ongoing management actions.

- Place increased emphases on selecting sites where a before-and-after comparison can be made of ecological conditions, and then make such comparisons.

- Employ the protocols for vegetation monitoring and functional assessment used in this study, or similar protocols shown to be equally or more informative and cost-effective. Ideally, the protocols should be do-able by only a single field person visiting a site for one day.

- Allow for thorough data analysis at the conclusion of the field season and continue to refine and update methods over time and potentially measure new indicators (amphibians, water regimes).

- Support the long-term development of more sensitive indicators of wetland condition, such as the floristic quality assessment indices that many eastern states have developed.

Data analysis across up to four years of wetland sampling revealed two different suites of attributes that are significantly different at most-impaired versus least-impaired sites at natural riverine and natural flats wetlands. However, the data also indicate that there is substantial community similarity among natural wetlands at all levels of human disturbance, but that the community composition may change by as much as 50% from year to year at a single site. Therefore, in order to determine the most consistent and predictive indicators for wetland biological condition, and to better investigate the effects of restoration activities on wetland invertebrate communities, the following recommendations are offered:

- Investigate differences in macroinvertebrate communities among restored wetlands by sampling at a targeted selection of restored sites across more years. The most effective way to do this could be to focus on only most-impaired and least-impaired natural riverine and natural flats wetlands as reference groups, and attempt to pair reference with restored sites in the same area that are as similar as possible. The restored wetlands should also encompass a more limited post-recovery period, and be monitored for several years; the restored sites used in this study were at a different number of years post-restoration.

- Investigate the minor taxonomic differences seen between natural and restored sites to determine if they persist across time and have predictive value regarding the biological condition of restored wetlands.

- Incorporate a greater number of natural flats wetlands into the reference group, as many fewer natural flats than natural riverine sites were able to be identified for this study. It would be most effective to use only sites that are assessed as least-impaired and most-impaired.

- Obtain additional sampling data at all natural wetland sites to further assess the magnitude of annual variation in macroinvertebrate community composition at the same site sampled across consecutive years. This work will be especially important for the flats sites, for which only two years of sampling data were obtained.

- Continue to evaluate the consistency, reliability, and predictive value of the macroinvertebrate community attributes that were identified in this study as being significantly different between

most-impaired and least-impaired natural wetlands. If these attributes retain their significance across several years in the face of annual macroinvertebrate community variation, they may be considered reliable enough to be incorporated into an IBI.

- Depending on the results of continued testing of the above-mentioned attributes, it may ultimately be deemed more effective to use this expanded reference site dataset to generate a predictive model instead of a static IBI. The predictive model would compare identified attributes at a test site to those in a reference group of similar sites in the same ecoregion.

Next steps

These findings help demonstrate the need for providing more specific information regarding proposed wetland restoration and mitigation actions. From this effort, it was found that detailed information on pre-existing wetland conditions was lacking in some cases or not easily identified. Additional requirements from grantees/permittees, such as implementing some of the tools developed from this pilot study, may allow for a more complete perspective of current wetland condition and help to define what may be realistically expected for certain wetland types while preserving function and condition. Implementation of these, or similar, tools would allow OWEB to incorporate this information into our grant program to provide additional certainty that baseline conditions are adequately understood and results from monitoring efforts will continue to provide valid, reliable information. Implementation and further use of these tools including the improvements to the mapping and database information systems will allow for the continued tracking of wetland acreage gain and loss including the tracking of wetland condition and function over time. The results from this project shed light on the current state of wetlands as a result of restoration and mitigation practices and helped to identify what areas can be improved to increase the effectiveness of such actions. Current results from this study will be disseminated in different forums and delivered to groups including watershed councils, state and federal agencies, tribes, and professional groups. Other action items included in this project were to improve and increase the capability to report on the effectiveness of past wetland mitigation and enhancement actions, including mapping and database improvements. It is anticipated that this effort will make these data accessible to the public through the use of Oregon Wetland Explorer in the near future, thus providing a more widely accessible venue both for reporting of information and also the prioritization of restoration and mitigation opportunities.

Preliminary results from the Landscape profiling show that this method can be used effectively for site identification, identification of atypical wetlands, and prioritizing potential restoration and mitigation locations. In addition, the landscape profiling concept could be used to build a statistically valid sample of wetlands in a natural condition in order to provide reference sites against which to compare the results of management actions. This sampling process could also provide the means to improve the pre-implementation evaluations by making early determinations of proposed wetland restoration and mitigation sites.

Improvements to the quality and management of wetland data made by DSL under this project will allow for more detailed quantitative analysis of the ecological effects of the mitigation actions that have taken place over time. In addition, database refinements will allow for timely, accurate reports that can demonstrate the gains and losses in wetland function. It will be important to continue work to make this information more widely available, so that it can result in a clearer understanding of the suite of

restoration and enhancement actions taking place on a voluntary basis and as a condition of permit requirements, respectively.

Rapid assessment techniques such as ORWAP and the HDA have proven an effective method for evaluation of wetland condition and function. As this project demonstrates, ORWAP and HDA indeed show some measure of correlation and, thus, could be implemented by practitioners to assess wetland condition (HDA) and function (ORWAP). These methods also give a range of monitoring intensity that can be tailored based on the resources that are available. Creating a network of monitoring sites across the state that range in HGM class and wetland type (i.e., natural, restored, enhanced) is important for the long-term evaluation of wetland condition and the effectiveness of wetland restoration and enhancement. In addition, the conclusions from this pilot study (e.g. enhanced wetlands may be wetter than normal, restored wetlands may have higher % of non-native species) will be shared with people interested in wetland restoration to build upon past successes and improve the success of future projects.

Detailed effectiveness monitoring correlated to some degree with rapid techniques and, if implemented, could provide another level of evaluation that begins to answer questions relating to the changes in plant communities through time as a result of restoration actions. A high-quality effectiveness monitoring program for wetlands also will depend heavily on collecting baseline information so that pre-post comparisons can be made to determine the ecological outcomes of restoration efforts. This level of monitoring will require additional effort, but will provide critical results to inform future restoration investments.

Another tool that holds promise is the invertebrate-based bio-assessment. There is more refinement and development that is needed to expand these invertebrate indicators in other regions of the state and additionally to be more robust in the Willamette Valley. Additional years and sampling sites would help develop a more robust tool. When the invertebrate-based assessment tool is completed it would allow questions about the relative health of the wetland to be defined and would assess wetland health along a gradient of impairment. Already, this tool correlates with the HDA evaluation and with ORWAP.

These monitoring and assessment tools are intended for inclusion in an effort recently initiated by DSL to develop a Coordinated Wetland Program Plan for Oregon, combining information and outcomes from this study along with past efforts (e.g., development of ORWAP and two HGM guidebooks, data from more than 400 reference sites, etc.) to establish a broader wetland monitoring and assessment strategy for the entire state. The ultimate product will be a strategic plan developed in coordination with other agencies, tribes and resource practitioners that will function as a roadmap for mutual wetland protection goals and measuring progress in achieving those goals.

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Appendix A: Quality Assurance Program and Project Plans

Invertebrates and Water Chemistry

Consistency and accuracy:
All wetland sites are within a single ecoregion (Willamette Valley).

- Sampling will be done within a single time frame (mid-May 2009 & 2010), with all samples taken in the near shore zone of emergent vegetation. All efforts will be made to complete sampling within a 3-week period, if weather conditions and water levels permit.
- All equipment will be inspected, calibrated and tested prior to sampling.

Invertebrate sampling method:

- Samples will be taken in water 0.5-1m deep using a D-frame dip net with 500 μm mesh. Depending on the extent of dry down that has occurred at the time of sampling, some sites may have less than 0.5 m depth of water but still have sufficient water to allow net sampling.
- Two composite net samples will be taken at each site; each will be a composite of 3 sweeps repeated through three different 1 m transects, such that each composite sample represents 9 individual sweeps.

Invertebrate sample processing:

- Each of the two composite net sample sets from each site will be pooled separately in the field, large detritus rinsed and removed, and samples placed in labeled jars with alcohol added to a final concentration of 80%.
- Sample volume will be no more than 75% of the total volume in the jar. If a sample contains excessive amounts of organic material (i.e filamentous algae, plant fragments, etc) that will leach water from their tissues and effectively dilute the ethanol below the desired concentration of 80%, sample volume will be no more than 50% of the total volume in the jar.
- Jars will be drained in the lab and fresh 80% ethanol added to maintain sample quality.

Water chemistry:

- Conductivity, pH, dissolved oxygen, and water temperature will be measured and recorded at each site between 7:30 am and 11 am.
- Water samples will be collected in acid-washed sample jars provided by Alexin Analytical, Inc, and kept on ice until delivered to the lab for analysis of total Kjeldahl N, P, and Cl.
- Chemical analyses will be performed by Alexin Analytical Laboratories Inc., which is accredited by the Oregon Environmental Laboratory Accreditation Program (ORELAP). ORELAP is recognized by the U.S. Environmental Protection Agency's National Environmental Laboratory Accreditation Program (NELAP) to accredit environmental testing laboratories to national standards. The ORELAP identification number for Alexin Analytical is 100013. See Alexin sample processing QA/QC (attached).

Personnel and training:

- Xerces staff will train and monitor all field assistants. Samples will be collected only by qualified Xerces Society staff with extensive experience in stream assessment, sampling, and aquatic invertebrate identification.

- In order to complete sampling at all wetlands within the desired 3 week time frame, sites will be divided among 2 sampling teams operating simultaneously at different wetlands. Each sampling team will consist of a team leader (full-time Xerces staff: project manager and conservation associate) and a field assistant. Each team will be able to sample 2-4 sites per day.
- To minimize variations in sampling technique that could affect data collection, the project manager will work extensively with the team leaders to standardize the dip netting technique and render it as consistent as possible between the two sampling teams.
    - Sampling sites will be distributed as equally as possible among the teams, i.e. each team will be sampling wetlands of both HGM classes, and all levels of human impairment, and different management techniques.

Invertebrate identification:

- Identification of organisms to the lowest possible taxonomic level will be made by contracted experts (see QA/QC for ABR, Inc. below). Each composite sample will be randomly sub-sampled in the lab to a count of 500 organisms. The entire sample will be processed in the event that < 500 organisms are present. Samples will also be searched for "large and rare" organisms that may be missed during sub-sampling.

Documentation:

- Field documentation (maps, aerial photographs, topographic maps, data sheets, site descriptions), invertebrate taxa lists and data files will be stored electronically and on paper at the Xerces Society offices for at least 1 year after project completion.
- Wetland invertebrate taxa lists and details of the IBI will also be made available on the Xerces Society web site (www.xerces.org).

Measures to control, prevent, and/or avoid spread of invasive species :

- Physical site assessments made by contracted OWEB staff using the ORWAP protocol will provide additional information prior to sampling about invasive plants or animals known or suspected to be present at the sites.
- Equipment and waders will be cleaned thoroughly between each wetland visit.

QUALITY ASSURANCE PLAN, ABR Inc.

ABR maintains a rigorous quality assurance program for our macroinvertebrate assessment projects. ABR's procedures and standards for our laboratory sample processing and taxonomy work are well documented and are described in detail in two *Standard Operating Procedures and Quality Assurance Plans* developed and maintained by Dr. Cole. Our aim is to provide the highest quality of macroinvertebrate data by including the following elements into our QA/QC program:

1) Development of internal standard operating and quality assurance procedures.
2) Internal training of all ABR staff performing sample processing (includes a written test).
3) Development of project specifications sheets and project-specific protocols, as necessitated.
4) Adherence to written protocols in each step of sample processing.
5) Proper labeling and logging-in of samples received, and tracking of samples as they move through the processing, identification, and analysis phases of the project.
6) Standardized record keeping of each sample processed.

7) Sorting efficacy QC inspections of a specified portion (or the entire lot) of each sample lot received (normally 10% unless otherwise specified by the client) and documentation of such inspection.
8) Internal taxonomic QC inspections of a subset of samples of each sample lot received, as requested by the client. Normally, this would include re-identification of 10% of the samples by a second ABR taxonomist.
9) Documentation of results of quality-control activities and corrective actions taken.
10) Regular attendance of taxonomic and taxonomy quality assurance workshops.
11) NABS certification of ABR taxonomists.
12) Use of extensive and up-to-date taxonomic literature.
13) Assembly of a synoptic voucher collection for each new ABR project.
14) Independent validation of specimens using research taxonomists and other outside experts on an as-needed basis.
15) Thorough documentation of uncertain identifications through illustrating and photographing characters used to make the determination.

Vegetation, Soils, Birds, Amphibians

Data Quality Objectives

Major aspects of data quality include: completeness, representativeness, comparability, precision, accuracy, and measurement range. These are described as follows.

Completeness:

Level 2 Assessment: Completeness of the ORWAP data entry process is assured partly by validation routines currently built into the spreadsheet, and partly by visual comparison of the entered data with the field data forms.

Level 3 Assessment: Completeness of the plant data will be determined by comparing, at each site, the list of species found in the quadrats vs. ones found incidentally outside the quadrats, and also by examining species accumulation curves. If so indicated by year 1 data, the number of quadrats may be increased at some sites during year 2. Completeness of the soils data will be weighed by comparing field-determined soil texture with that alleged to occur in the wetland according to the county soil survey map. Completeness of the data entry process for plants, soils, birds, amphibians, and all other data will be determined by visual comparison of the entered data with the field data forms.

Representativeness and Comparability:

Level 2 Assessment: ORWAP scores will immediately be compared with those from Willamette wetlands the author believes are at least superficially similar, to determine representativeness.

Level 3 Assessment: Plant data will be compared with county lists of Oregon wetlands flora, as well as (when available) more localized lists and data from other wetland botanical surveys. Early-season vs. late-season floristic comparisons from the same site will also be made at 10% of the sites. Soil profiles as characterized in the field will be compared with published descriptions of soils mapped at the site by NRCS. Numeric values for soil chemical parameters will be compared with those published from other studies of Willamette wetlands. Bird lists will be compared with species potentially present in the same HUC6 as available at the Oregon Wildlife Explorer web site. Records of amphibians and turtles made incidentally during routine field work will be compared to existing data based on observations of qualified observers.

Precision:

Level 2 Assessment: ORWAP assigns scores on a 0 to 10 scale for each of 16 wetland functions and their values. During 2008 the DSL independently tested the repeatability rates among different users who applied ORWAP to assess the same wetlands. Among the functions and values ORWAP estimates, the median confidence interval (alpha= 0.05) was determined to be ±0.5 points on that 0 to 10 scale. Repeatability is anticipated to be much higher during the OWEB study because all wetlands will be assessed by the same individual, who is the author of ORWAP. Variability in ORWAP scores may result not only from different users, but also from seasonal variation in wetland conditions. Thus, ORWAP assessments will be repeated during winter high water in at least 10% of the sites, with a data quality objective of being within ±0.5 points on the 0 to 10 scale.

Level 3 Assessment: For plant identification, a precision objective is to determine at least 85 percent of the plants to species (>95% for co-dominants), an additional 10 percent only to genus, with no more than 5 percent (and no co-dominants) remaining unknown. An additional objective is to preserve voucher specimens for 100% of the plants that could not be identified fully but which have potential for identification (i.e., specimen is mature enough). For the avian data, precision will be estimated by a repeat visit to each wetland in which birds were surveyed. Amphibians and turtles will be noted incidental to other field work. For soil samples, the precision may be determined by computing the standard deviations of each sample's raw output data from the analysis lab.

Accuracy:

Level 2 Assessment: Accuracy of ORWAP, as with all rapid assessment methods, cannot be determined in any absolute sense. Such determinations would require long-term direct measurement of ecosystem processes.

Level 3 Assessment: Accuracy of plant identifications will be independently verifiable because voucher specimens will be preserved. Accuracy of soil chemical determinations is assured and/or measured in three ways by the Central Analytical Laboratory for Soils at Oregon State University: (1) All analyses follow a detailed standardized protocol described in the manual (available for purchase), "Methods of Soils Analysis used in the Soils Laboratories of Oregon State University, (2) As part of a Proficiency Testing Program, the OSU Lab analyzes at least 5 samples per quarter that are simultaneously analyzed by about 80 other labs statewide, and values are compared, (3) The OSU Lab analyzes one in-house sample of known chemical composition about once every 10-12 samples to insure remedial action for any instrument drift that may occur, and (4) The OSU Lab is willing to occasionally provide a sample of predetermined chemical composition to the field investigator, to be inserted blindly among other samples the Lab is analyzing for this project.

Accuracy of bird, amphibian, and turtle identifications cannot be independently verified, but the investigator is a skilled birder with many decades of experience with both visual and auditory recognition of wetland birds, and has advanced amphibian and turtle identification skills.

Measurement Range:

Level 2 Assessment: ORWAP measures functions and values on a scale of 0 to 10.

Level 3 Assessment: Plant species detectability and thus measurement range may be roughly estimable from species accumulation curves and knowledge of the usual local flowering times of individual species. The detection range of the soil chemical analyses will be specified with all values reported.

Data Management (Documentation and Records):

Maps, aerial images, office data forms, and field data forms will be stored in a marked folder (one per site) at ARA's office for a minimum of one year after the completion of this project. In addition, data will be entered biweekly into an Excel spreadsheet and a backup copy will be emailed to OWEB.

Data Validation and Verification:

Data entered into the Excel files will be compared to field and office data forms to verify accuracy. Data outliers in particular will be flagged for closer inspection. Outliers can be identified with box plots and scatter plots. Where mistakes are discovered, they will be corrected if possible, otherwise those data points will be deleted.

Reconciliation with Data Quality Objectives:

Data will be evaluated as described above with regard to precision, accuracy, completeness and representativeness. If the data do not meet some of the objectives and corrective action is not possible or is ineffective, those instances will be noted explicitly in the final report.

Other Considerations:

Safety: At all times the following will be carried in the field and used in case of an emergency:

(1) cell phone, fully charged, (2) name and phone number of the landowner, (3) first aid kit, (4) maps and GPS, (5) extra water and sunscreen to prevent dehydration. In addition, wherever possible work will begin as early in the day as possible (6 a.m. or earlier) to minimize sun exposure, and at least one other person will know of the intended itinerary.

Invasive Species: To help limit the spread of invasive species, external clothing will be changed completely before moving from one wetland to another. Boots will be washed and examined for macroscopic plant propagules and New Zealand mud snail. Those will be removed when found.

Appendix B: Protocols

Vegetation (Floristic Composition)

(Protocols may have been slightly modified over the course of the study, if this was the case please refer to the methods section in the individual sub-reports)

At each wetland, a baseline transect will first be established along the long axis of the wetland, at the wetland-upland edge. A series of transects spaced equidistantly apart will be established perpendicular to the baseline and extending across the wetland (safety considerations allowing). With landowner permission, a short length of rebar will be hammered into the ground to mark one end of each transect so that it can be relocated with confidence during the second year, and the orientation (compass direction) of the transect will be recorded. Coordinates will also be noted using a GPS, and waypoints recorded. Along each transect, vegetation quadrats with dimensions of 1x1 m (herbs) or 10 x 10 m (shrubs) will be spaced equidistantly with their lower left corner at the predetermined point on the meter tape. Percent relative cover by species will be assessed in each herbaceous quadrat. The separation distance between quadrats and between transects will depend on wetland size, with larger wetlands requiring wider standardized spacings. The spacing will be recorded so that quadrat positions can be relocated during year 2, using the rebar marker, compass direction, and/or GPS. Among the wetlands visited, approximately the same number of quadrats will be assessed; the target number will be 20-30 quadrats. Unknown or questionable plants will be bagged and labeled for later identification. A voucher specimen will be preserved of each different species encountered except for the most commonly-known and obvious species (e.g., cat-tail) and species considered to be very rare (S1, S2, S3 species). Quadrats may also be photographed from directly above with a digital camera for archiving. A sketch map will be prepared on a gridded field form as part of ORWAP, which will be completed as part of Task 1. As the transects are being run, this map will be used to show any distinct boundaries between vegetation forms or communities, as well as areas of open water, bare soil, or obvious upland. That will be useful for estimating overall areal cover of various types. Vegetation communities will be identified and classified according to McCain and Christy (2005). Species lists from the study wetlands will be compared with those from the natural reference wetlands of the same association described by those authors.

In addition, (a) plant species not intercepted by the vegetation transects or quadrats will be noted incidentally but no estimate made of their percent cover, and (b) off-transect areas will be searched for species comprising more than 10% of the vegetated area but which were missed by the quadrats, and (c) vegetation will be characterized at the closest point to the exact location where the Xerces Society is collecting invertebrate samples.

Soils

At least three soil pits will be dug to a depth of 12 inches measured from the top of the mineral surface. A soil profile description will be written describing the depth and composition (texture) of each horizon, as well as standard moist-soil Munsell colors and redox indicators (NRCS 2006, US Army Corps of Engineers 1987). One of the 3 pits will be in adjoining upland, another at a relatively high location within the wetland, and the third at a relatively low but not inundated location in the wetland (or at the opposite end of the wetland if entire wetland is at the same elevation). Soils in one or more additional

pits may be examined if NRCS maps depict multiple soil map units occurring in the wetland, and the descriptions of those soils differ from evidence from the first 3 pits. Locations of the pits will be marked on the sketch map.

For the analysis of soil chemical levels, a quart-sized ziploc bag will be filled with soil (about 150 g) from the uppermost mineral horizon from each of the 2 or more pits located in the wetland. The soil from the pits will be composited into that single sample, labeled, and placed in a cooler, then (if necessary) dried or refrigerated for up to one week before being analyzed in the laboratory. At a minimum the following analyses of soil chemistry will be performed by the Soil Science Physical Characterization Laboratory (Central Analytical Laboratory) at Oregon State University: pH, extractable bases (Ca, Mg, Na, K), organic matter (LOI), total phosphorus, nitrate nitrogen, and heavy metals (Cu, Zn, Mn, Fe).

Wetland Birds and Amphibians

Because its time demands are low, a systematic avian survey protocol (the USFWS's Marsh Bird Monitoring Protocol) will be used in 10% of the wetlands. In addition, the auditory or visual detections of all birds and amphibians made incidentally during the course of the routine field work will be recorded to species, and any existing data based on observations of qualified observers will be reviewed. Although these sources together will not constitute a comprehensive survey (the available resources do not permit such a survey), this information will help corroborate the floristic and other indicators of condition.

Water Quality

The location of the sampling site within each wetland was recorded using a Garmin Rino 120 GPS unit (NAD 83 datum). The sampling transect was also photographed to allow sampling to be conducted in the same place in the wetland each year. Prior to macroinvertebrate sampling, water quality measurements were taken adjacent to the sampling region, to avoid trampling or disturbing the region from which macroinvertebrates would be netted. All water chemistry measurements were taken between 7:00 and 11:30 am to minimize the effects of normal daily fluctuations in dissolved oxygen (DO) levels. Water temperature, conductivity (uS), and pH were measured using a Hach SensIon 156 multiparameter meter. Dissolved oxygen (mg/L) was measured using the Hach multiparameter meter in 2009, and a Hach Winkler titration kit in 2010. Calibration of the pH and conductivity probes was checked at the beginning of each sampling day. Additional water samples were taken for off-site determination of total Kjeldahl nitrogen, total phosphorus, and chloride. Samples to be analyzed for nitrogen and phosphorus were placed in acid-washed 1-liter containers, and a separate sample for chloride determination was taken in a 250 mL container. All samples were immediately placed in a cooler, and refrigerated afterwards until being delivered within 14 days to Alexin Analytical Laboratory (Portland, OR) for analysis.

Macroinvertebrate Sampling

Two teams consisting of two people each conducted sampling all sites within the first three weeks of May each year. This index period was used because it is late enough in the spring that most macroinvertebrates will be mature enough to identify to genus and species, while being early enough in the season that there is less risk of losing sampling sites to dry down. One to three sites each year were too dry to sample by May, but sampling at pre-selected back-up sites enabled us to sample a total of 50 wetlands each year.

Macroinvertebrates were sampled using a D-frame dip net with 500 um mesh in the near-shore zone of emergent vegetation, in water 1.6 – 3.2 ft. (0.5 to 1 m) deep. Sampling transects were 24-30 ft.

(7-9 m) long, and were delineated using three 4-foot cedar stakes driven into the substrate. The water depth at each stake was measured and recorded. Two composite dip net samples were taken at each site. Each composite sample consisted of three sets of 1-meter sweeps taken through the top 1-3 in. (2.5-7.5 cm) of the benthos and up through the water column on one side of each of three cedar stakes ("shore" side and "open water" side). Thus, each composite sample was comprised of nine individual 1-meter sweeps, three sweeps each on one "side" of each cedar stake.

The volume of sediment in the net bag after three consecutive sweeps was often excessive. Sample volume was reduced by submerging the bottom of the net bag in the water in a region of the wetland away from the sampling site, and stirring the contents with one hand while gently swirling and bouncing the net in the water. This also allowed large pieces of debris to be rinsed and removed, along with any captured amphibians and fish. All nine sweeps comprising a single composite sample were pooled in a bucket. Any remaining fish and amphibians were removed, and larger pieces of debris were rinsed and discarded. The pooled material was then poured through a sieve with 500 um mesh, and rinsed further to remove sediment. All rinse water was poured through a 500 um mesh sieve prior to use, to avoid accidentally introducing additional invertebrates into the sample. Sample material was transferred to 1-L Nalgene jars and 80% ethanol was added as a preservative. For maximum preservation, sample volume comprised no more than 75% of the jar, and samples that contained large amounts of filamentous algae comprised no more than 50% of the jar volume. At the end of each day, the ethanol in each sample was poured off and replaced with fresh 80% ethanol. All samples were delivered to the taxonomic lab (ABR, Inc., Forest Grove, OR) by June 1st of each year for identification. Each composite sample was randomly subsampled to a target count of 500 organisms; if a sample contained fewer than 500 organisms, the entire sample was picked, counted, and identified. For samples with more than 500 organisms total, "large and rare" invertebrates were also picked and identified after the target subsample was reached. Organisms were identified to the lowest taxonomic level possible, usually genus.

Appendix C: Checklists & Forms

Before Leaving for the Site:

__ Landowner was notified of this visit

__ Site folder is complete and was reviewed (location, aerials, delineation report, completed ORWAP "data form OF", maps)

__ Desired spacing of quadrats was estimated by measuring wetland width on aerial image

__ All equipment is working, charged up, and loaded (see list, next page)

__ Enough blank data forms are loaded

At the site:

__ Met with landowner if possible. Asked about site history, current management practices, and hydrology

__ Walked boundary and marked perimeter of the Assessment Area (AA) as GPS waypoints

__ Sketched AA boundaries on ORWAP Sketch form and/or aerial

__ Established baseline transect and marked ends with rebar (if allowed). Confirmed the desired quadrat spacing. Recorded compass direction.

__ Established quadrats. Photographed and (if allowed) flagged each. Identified plants and estimated species cover in each quadrat. Bagged and labeled unidentifiable plants and plant species not previously archived.

__ Walked rest of site as needed and:

- __ refined sketch
- __ did ORWAP assessment (fill out forms FieldF and FieldS)
- __ noted plant species at flagged spot of prior invertebrate collection
- __ searched for additional plant species overall
- __ identified and mapped major plant communities
- __ noted any amphibians or turtles; recorded in field notebook
- __ looked for hydrologic indicators
- __ determined soil texture in 1 upland pit and ~2 wetland pits
- __ collected and then composited ~20 soil samples in a labeled baggie, then placed in cooler

__ Completed the ORWAP forms (FieldF, FieldS)

__ Revised ORWAP form OF if necessitated by field observations

Afterwards

__ All plant specimens pressed and labeled, or temporarily refrigerated

__Took soil sample to OSU Lab for analysis, filled out request form

__ Made sure all data forms were complete, legible, and filed correctly

Field Equipment Checklist

__ quadrat frame
__ 50-m tapes (2)
__ rebar and hammer
__ flagging
__ ORWAP data forms
__ Veg data form
__ site folder
__ baggies
__ labels
__ pencils
__ GPS
__ clinometer-compass
__ rangefinder
__ camera & batteries
__ Blackberry
__ field notebook (rainproof)
__ spray bottle
__ Munsell color book
__ folding ruler & knife
__ binoculars
__ plant ID books
__ first aid kit
__ drinking water
__ leather gardening gloves, field vest, day pack
__ sunscreen, hat, sunglasses
__ boots/ waders
__ wire scrub brush & Clorox for cleaning boots
__ change of clothes

Vegetation Data Form

Site: _____ Date:_____

Transect Info

ID #	LATstart	LONGstart	Bearing

Quadrat Data (continue on subsequent pages)

TransID	Quad#	SpCode/ uid#	PctCov

Wetland Human Disturbance Assessment Form

Site name: Date:
County/City: Rated by:
Total HDA score (75 possible) =

1. Buffer landscape disturbance (land use within 50 ft/15 m of wetland): _____ points

Excellent: reference-quality; little to no evidence of disturbance in buffer	(0)	
Mod.: mainly unimpaired, some evidence of human use in buffer	(5)	
Fair: significant human influence; large proportion of buffer filled with human use	(10)	
Poor: intense human influence; all or almost all of buffer filled with human use	(15)	

Use the checklist below to guide your rating:

Excellent		Moderate	
	Mature woodlot (>20 yr.), forested	Old field, rangeland, conservation reserve	
	Mature prairie	Restored prairie (>10 yr)	
	Other wetlands	Young 2nd growth woodlot (<20 yr)	
	Other long-recovered area	Shrubland	
Fair		Poor	
	Residential with unmowed areas	Urban development	
	Active pasture/grazing	Industrial development	
	Less intensive agriculture	Intensive residential, mowed	
	Park turf or golf course	Intensive agriculture or grazing	
	Newly fallowed agricultural fields	Mining in/adjacent to wetland	
	High road density/other impervious surface	Active construction activity	

Comments:

2. Immediate landscape influence (500 ft/150 m of surrounding land): _____ points

Excellent: reference-quality; natural landscape; little/no evidence of human use	(0)	
Mod.: mainly unimpaired, some evidence of human use influence	(5)	
Fair: significant human influence; large proportion of landscape filled with human use	(10)	
Poor: all or most of landscape area filled with human use, isolating the wetland	(15)	

Use the checklist below to guide your rating:

Excellent		Moderate	
	Mature woodlot (>20 yr.), forested	Old field, rangeland, conservation reserve	
	Mature prairie	Restored prairie (>10 yr)	
	Other wetlands	Young 2nd growth woodlot (<20 yr)	
	Other long-recovered area	Shrubland	
Fair		Poor	

	Residential with unmowed areas	Urban development	
	Active pasture/grazing	Industrial development	
	Less intensive agriculture	Intensive residential, mowed	
	Park turf or golf course	Intensive agriculture or grazing	
	Newly fallowed agricultural fields	Mining in/adjacent to wetland	
	High road density/other impervious surface	Active construction activity	

Comments:

3. Habitat alteration, immediate landscape (500 ft/150 m of surrounding land): _____ points

Excellent: reference-quality; natural landscape; no evidence of alteration	(0)	
Mod.: low intensity alteration or past alteration not currently affecting wetland	(5)	
Fair: highly altered but with some recovery from previous alterations	(10)	
Poor: little natural habitat present, highly altered habitat	(15)	

Use the checklist below to guide your rating:

Vegetation removal/disturbances present			
	Excessive mowing	Shrub removal	
	Tree plantations	Woody debris removal	
	Tree removal/logging/clearcutting	Emergent vegetation/aquatic bed removal	
	Low spp diversity and/or predominance of nonnative or disturbance-tolerant native spp	Excessive grazing/herbivory	
	Livestock hooves	Vehicle use	
	Cultivation	Other:	

Comments:

4. Hydrologic alteration, immediate landscape (500 ft/150 m of surrounding land): _____ points

Excellent: reference-quality; natural landscape; no evidence of alteration	(0)	
Mod.: low intensity alteration or past alteration not currently affecting wetland	(5)	
Fair: current or active alteration at significant levels	(10)	
Poor: current or active alterations with major hydrologic disturbance	(15)	

Use the checklist below to guide your rating:

	Ditch inlet/outlet	Berm, levee or dike	
	Tile drain	Road or railroad bed	
	Point source input	Drainage	
	Weir or dam	Unnatural connection to other waters	
	Dredging	Dewatering in/near wetland	
	Grading or filling in/near wetland	Source water alteration	
	Other:		

Comments:

5. Chemical & Sediment Inputs: _____ points

Excellent: as expected for natural site, little/no evidence of additional human-related input (0)	
Mod.: inputs in low range, little/slight evidence of additional human-related input (5)	
Fair: inputs in mid-range, significant evidence of additional human-related input (10)	
Poor: high levels of human-related inputs, high potential for biological harm (15)	

Use the checklist below to guide your rating:

	High [Cl]	High conductivity	
	High [total P]	Unnaturally high or low pH	
	High [total N]	High turbidity reading	
	Excessive algal growth/density	Soil disturbance in immediate buffer	
	Eroding banks/slopes	Other:	

Comments: