Rinearson Natural Area
Baseline Monitoring Report

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Acronyms and Abbreviations

City	City of Gladstone
DDE	dichlorodiphenyldichloroethylene
DEQ	Department of Environmental Quality
DMMU	dredge material management unit
EDRR	early detection rapid response
EPA	Environmental Protection Agency
ESA	Endangered Species Act
HUC	Hydrologic Unit Code
IBI	Indices of Biological Integrity
LiDAR	light detection and ranging
LWD	large woody debris
MHBI	Modified Hilsenhoff Biotic Index
ODA	Oregon Department of Agriculture
O/E	observed/expected
ODFW	Oregon Department of Fish and Wildlife
OHWM	ordinary high water mark
OWEB	Oregon Watershed Enhancement Board
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
PCS	point count stations
PREDATOR	Predictive Assessment Tool for Oregon
Project	Rinearson Natural Area Restoration Project
PSET	Portland Sediment Evaluation Team
RM	river mile
RRPOA	Robinwood Riviere Property Owners Association
SLs	screening levels
Trustees	Portland Harbor Natural Resource Trustee Council
USACE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1 Introduction

This report describes baseline monitoring (pre-construction) for the Rinearson Natural Area Restoration Project (Project). The Project is an aquatic, wetland, and riparian restoration and enhancement project being developed as part of a regional restoration plan for the lower Willamette River to mitigate for environmental damages incurred as a result of industrial contamination of the Portland Harbor. The Project has been developed in coordination with the Portland Harbor Natural Resource Trustee Council (Trustees), formed for the purpose of coordinating the Natural Resource Damage Assessment (NRDA) process for the Portland Harbor and implementing the regional restoration plan. Baseline monitoring has been conducted with the guidance of the Trustees and the *Portland Harbor NRDA Monitoring and Stewardship Framework* (Trustees 2014) to document pre-construction conditions and serve as the basis of comparison to post-construction monitoring.

1.1 Site Description

The 34-acre Project site is located in a remnant floodplain at the confluence of the Willamette River and a small tributary, Rinearson Creek, at river mile (RM) 24, just downstream from the mouth of the Clackamas River (HUC# 170900120104) within Section 19, Township 2 South, Range 2 East in Gladstone, Clackamas County, Oregon (Figure 1).

The reach of Rinearson Creek within the site is impounded by an earthen dam located upstream of its confluence with the Willamette River. Above the dam, the creek backfills into a constructed depression, creating an approximately 3-acre pond within the Project site. Below the dam, Rinearson Creek drops abruptly into a narrow, incised channel and then joins the Willamette River through two channels: the historical channel and a channel that was constructed in 1997, referred to as the Meldrum Bar Channel (Figure 2). Currently, Rinearson Creek is connected to the Willamette River via its historical outlet only during Willamette River high-flow periods (e.g., during the winter-spring), flowing solely through the Meldrum Bar Channel during periods of low water.

Habitat types within the site include active channel margin (ACM; the area between ordinary high and ordinary low water), riparian, upland, floodplain, and tributary habitats (Figure 2). Generally, habitats are degraded, featuring abundant invasive vegetation cover, steep slopes, and hydrological disconnection.

Much of the Project site is currently managed as part of the City of Gladstone's (City) 85.37-acre Meldrum Bar Park. The park features a boat ramp, picnic areas, large parking lots, and a 12–acre sports field complex located to the south and west of the Project site. A mulched trail traverses the forested area within the Project site, just south of the pond, terminating at two viewing platforms; various other unofficial and unmaintained footpaths crisscross the forest (Figure 2). While recreational use is heavy for most of the park year-round, access to the study area is limited by dense vegetation and use is more moderate. The parcels owned by the City are zoned Open Space (OS). In addition, the Project site also includes a portion of the Robinwood Riviere Property Owners Association (RRPOA) common area parcel, a residential parcel, and channel areas below the Ordinary High Water Mark (OHWM; Figure 2). It is bordered by high-density residential development to the north and east, developed City park to the south, and the Willamette River to the west.

1.2 Project Overview

The Rinearson Natural Area Project was developed in alignment with the goals and objectives set forth in the *DRAFT Portland Harbor Programmatic EIS and Restoration Plan* (*Portland Harbor Restoration Plan*; National Oceanic and Atmospheric Agency [NOAA] 2012). The Project design and construction plans are described in detail in the Rinearson Natural Area Restoration Plan (Cascade Environmental Group 2015) under review by the Trustees.

Monitoring for the site is divided into four phases, with the first three phases making up the performance period. Baseline monitoring fieldwork was conducted from summer 2013-spring 2015. Implementation monitoring will take place during and following restoration construction via as-built surveys. Following construction, the site will receive 10 years of effectiveness monitoring and potential adaptive management activities, during which time site conditions will be documented and reported to the Trustees. After the effectiveness monitoring and adaptive management period is complete, the Project will be protected and managed by an approved long-term land steward using a perpetual, project-specific endowment fund. Site stewardship responsibilities, site maintenance activities, and adaptive management activities will be drafted after the long-term steward is selected in a formal site-specific long-term Stewardship Plan. This report only addresses the pre-construction monitoring phase.

1.2.1 Portland Harbor Restoration Goals

The Trustees' overall goal is to restore, rehabilitate, replace, or acquire the equivalent of those natural resources that were potentially injured as the result of hazardous substance and oil releases from the Portland Harbor Superfund site. Projects developed under the Portland Harbor NRDA program must be designed to achieve the following goals:

- Move towards normative hydrology.
- Restore floodplain function.
- Reestablish floodplain and riparian plant communities.
- Improve aquatic and riparian habitat conditions.
- Improve river margin habitat (increase complexity).
- Restore habitat that provides ecological value in the landscape perspective (through connectivity, patch size, patch shape, and distance between different patches of habitat).

1.2.2 Site-Specific Goals and Objectives

Site-specific goals are based on NRDA program goals and address factors that limit juvenile salmonids in the lower Willamette River by aiming to provide high flow refugia, cold water tributary connectivity, floodplain access and interaction, detritus export, fish access to shallow water habitats, and vegetated shorelines. Project goals are supported by specific actions, or objectives, designed to meet goals effectively. Site goals and objectives are as follows:

1.2.2.1 Goal 1 – Restore typical floodplain structure

- Objective 1 – Grade the Project site to typical floodplain topographic conditions; modify existing dam; establish floodplain benches; restore Rinearson Creek channel.
- Objective 2 – Install and retain woody structures, and rock and debris piles typical of ACM, tributary, floodplain, and upland habitats.
- Objective 3 – Provide fish passage throughout aquatic habitats.

1.2.2.2 Goal 2 – Restore native vegetation communities

- Objective 1 – Establish native-dominated marsh vegetation in areas that are currently ponded; control invasive marsh species.
- Objective 2 – Establish riparian and wetland forest vegetation in graded portions of the site; control invasive wetland and riparian species.
- Objective 3 – Enhance existing riparian and wetland forest vegetation where existing vegetation includes both native and invasive species.
- Objective 4 – Control invasive vegetation in riparian and upland forests with existing mature tree canopy.

1.2.2.3 Goal 3 – Restore typical hydrologic conditions

- Objective 1 – Restore floodplain interaction between Willamette River and areas upstream of the remnant dam.
- Objective 2 – Increase area inundated by regularly recurring flood events in the Willamette River.

1.2.2.4 Goal 4 – Improve water quality over existing conditions

- Objective 1– Improve water temperature, dissolved oxygen, and conductivity in aquatic habitats.

1.2.2.5 Goal 5- Increase use by fish and wildlife species by improving access and improving habitat quality

- Objective 1 – Increase use of site by native fish species by providing upstream fish access, enlarging ACM area within the site by 2.52 acres, and installing 17 engineered woody habitat structures accessible to fish, and retaining all existing logs.
- Objective 2 – Increase use of site by native bird species by retaining (occurring as existing debris, or trees cleared from construction) more than 3 terrestrial and aquatic woody structures per acre, establishing 1.22 acres of native emergent marsh area adjacent to open water and forested habitat, and increasing native vegetative cover across the entire site.
- Objective 3 – Increase use of site by bald eagles by planting black cottonwood, grand fir, bigleaf maple, and Douglas fir trees in 14.37 acres of the site, and by installing 17 woody habitat structures in aquatic and riparian areas in addition to retaining existing woody structures.
- Objective 4 – Increase use of site by mink by increasing ACM area within the site by 2.52 acres, installing 17 habitat structures in aquatic and riparian areas, and enlarging the area dominated by native overstory by 5.72 acres.

Objective 5 – Increase abundance and diversity of macroinvertebrates present on site through increasing stream channel length within the site by 150 feet, improving water quality, and establishing native vegetation in 10.09 acres of ACM area.

2 Baseline Monitoring Methods

Baseline monitoring methods are based on the Portland Harbor NRDA Monitoring and Stewardship Framework and assess pre-construction site conditions for the purpose of comparing them to post-construction site conditions. Baseline monitoring is conducted prior to construction activities to have reference data to gauge whether the goals and objectives are being met.

Baseline monitoring was conducted from summer 2013 through spring 2015 and included qualitative and technical site assessments; mapping exercises; review of existing documents, landowner accounts, and agency data; and field surveys related to vegetation cover, habitat type, and wildlife presence and use. The parameters assessed and the methodology utilized to measure each are described in the following table and sections below.

Table 1. Baseline Monitoring Requirements

Habitat Type	Monitoring Objective	Monitoring Technique and Timing
Geomorphic/Structural		
Tributary, Active Channel Margin, Riparian	Document how much mink and eagle habitat was restored.	Measure length of shoreline with GIS and a topographic survey during baseline conditions.
Water Quality		
Tributary, Active Channel Margin	Document water quality over time and compare to appropriate reference conditions	Deploy temperature probes with data logger for continuous collection.
Fish and Wildlife		
Tributary, Active Channel Margin	Document site use of lamprey.	Electrofishing and site surveys during baseline conditions. Record species and size of fish observed.

Habitat Type	Monitoring Objective	Monitoring Technique and Timing
Active Channel Margin, Riparian, Upland	Document site habitat use over time by birds. Compare bird assemblage to baseline and appropriate reference conditions. Determine relative abundance/diversity.	Conduct presence/absence bird surveys: point counts 3 times approximately monthly in each habitat type during the breeding season pre-construction baseline.
Active Channel Margin, Riparian, Upland	Document site use over time by bald eagles	Conduct presence/absence eagle surveys; frequency of use; and habitat metrics; observe behaviors weekly mid-December to August pre-construction baseline.
Active Channel Margin, Tributary, Riparian, Upland	Document site use over time by minks. Document presence/absence and habitat use of mink.	Camera traps with scent stations within 50-feet of waterway, walking surveys for track, scat, and den sites twice monthly for 3 months spring/summer to include mid-April through mid-July pre-construction baseline.
Tributary	Document changes in macroinvertebrate community.	Macroinvertebrate surveys, lab identification to determine species abundance/diversity once yearly during late spring pre-construction baseline.

2.1 Shoreline Geomorphology

The amount of suitable habitat for mink and eagle was assessed via a GIS (office) exercise. Using Arc GIS, the total length of shoreline was determined in the tributary, active channel margin, and riparian habitat types.

2.2 Water Quality

Water temperature at the site has been monitoring continuously with the use of Solinst data loggers from summer 2013 to provide an account of year-round conditions. Two data loggers were deployed, one located in the ponded area near the inlet of the dam, and one located in Rinearson Creek upstream of the ponded area, and programmed to record temperature every 30 minutes. It is expected that water quality will improve at the Project site as a direct result of restoration activities, particularly the parameter of temperature. Logger locations are depicted in Figure 3.

2.3 Bird Assemblages

Bird monitoring includes both breeding bird and eagle surveys. Bird monitoring was conducted by a qualified wildlife biologist who collected data on species presence and site use, and species abundance and richness. Bird monitoring will be used as an indicator of site habitat structure and function and to document changes in species assemblages over time. Bird use and productivity is expected to increase because of restoration. Bird monitoring station locations are illustrated in Figure 3.

2.3.1 Breeding Bird Surveys

The breeding bird survey design utilized a habitat-based bird monitoring point count protocol discussed by Brown and Huff (2000). A total of 15 point count stations (PCS) were established: eight located in riparian habitat and seven located in upland forest habitat. Each PCS location was assigned an identification number, recorded with GPS, and marked with flagging. In order to maximize the number of PCS within the project site boundaries, distances between PCS varied between 30 and 125 meters. Bird sampling was conducted three times per month from May 15 through the end of June in 2014 to capture peak breeding season. Sampling events began 30 minutes before legal sunrise and the first PCS monitored was varied for each sampling event to minimize sampling bias. Each PCS was monitored for 5 minutes and bird species identified visually and/or aurally. Data for each bird recorded includes cardinal direction and distance from the PCS, observation type (sight and/or sound), and observed behaviors such as calling or singing, feeding, or traveling. Environmental conditions were also recorded at each PCS. To minimize sampling errors, the surveyor avoided re-counting individual birds recorded at adjacent stations. In addition, only birds detected within 50 meters of a PCS were recorded because detection rates begin to vary and decrease rapidly beyond this distance.

Data was analyzed following guidance from Brown and Huff (2000), which suggests data from breeding bird surveys "should be communicated in a way that clearly reflects the method and can be repeated by others." Since birds were counted at individual stations over a 5-minute period, results will be presented in terms such as "6 birds per station." These units communicate that if an observer monitors one station for 5 minutes, they would likely see six birds. These values can also be averaged over the entire site. To determine the birds per station for each species observed, data was analyzed using the following formula:

Birds per Station =

Sum of Individuals Recorded for All Visits/ (Number of Survey Days x Number of Stations)

2.3.2 Bald Eagles

Bald eagles were monitored as representative of the feeding guild of piscivorous birds potentially affected by feeding on contaminated fish in the Portland Harbor. Bald eagles were monitored with presence/absence surveys designed in accordance with McGarigal et al. (1991) to assess bald eagle usage onsite. The survey design involves recording observations from three monitoring stations to maximize observation opportunity. Monitoring stations have been recorded with GPS and marked in the field with flagging. Surveys occurred weekly, for a total of two hours, from mid-December 2013 through August 2014 and amounted to 20 total events. Surveys occurred at either dawn or dusk to coincide with periods of highest anticipated eagle activity and alternated in timing each week. During each survey, approximately one-half hour was spent at each monitoring station, and approximately 10 minutes were spent traveling between stations to allow for active eagle searching onsite. The starting monitoring station for each event was varied to minimize sampling bias. Data collected included observation by general activity (e.g., perching, directional flight, soaring flight, foraging attempt, etc.), specific activity (e.g., prey pursuit, hunting, resting, handling prey, feeding self, etc.), habitat type (e.g., open water, mud flat, old-growth conifer, etc.), perch substrate (e.g., tree species, piling, driftwood, ground, etc.), and weather conditions (e.g., cloud cover, precipitation, wind speed). Hunting tactic (direct predation of live prey, scavenging, pirating), outcome (successful, unsuccessful), prey species, and prey size for foraging attempts were recorded where possible. Time of day, duration of activity, and height above water (estimated visually) were also recorded. Eagle sightings were mapped along with behaviors observed.

2.4 Mink

Mink were monitored as representative of the feeding guild of piscivorous mammals potentially exposed to Portland Harbor contaminants. Mink were monitored with presence/absence surveys consisting of a two-part design: five camera trap stations, similar to those discussed by McKinney and Haines (2010), were established and visual searches for tracks and scat were conducted. Camera trap stations were located in active channel margin habitats, habitat most likely to be used by mink, and equipped with Browning Strike Force infrared motion-detection cameras with 16 GB memory cards. Cameras were programmed to take a series of four pictures 0.3 seconds apart and with a 4-second delay between each series. Each camera trap station featured a 0.5-meter wood stake placed 3 meters away from the camera baited with Three Rivers Mink scent lure to attract mink. All stations were serviced twice monthly from mid-April through mid-July in 2014, during which time memory cards were retrieved, camera functionally tested, and scent lure applied. Visual searches were also be conducted during these visits within target habitats, particularly open areas featuring sandy or muddy substrates, for tracks and scat. Visual sampling events were conducted approximately one hour following legal sunrise to minimize corruption of tracks and scat, observations of which were recorded and mapped. Mink photographs were stored digitally. Efforts were made to identify individual mink according to distinctive face and chest markings in order to assess the number of individuals using the site. Camera trap and survey areas are depicted in Figure 3. Photographs captured of mink are included in Appendix A.

2.5 Pacific Lamprey

Pacific lamprey monitoring is applicable to all NRDA restoration projects in the Portland Harbor. Lamprey biological and site use data will be used to increase understanding of juvenile lamprey habitat preferences.

Baseline lamprey monitoring was conducted by the U.S. Fish & Wildlife Service (USFWS) according to a lamprey monitoring plan developed by the Trustees. Lamprey monitoring took place during May 2015 in Rinearson Pond and in Meldrum Channel.

2.6 Benthic Macroinvertebrates

Benthic macroinvertebrate communities are associated with aquatic habitat type and quality; benthic macroinvertebrate monitoring data will be used to indicate water quality and habitat health over time as a result of restoration. It is expected that community composition will shift following site construction as stream function is restored and water quality improves.

Monitoring methods for the benthic macroinvertebrate community at the Project site were developed with guidance from a sub-group of the Portland Harbor restoration committee, Oregon Department of Environmental Quality (DEQ)'s Water Monitoring and Assessment Mode of Operations Manual (DEQ 2009), and the Water Quality Monitoring Technical Guide Book (Oregon Watershed Enhancement Board [OWEB] 1999), as well as consultation with The Xerces Society in Portland, Oregon. In accordance with Trustee guidance, a Level 3 protocol was used at the site to provide the best measure of stream condition using macroinvertebrates as the indicator.

Sampling locations were positioned to capture all onsite aquatic habitat types and include the tributary habitat within the Meldrum Bar Channel, the vegetated fringes of the pond, and upstream of the pond in a relatively intact reach of Rinearson Creek. The goal of sampling at each of the sites was to obtain a representative but random sample of the macroinvertebrate community. Sample protocols differed slightly between sample sites depending on whether the site is within a stream reach (Rinearson Creek upstream of the pond) or within the pond/emergent wetland fringe based on different conditions associated with the each habitat type. Baseline collection efforts took place in May 2015. Sampling locations are depicted in Figure 3

At each sampling location, 20-foot transects were established parallel to the bank, extending both upstream and downstream of the sampling point. Collectors used D-frame nets placed on the bottom of the channel perpendicular to the flow to capture macroinvertebrates, debris, and sediments that are loosened by disturbing the stream bottom upstream of the net. Samples of the benthos were collected at 5-foot intervals along the transect, totaling eight net sets (4 upstream, 4 downstream). The eight net sets from each sampling locations were combined into one composite sample to represent each habitat type (pond fringe/emergent wetland, tributary stream reach, reference reach).

Sampling within the reference reach was conducted by positioning a 3 ft. x 3 ft. grid upstream for the sampling location and alternating sample collection from left bank to thalweg to right bank and back until eight net sets were completed. All eight net sets from both sampling locations were combined as one composite sample to represent the reference Rinearson Creek tributary habitat type.

All net samples were treated with standard sorting, rinsing, and storage protocols outlined in the DEQ and OWEB methods and were sent to a qualified laboratory for taxonomic identification; the Xerces Society performed the data analysis.

2.6.1 Macroinvertebrate Data Analysis

Data analysis was performed by the Xerces Society and is detailed in the report included in Appendix B. The analysis involved two approaches: the PREDATOR model and the Indices of Biological Integrity (IBI) multimetric model. PREDATOR (Predictive Assessment Tool for Oregon; [Hubler 2008]) is a predictive model that has been developed for two major regions in Oregon: the Marine Western Coastal Forest (Willamette Valley and Coast Range ecoregions) and the Western Cordillera and Columbia Plateau (Klamath Mountain, Cascades, East Cascades, Blue

Mountains, and Columbia Plateau ecoregions). The model compares observed taxa at a site with expected taxa that may be found in the least-disturbed reference sites that share similar physical, chemical, and biological conditions to generate a score. Because the model was developed from samples taken from late June through early October from riffle habitats in cobble-and gravel-bottomed streams, it is best applied to samples collected from similar habitat types and during the same period; it does not provide an accurate assessment of low-gradient streams with substrates composed of finer sediments, or samples collected during different periods. As data at the Project Site was collected in May, an artificial sampling date of June 20 was used in the model, which was the earliest date within the model's experience.

The IBI was developed for use in Oregon and evaluates a suite of community metrics that have been shown to respond predictably to human-induced stressors. Individual metrics are scored and summed to provide a total IBI value that reflects the biological condition of the habitat. A level 3 assessment requires the identification of taxa to the species level. Metrics included in a level 3 assessment are as follows:

- Taxa richness (# of taxa at site)
- *Ephemeroptera* (mayfly) richness
- *Plecoptera* (stonefly) richness
- *Trichoptera* (caddisfly) richness
- Number of sensitive taxa
- Number of sediment-sensitive taxa
- % dominance of the top taxon
- % tolerant taxa
- % sediment-tolerant taxa
- Pollution tolerance using the Modified Hilsenhoff Biotic Index (MHBI)

The range used to calculate the score of each metric are based on community composition in reference streams. A score of 5 indicates a healthy stream, while a score of 3 or 1 indicates degraded conditions.

Similar to PREDATOR, the IBI model is also best suited to evaluating benthic communities in flowing streams with cobble-gravel substrates. Both analysis approaches were used in spite of a poor fit because planned restoration activities may alter conditions in the future such that the models are more applicable and determining the baseline score pre-construction will thus provide the basis for future comparison.

2.6.2 Freshwater Mussels

Also of interest is the possible presence of freshwater mussels within the Project site. No current records of mussel survey effort in Rinearson Creek exist. According to The Xerces Society databases, *Margaritifera falcata* were found a mile downstream at the confluence of the Willamette and the Clackamas River in 1944 and about a mile upstream of the Project site in 1935 (waterway not known, possibly the Willamette). *Anodonta spp.* were also found in the Willamette near Mary S. Young Park, just to the northwest of the confluence of Rinearson Creek and the Willamette, in 1997 by Al Smith (Mazzacono, Xerces Society, pers. comm. 2014). No other survey efforts are documented in this area.

The Xerces Society led the performance of mussel surveys for the Project site. Surveys were conducted by wading the length of the entire site, starting at the downstream end of the Meldrum Bar Channel, and extending upstream through the pond and the creek reach to the eastern Project boundary. In shallow water or areas of good visibility, surveyors visually scanned the substrate for mussels with the use of an underwater viewing scope; in areas of poor visibility, dredge netting and finger sifting of sediments were performed to search for mussels. Mussels observed during the survey were identified to species when possible and recorded.

2.7 Vegetation

For the purposes of establishing baseline vegetation and habitat conditions for the HEA model, existing vegetation communities throughout the site were characterized by species assemblage and mapped via GIS. The entire site was walked by a qualified ecologist and vegetation communities were identified based on the presence of each stratum (herbaceous, shrub, tree) and its dominant constituents. A species list for each community was compiled and absolute cover for each was estimated. The extent of each community was mapped using a combination of high-resolution aerial photographs available from the USGS and a Trimble handheld GPS unit capable of sub-meter accuracy. Vegetation mapping was conducted several times over the 2014 growing season to capture the seasonal succession of vegetation growth.

2.8 Soils and Sediment

A geotechnical investigation and sediment testing were conducted on the Project site in 2014. The purpose of the geotechnical study was to characterize soils for suitability as construction materials and provide guidance for grading and other earthwork activities. The work was completed by HartCrowser and included the collection and analysis of 21 soil samples from locations distributed throughout the site. Samples were analyzed for composition, moisture content, and stability (HartCrowser 2014).

Sediment sampling was performed by Maul, Foster, & Alongi and included the collection of sediment from beneath the water surface of the pond at four locations. The samples were analyzed for grain size, organic content, and the presence of standard contaminants (Maul, Foster, & Alongi 2014). The results of the sediment analysis were submitted to the Portland Sediment Evaluation Team (PSET) for evaluation.

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3 Baseline Conditions

3.1 Shoreline Geomorphology

In order to evaluate how much mink and bald eagle habitat was restored, the shoreline length of the ACM in the existing conditions was measured via GIS. Total length of unrestored habitat is 7,500.22 feet of shoreline. There is no shoreline outside of ACM habitat in the HEA habitat types for the existing condition maps.

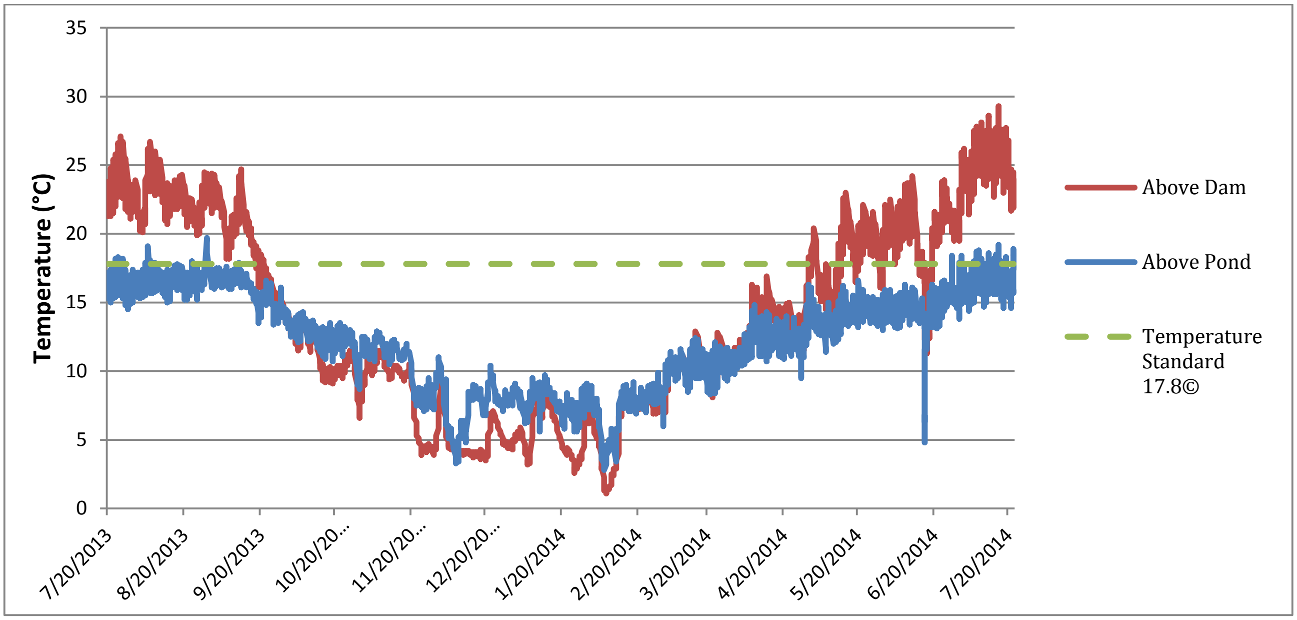
3.2 Water Quality

The Rinearson Creek Watershed consists largely of built-out residential and commercial land uses. It originates from cold springs within the City of Gladstone, and numerous springs add cold-water flow to the creek within the Project site. Throughout its watershed, the creek travels through wetland areas and channelized segments, and it is contained in a pipe for approximately one-third of its length, before reaching the Project site.

Water quality conditions in Rinearson Creek and the pond are affected by stormwater runoff from these developed areas and the pollutants generated by the associated impervious surfaces. Illicit discharges to the storm system are also possible but have not been researched. Water quality conditions may also be affected by high Willamette River flows which backwater over the dam and flood the pond one or more times annually.

Water temperatures in the creek before entering the pond are typical of spring-fed systems. The following graph illustrates water temperature patterns during mid-July 2013 to mid-July 2014. The figure compares conditions in the pond just above the dam with conditions in Rinearson Creek above the pond (intended to function as a reference site) and depicts the Oregon temperature standard for streams with cold-water fisheries of 17.8° C (64 °F; Boyd et al 1997). Temperatures in the pond exceeded the standard considerably in the spring and summer, likely due to solar inputs and stagnated flow; in late fall, temperatures in the pond decreased rapidly with the onset of seasonal rains, and to less effect, the lowering of ambient air temperature. In the Creek upstream of the pond, except for a few minor breaches in the summer, temperatures were generally maintained below the temperature standard, likely due to an established tree canopy and continual flow. The springs described above also contribute cool surface and subsurface water to the creek, which probably helps to moderate any thermal loads.

Water Temperature within the Project Site



3.3 Bird Assemblages

3.3.1 Breeding Birds

The results of the spring 2014 breeding bird surveys are summarized in Table 2 below for both riparian and upland forest habitats. Song sparrow, spotted towhee, and black-capped chickadee were the three most recorded species in both habitats, species common to the Pacific Northwest that tend to favor dense thickets and riparian growth (Marshall et al. 2003). The song sparrow and spotted towhee had similar abundance at both habitat-based PCS sites, while black-capped chickadees were almost twice as abundant at upland PCS relative to riparian PCS, which reflects their preference for deciduous upland forest habitat (Marshall et al. 2003). Considering additional observations of habitat preference, willow flycatcher detections were found to be concentrated at riparian PCS and brown creeper detections concentrated at upland PCS (Marshall et al. 2003). Waterfowl such as Canada geese (*Branta canadensis*), mallards (*Anas platyrhynchos*), and wood ducks (*Aix sponsa*) were commonly observed using the pond.

Table 2. Summary of 2014 Baseline Breeding Bird Surveys.

Species Name	Birds per Station	Habitat Type Observed	
		Riparian	Upland
American Crow - *Corvus brachyrhynchos*	0.43	X	X
American Goldfinch - *Spinus tristis*	0.07	X	X
American Robin - *Turdus migratorius*	0.46	X	X
Anna's Hummingbird - *Calypte anna*	0.04	X	X
Bewick's Wren - *Thryomanes bewickii*	0.36	X	X
Black-capped Chickadee - *Poecile atricapillus*	0.61	X	X
Black-headed Grosbeak - *Pheucticus melanocephalus*	0.11	X	X
Black-throated Gray Warbler - *Setophaga nigrescens*	0.04	X	X
Brown Creeper - *Certhia americana*	0.07	X	X
Brown-headed Cowbird - *Molothrus ater*	0.25	X	
Bushtit - *Psaltriparus minimus*	0.07	X	X
Canada Goose - *Branta canadensis*	0.04	X	
Cedar Waxwing - *Bombycilla cedrorum*	0.04	X	
Downy Woodpecker - *Picoides pubescens*	0.18	X	X
European Starling - *Sturnus vulgaris*	0.07	X	
Great Blue Heron - *Ardea herodias*	0.11	X	
House Finch - *Haemorhous mexicanus*	0.07	X	
Lesser Goldfinch - *Spinus psaltria*	0.04	X	
Mallard - *Anas platyrhynchos*	0.5	X	
Northern Flicker - *Colaptes auratus*	0.04	X	
Red-breasted Sapsucker - *Sphyrapicus ruber*	0.18	X	X
Red-winged Blackbird - *Agelaius phoeniceus*	0.14	X	
Rufous Hummingbird - *Selasphorus rufus*	0.04	X	
Song Sparrow - *Melospiza melodia*	1.93	X	X
Spotted Towhee - *Pipilo maculatus*	0.93	X	X
Swainson's Thrush - *Catharus ustulatus*	0.07	X	X
Turkey Vulture - *Cathartes aura*	0.04	X	
Violet-green Swallow - *Tachycineta thalassina*	0.04	X	
Western Tanager - *Piranga ludoviciana*	0.04	X	
White-breasted Nuthatch - *Sitta carolinensis*	0.04	X	X
Willow Flycatcher - *Empidonax traillii*	0.14	X	X
Wilson's Warbler - *Cardellina pusilla*	0.11	X	
Wood Duck - *Aix sponsa*	0.11	X	

Note: Only birds recorded within 50m of each PCS are listed.

Bird habitat quality on the site, in general, is degraded due to abundant invasive species cover and hydrological disconnection. Areas of dense canopy and presence of mature black cottonwoods and sparse Douglas fir trees in the forested areas provide some roosting and nesting sites for large raptors, and a dense shrub layer and ample large woody debris (LWD) provides cover, foraging, and nesting sites for other birds. However, predominantly invasive forest understories limit habitat quality, and areas with low or no forest overstory feature extensive Himalayan blackberry thickets that do not provide adequate habitat to support species diversity.

3.3.2 Bald Eagles

Bald eagles were documented within the project site boundaries on four occasions for a total of 67.50 minutes (3% of the total survey time). The first sighting occurred on June 26 2014, which involved an adult briefly (15 seconds) flying south over the pond. On December 12, 2014, two adults were observed perched in separate cottonwoods along the bank of the Willamette River on the west side of the site for 33 minutes. During this time, two prey pursuits were attempted by the same individual with the second attempt being successful. The prey item was an unidentified fish. The third observation occurred December 22, 2015, and involved an adult briefly (1 min) flying up the Meldrum Bar Channel, over the pond, and back out along the same path. A brief (15 seconds) sighting on January 17, 2015 involved one adult flying north along the east bank of the Willamette River and momentarily into the project site boundaries.

During sampling events, bald eagles were detected outside of the project site boundaries on 12 different site visits. The first detection occurred during the first site visit on May 23, 2014, and included two adults along the west bank of the Willamette River. The pair was observed in the same general area during subsequent site visits, which lead to the discovery of an active nest with one nestling on June 12, 2014. The actual fledge date is unknown, but the immature eagle was observed in flight on July 18, 2014, and has been seen periodically since. As of January 2015, it appears the breeding pair has remained in this territory.

Bald eagles are typically associated with large bodies of water. Estuaries, lakes, and reservoirs with ample shorelines and shallow water provide foraging habitat for resident breeders, winter residents, and migrants (Marshall et al. 2006). In Oregon, prime nesting locations are large trees generally within one mile of water. West of the Cascades, primary nest tree species include Sitka spruce (*Picea sitchensis*) and Douglas fir with more frequent use of black cottonwood as local bald eagle populations increase. Typically, nest trees are old, feature large limbs and open structure, and provide views of the surrounding area. Protection from human disturbance tends to be important for nesting, successful hunting, and feeding of young, but some individuals do show tolerance for human activity (Marshall et al. 2006). Foraging behaviors vary by location and season, but one study along the lower Columbia River Estuary found bald eagles acquire a little more than half their food by hunting live prey, about one quarter from scavenging, and the remainder from pirating. Fish comprise over two-thirds of prey taken, and waterfowl and seabird consumption increase in winter as they become more abundant. Foraging is dependent on availability of tidal flats and water less than 4 feet deep, and varying opportunistic strategies determined differences in diet between pairs and season (Watson el al. 1991).

Currently, the Project site supports limited habitat areas that benefit bald eagles. The site is in close proximity to the Willamette River and, although few conifers are present within the site, mature black cottonwoods in upland and riparian forests provide suitable roosting and perching habitat. The pond supports waterfowl, and some fish are present within onsite waterways for bald eagles to feed on; however, the pond's disconnection from the Willamette River mutes hydrologic and fluvial processes necessary to create habitat variability and complexity essential for high quality fish and wildlife habitat and prevents fish passage into the pond. In addition, the Project site's proximity to ongoing human disturbances, such as fishing, boating, and other recreational activities, renders the site largely unsuitable as nesting habitat.

3.4 Mink

Mink were photo-documented onsite four times; photographs are included in Appendix A. The first observation occurred mid-morning on May 23, 2014 and involved a lone individual spied atop a floating board at the dam outflow. The three subsequent observations were made with the motion-detection cameras on June 23, August 13, and August 16, 2014. All three motion-detection camera recordings occurred between dusk and dawn and were of traveling individuals. Mink tracks were observed during an active visual search on July 18, 2014. The number of individuals is unknown as identification by distinctive face and chest markings was not possible. It is also unknown for what purposes or how often mink use the site; no den sites or scat was found and the presence of tracks was rare.

Mink are semi-aquatic, carnivorous mammals typically associated with riverbanks, lakeshores, freshwater and saltwater marshes, and marine shore habitats (Gerell 1967). Mink prefer continuous, structurally complex riverbank corridors with cover provided by woody vegetation and debris, and avoid straight, open, exposed shorelines (Allen 1986). Their foraging niche is generally within aquatic habitats, and prey includes crayfish, fish, reptiles, waterfowl, birds, rodents, rabbits, and other mammals. Prey availability is the primary factor influencing movement and habitat use throughout the year (Allen 1986). Movement around and within water is dictated by bank slopes, and access to aquatic prey becomes increasingly limited as bank slopes become steeper. In-stream habitat structures including logs and logjams are important for mink when foraging (Verts and Carraway 1998).

Riparian and active channel margins within the Project site currently offer limited mink habitat. Banks of waterways, particularly of the Meldrum Bar Channel, are steep, and the channels have little to no structural complexity or presence of in-stream large wood, which limits foraging access. The poor aquatic habitat and the fish passage barrier of the pond also limit mink prey availability. In addition, the dominance of invasive species in the riparian areas affects the quality of cover and denning habitat.

3.5 Pacific Lamprey

According to USFWS personnel, lamprey were noted downstream of the dam in the Meldrum Bar Channel during the survey; however, no evidence of lamprey was found in the pond (Jen Kassakian, personal communication, May 19, 2015).

3.6 Benthic Macroinvertebrate

Analysis results are provided in detail in the report attached as Appendix B and summarized below. Because the PREDATOR and IBI models were developed for use in habitats with different flow conditions and substrate types than those found at the Project site, and were intended to be applied to samples collected at a different seasonal period, the results produced by the models may not be accurate and are presented only as a basis for future comparison.

The models both indicate severely impaired biological conditions among all habitats sampled (Searles Mazzacano 2015). The macroinvertebrate community is dominated by taxa tolerant of sediment, warm temperatures, and disturbance including aquatic earthworms (Oligochaeta), scuds (Amphipoda), and non-biting midges (Chironomidae). The invasive New Zealand Mud Snail (*Podamopyrgus antipodarum*) was found in Rinearson Creek upstream of the pond, and the Ephemeroptera, Plecotera, and Trichoptera genera, regarded as a key indicators of high-quality water conditions, were absent, with the exception of two caddisfly (Trichoptera) larvae identified in Rinearson Creek.

PREDATOR and IBI scores are presented in the Tables 3 and 4. Table 3 includes PREDATOR scores are presented as observed taxa/expected taxa (O/E) that correlates with biological conditions as follows: ≤0.85 = most disturbed; 0.86 - 0.91 = moderately disturbed; 0.92 – 1.24 = least disturbed; and > 1.24 = enriched. The PREDATOR model results indicates severe disturbance for all three sample sites, reflecting current degraded habitat conditions, as well as the low-flow and silty substrate characteristics of the site, and early season sampling (factors confounding model output).

Table 3. PREDATOR O/E Scores for the Rinearson Natural Area

Habitat	Pond	Rinearson Creek	Meldrum Bar Channel
O/E Score	0.194849	0.243395	0.194913
Rank	severely disturbed	severely disturbed	severely disturbed

Note: Table adapted from Searles Mazzacano 2015

Table 4 presents IBI scores for the site. IBI scores correlate with PREDATOR scores; however, the score for Rinearson Creek indicates moderate, as opposed to severe, disturbance, and the pond scored near the threshold of moderate/severe. The Meldrum Bar Channel received the lowest possible IBI score. The results of the model are ascribed to the greater abundance and variety of vegetation and substrate heterogeneity in the pond when compared with the channel, which lacks vegetation and features a single substrate type.

Table 4. IBI scores for the Rinearson Natural Area

Metric	Pond	Rinearson Creek	Meldrum Bar Channel
Taxa richness	3	3	1
Mayfly richness	1	1	1
Stonefly richness	1	1	1
Caddisfly richness	1	1	1
Number of sensitive taxa	1	3	1
Number of sediment-sensitive taxa	1	1	1
% dominance of the top taxon	3	3	1
% tolerant taxa	3	5	1
% sediment-tolerant taxa	3	5	1
MHBI	1	3	1
TOTAL	**18**	**26**	**10**
Rank	**Severely disturbed**	**Moderately disturbed**	**Severely disturbed**

Note: Table adapted from Searles Mazzacano 2015; only the scaled score is presented here

3.6.1 Freshwater mussels

A single floater (*Anodonta* spp.) was identified in the lower third of the Meldrum Bar Channel in cobble substrate. The mussel was estimated at 4-6 years old based on size. Nonnative Asian clams (*Corbicula fluminea*) were found to be abundant in the pond and downstream of the dam. Asian clams were not noted in Rinearson creek above the pond.

Of some interest, freshwater shrimp were found in abundance in the Meldrum Bar Channel during the mussel survey. Though their taxonomy is unknown, exotic Asian freshwater shrimp

(*Exopalaemon modestus*) are known to be abundant within the lower Willamette River at various times of the year per a 2005 ODFW report: *Biology, Behavior, and Resources of Resident and Anadromous Fish in the Lower Willamette River*. The shrimp may constitute a potentially important food source for mink, birds, and other piscivorous wildlife using the site.

3.7 Vegetation Types and Condition

The project site is primarily vegetated with upland and riparian forest with areas of shrub thicket, forested wetland, and emergent wetland (Figure 4). Forest stands are mid-seral to mature with open-to-closed canopies composed of native tree species. Understories are generally well developed and dense and feature widespread presence of invasive species; breaks in forest canopy are dominated by invasive species. Vegetation communities are described in the following; photographs of vegetation conditions are included in Appendix A.

1. **Red alder forest:** This community is an early-to-mid seral, even-aged, open-to-closed canopy riparian forest stand occurring along the southwestern boundary of the ponded area. The understory is dense and dominated by red-osier dogwood, Himalayan blackberry, trailing blackberry (*Rubus ursinus*), and orange jewelweed (*Impatiens capensis*). This vegetation community covers 4.39 acres of the project site.
2. **Black cottonwood forest**: Occupying 8.66 acres in the southwestern section of the site, this is a mid-seral, closed canopy floodplain/riparian forest stand, mostly even-aged, but including some large, mature cottonwoods. Bigleaf maple also occurs frequently. The understory is dense and diverse with a fairly well-developed structure and a few emerging conifers. Dominant species include hazelnut (*Corylus cornuta*), English ivy (*Hedera helix*), trailing blackberry, and orange jewelweed.
3. **Black cottonwood – Himalayan blackberry forest:** An open canopy riparian stand occurring both in the eastern section of the property and on the floodplain island in the western section of the property. This vegetation community features some large, mature trees, a few scattered hazelnuts and large Pacific willows (*Salix lasiandra*), and an understory dominated by Himalayan blackberry. This vegetation community covers 5.61 acres.
4. **Douglas-fir – bigleaf maple mixed forest**: a mid-seral, open-to-closed canopy upland forest stand occurring in the northeastern portion of the site and covering 2.15 acres. The Douglas-fir and bigleaf maple dominated overstory is interspersed with Oregon ash, Oregon oak, western redcedar (*Thuja plicata*) and black cottonwood. The understory is largely herbaceous, outside of a few hazelnuts, and features western swordfern (*Polystichum munitum*), large-leaved avens (*Geum macrophyllum*), and English ivy.

5. **Oregon ash – bigleaf maple forest:** a narrow corridor of mid-seral, closed-canopy riparian forest covering 0.21 acres along the steeply-sloped valley and banks of Rinearson Creek upstream of the ponded area. The understory is largely herbaceous and is dominated by trailing blackberry, English ivy, and orange jewelweed.
6. **Oregon ash – Pacific willow palustrine forested wetland**: 1.21 acres of forested wetlands along the Willamette River in the southwestern portion of the site. This vegetation community features an understory of dogwood, emerging Pacific willow, reed canarygrass, and purple loosestrife (*Lythrum salicaria*). It is subject to seasonal-tidal flooding by the river.
7. **Palustrine scrub-shrub wetland**: 0.38 acres of dense, willow complex along both banks of the natural Rinearson Creek outlet to the Willamette River. Purple loosestrife, water smart weed (*Persicaria lapathifolia)*, water pepper (*Persicaria hydropiper*) and lady's thumb (*Persicaria maculosa*) also occur here. The area features a steeply-sloped topography and is subject to seasonal flooding by the river.
8. **Palustrine emergent wetland**: A narrow band of herbaceous emergent vegetation covering 1.42 acres along the margin of the ponded area and the banks of Rinearson Creek upstream of the pond. Dominant species include reed canarygrass (*Phalaris arundinacea*), yellow flag iris (*Iris pseudacorus*), common rush (*Juncus effusus*), and orange jewelweed. Field bindweed (*Convolvulus arvensis*) climbs over the vegetation in great abundance during peak growing season.
9. **Riverine emergent wetland**: This t vegetation community occurs in the tidally and seasonally flooded streambed and banks of the historical Rinearson Creek outlet, covering 0.91 acres. It is comprised of both persistent and non-persistent wetland communities based on the frequency and duration of inundation. The persistent vegetation community occurring along the banks is dominated by purple loosestrife, water pepper, and water smartweed with occasional willows. Field bindweed (*Convolvulus arvensis*) climbs over the vegetation in great abundance during the low-water summer season. Non-persistent emergent areas are dominated by water purslane (*Ludwigia palustris*) and spatulaleaf loosestrife (*Lythrum portula*), and include bearded flatsedge (*Cyperus squarrosus*), redroot flatsedge (*C. erythrorhizos*), and teal lovegrass (*Eragrostis hypnoides*) with some occurrence of water pepper. Higher water levels prevent the spread of field bindweed into the channel bottom.
10. **Himalayan blackberry – field bindweed (reed canarygrass) shrub thicket**: Dense blackberry covers 4.17 acres of the Project Site, colonizing breaks in forest canopy in

upland areas and along upland/wetlands transitions. Field bindweed climbs over the thickets and is very abundant by the peak of the growing season. Reed canarygrass is co-dominant in upland/wetland transitional areas.

11. **Ruderal/Weedy Clearing:** This is a 0.40 acre maintained clearing near the site of the dam. It has been colonized by a variety of weedy species including Canada thistle (*Cirsium arvense*), prostrate spurge (*Euphorbia maculata*), tansy ragwort (*Senecio jacobaea*), prostrate knotweed (*Polygonum aviculare*), and crabgrass (*Digitaria sanguinalis*).
12. **Open Water:** Open water covers 4.11 acres of the project site. This area includes 3.18 acres of ponded water ranging in depth from 1-5 feet, 0.21 acres of the 1-2 foot deep Rinearson Creek inlet to the pond, 0.56 acres of the seasonal-tidally fluctuating Rinearson Creek outlet, and 0.16 acres of the seasonal-tidally fluctuating Willamette River. Little to no aquatic vegetation is present in the open water area.

3.7.1 Invasive Species

Non-native plant species are defined by the Oregon Department of Agriculture's (ODA) Oregon State Weed Board as "noxious weeds" if they are considered to be injurious to public health, agriculture, recreation, wildlife, or any public or private property (ODA 2013). Noxious weed species are classified by the Board based on reproduction, distribution, management, and detrimental effects criteria into 3 Lists which include control recommendations:

- List A weeds occur in small, known infestations, and are easily contained. Populations of these weeds are subject to eradication when and where found.
- List B weeds are regionally abundant, but with limited distribution in some counties. Management is determined on a case-by-case basis and is generally limited to control at the state or county scale.
- List T weeds are species targeted for prevention and control under a statewide management plan developed and implemented by the ODA.

Aside from Oregon state-listed weeds, other nonnative species present concerns in areas of ecological restoration. The East Multnomah Soil and Water Conservation District (SWCD) has developed an Early Detection-Rapid Response (EDRR) program in an effort to promote the rapid eradication of newly introduced species and currently maintains a list of 11 high-priority target plant species.

The City of Portland maintains a Nuisance Plant List and a Required Eradication List that identifies non-native plants occurring within the four-county metropolitan Portland region that pose a risk to native plant and animal communities and may require removal per City ordinance. These plants are ranked according to their relative invasive potential and priority for control/eradication:

- A: species that are known to occur in the region but are limited in distribution; control priority is highest;
- B: distribution of these plants is higher than A-ranked species, but still limited to patches or specific habitats;
- C: species that are widely distributed and abundant;
- D: species that are non-native but have less impact on habitats than A, B, or C-ranked species;
- W: species to monitor for presence and/or determine the potential for invasiveness.

Trustees' guidance documents define non-native vegetation species as those species included in the Oregon Department of Agriculture (ODA) Noxious Weed List and the Portland Plant List (City of Portland 2011). In consultation with the Trustees' Restoration sub-committee, a modified vegetation classification has been developed for the Project site. The Restoration Plan refers to all non-native species that will be controlled as a component of site management as "*invasive species."* Cover of non-native plant species that are not considered "invasive" will be recorded in monitoring data but not reported as contributing to "invasive" species cover. No change was made to the native plant species reference. A table providing a comprehensive list of "invasive" and "non-native" species is provided in Appendix C. Additionally, all species classified as "early detection and rapid response" (EDRR) species on the Portland Plant List will be immediately eradicated from the site and monitored for return.

Widespread presence of invasive vegetation species is a significant issue on the site: forested areas are invaded by English ivy, English holly (*Ilex aquifolium*), cherry laurel (*Prunus laurocerasus*), and herb-Robert (*Geranium robertianum*); breaks in forest canopy are dominated extensively by Himalayan blackberry; the clearing around the dam features Canada thistle, St John's wort (*Hypericum perforatum*), and tansy ragwort; wetland areas feature abundant reed canarygrass, purple loosestrife, and yellow flag iris; and nearly all vegetation communities throughout the site include moderate-to-high field bindweed cover. Appendix C also lists the species observed onsite during the baseline mapping.

3.8 Soils and Sediment

The geotechnical investigation identified that site soils include fill material, alluvium ranging from silt to sand and gravel, fine-grained flood deposits, and topsoil. Fill material is largely related to the residential development on the north side of the pond, dam construction, and a relic roadbed that borders the upstream end of the pond.

Up to a few feet of sediment has accumulated in the pond behind the dam since the dam was constructed. The sediment is largely composed of fine-grained material with a small fraction of sand. Laboratory testing of sediments from the lower area of the pond identified relatively low levels of certain pollutants.

In 2014, the PSET evaluated concentrations of contaminants in the dredge material to be removed during project grading (the dredge material management unit, or DMMU) and new surface material (NSM) composite samples against the 2006 Sediment Evaluation Framework (SEF) for the Pacific Northwest (COE et al., 2006, 2009) freshwater screening levels (SLs). One set of composite samples was collected and analyzed for the lower pond area (DMMU1), and a second set of composite samples was collected and analyzed for the upper pond area and adjacent planned excavation areas (DMMU2). The evaluation was revised in 2015 based on revised screening levels (SLs).

Based on the laboratory analysis of the materials, the PSET found the following:

DMMU1

- The only sample that had detections exceeding the 2015 SLs was nickel (Ni). Across the six samples, the average Ni concentration is 27.98 mg/kg. The PSET agencies determined that this exceedance would not trigger bioassays for the following reasons: 1) This area is known to have elevated natural nickel issues; 2) the 2014 laboratory results of the 10 other metal samples are each below the 2015 SLs and their concentrations are similar across the DMMUs laterally and vertically, indicating that metals are not likely a cause for concern for contamination within the Rinearson Creek watershed (there is no mining or other possible point sources in the vicinity); 3) the average value was within 10% of the background value, which is within typically accepted analytical variability. Any one of these reasons alone would not be sufficient information to not trigger bioassays, but combined with the other rationales, the PSET agencies made a best professional judgment determination to not trigger bioassays in this case.
- In all samples, all other SEF metals were either not detected at their method reporting level, or they were detected below the SLs.

- Besides DDE, pesticides and polychlorinated biphenyls (PCBs) were either not detected at their method reporting level or were not detected or estimated above their respective SLs.
- Chlorinated hydrocarbons, phenols, phthalates, and miscellaneous extractable compounds were either not detected at their method reporting level or were detected at concentrations well below the SEF SLs.
- Polycyclic aromatic hydrocarbons (PAHs) were either not detected at their method reporting level or were detected at concentrations well below the SEF SLs.
- No mining or other sources of Ni are known in the Rinearson Creek watershed

DMMU2

- Laboratory analysis of the DMMU2 composite sample showed no exceedances of SLs.

Suitability Determination

The PSET's suitability determination is based on comparison of the sediment quality data to the 2015SEF freshwater SLs. According to the SEF guidance, the dredge prism material from DMMU1 and DMMU2 is suitable for unconfined, aquatic placement. The NSM sediments from DMMU1 and DMMU2 are suitable for unconfined, aquatic and floodplain exposure.

No future monitoring for soils or sediment is required.

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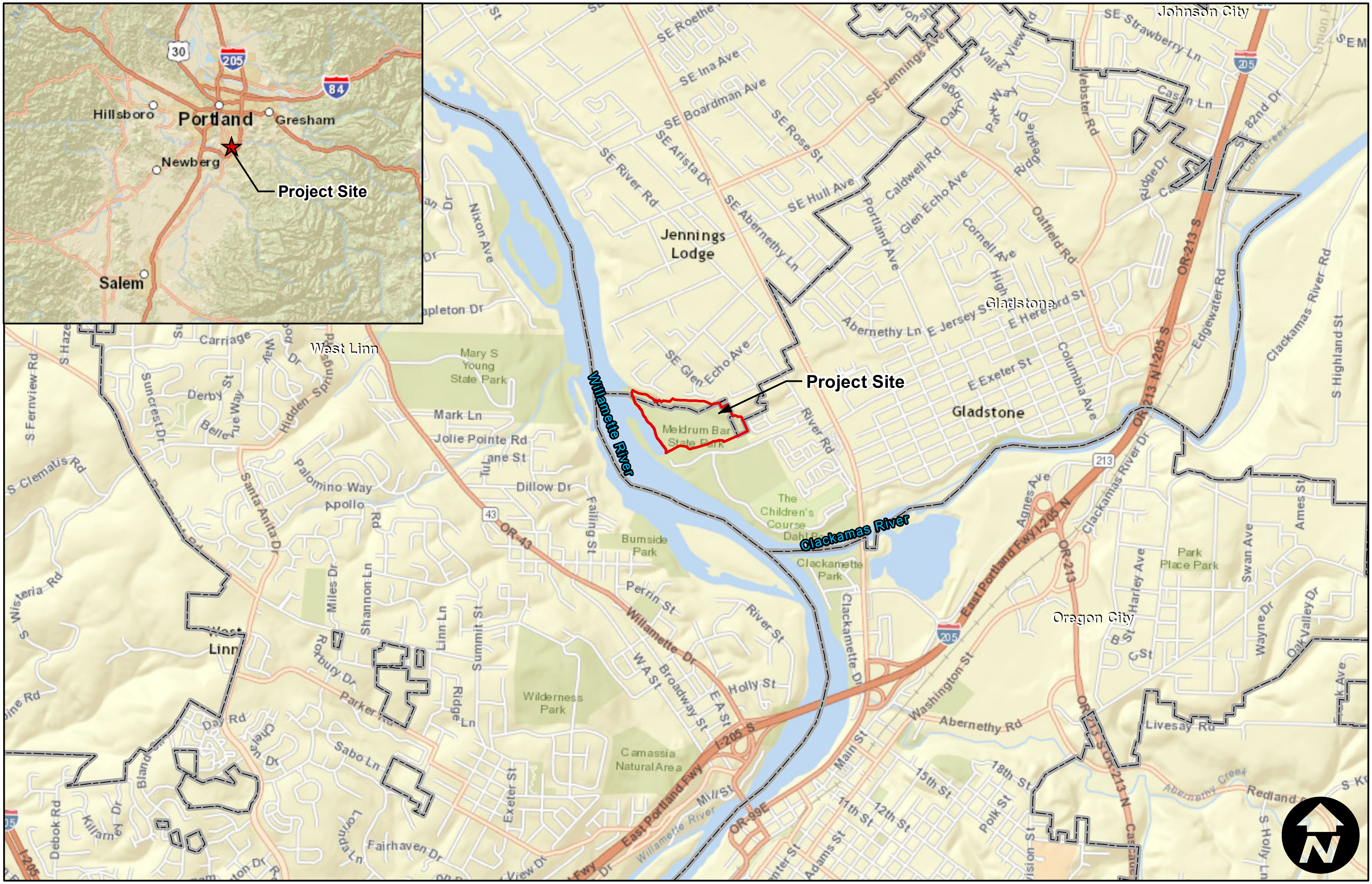
Figures



Date: 11/23/2015

Scale: 1 inch = 0.5 mile

Data Source: ESRI, 2015; Clackamas County GIS, 2013.

0 0.25 0.5 1 Miles

Figure 1. Location

CASCADE ENVIRONMENTAL GROUP

Rinearson Natural Area

Z:\GIS\30_RinearsonNaturalArea\Mapfiles\Baseline_Fig1_Loc.mxd

Date: 11/30/2015
Scale: 1 inch = 350 feet
Data Source: ESRI, 2015; Clackamas County GIS, 2013

Figure 2. Site Conditions and Existing Habitats

CASCADE ENVIRONMENTAL GROUP

0 250 500 Feet

Rinearson Natural Area

Z:\GIS\30_RinearsonNaturalArea\Mapfiles\Baseline_Fig2_SiteMap.mxd

Date: 11/30/2015

Scale: 1 inch = 300 feet

Data Source: ESRI, 2015

Figure 3. Wildlife Monitoring Map

CASCADE ENVIRONMENTAL GROUP

0 100 200 400 600 Feet

Rinearson Natural Area

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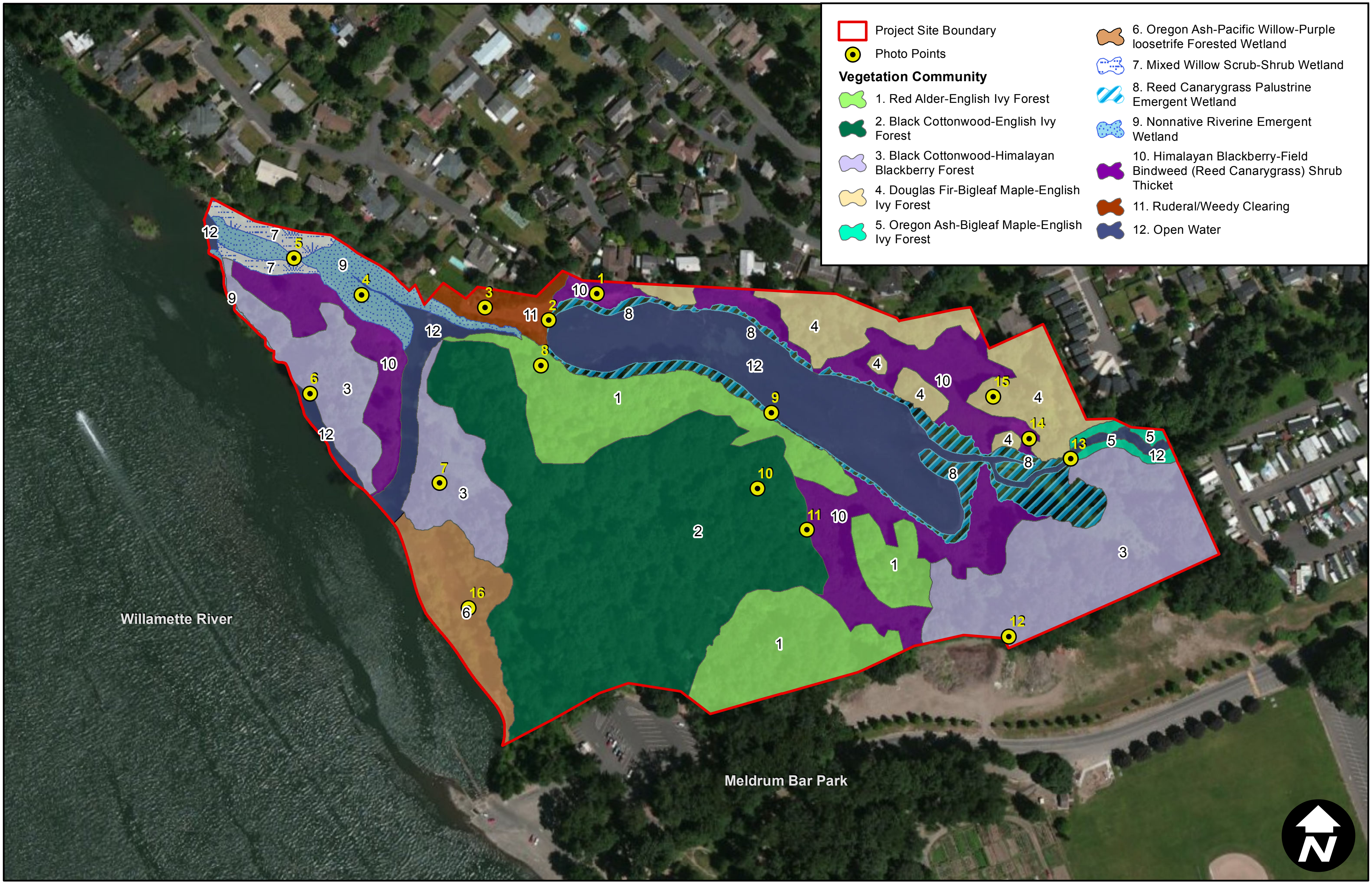


Date: 11/30/2015

Scale: 1 inch = 350 feet

Data Source: ESRI, 2014; CEG field survey, 2013.

0 200 400 Feet

Figure 4: Vegetation Communities

Rinearson Natural Area

CASCADE ENVIRONMENTAL GROUP

Z:\GIS\30_RinearsonNaturalArea\Mapfiles\Baseline_Fig4_VegComm.mxd

Appendices

Photo point 1. Reed canarygrass stand on northwest side of pond.

Photo point 2. Yellow flag iris in the emergent wetland fringe along the eastern shoreline of the pond.

Photo point 3. Ruderal/weedy clearing around dam site.

Photo point 4. Nonnative riverine emergent wetland in the historical outlet of Rinearson Creek (low water).

Photo point 5. Mixed willow scrub-shrub wetland on banks of the historical outlet.

Photo point 6. Black cottonwood-Himalayan blackberry forest on island at west end of site.

Photo point 7. Black cottonwood-Himalayan blackberry forest in the west end of site.

Photo point 8. Red alder-English ivy forest south of the pond.

Photo point 9. Yellow flag iris and jewelweed in emergent wetland fringe along south shore of the pond.

Photo point 10. Black cottonwood-English ivy forest south of the pond.

Photo point 11. Himalayan blackberry-field bindweed thicket south of the pond in the eastern section of the site.

Photo point 12. Black cottonwood-Himalayan blackberry forest in the east end of site.

Photo point 13. Oregon ash-bigleaf maple-English ivy forest along Rinearson Creek upstream of the pond.

Photo point 14. Reed canarygrass emergent wetland along with Himalayan blackberry thicket at the west end of the pond.

Photo point 15. Douglas fir-bigleaf maple-English ivy forest on the northeastern section of the site.

Photo point 16. Oregon ash0Pacific willow-purple loosestrife forest along the Willamette River in the southwestern section of the site.

Possible mink photograph captured at Camera 2 June 23, 2014

Mink photograph captured at Camera 4 on August 13, 2014.


Possible mink tracks photographed on July 25, 2014.

Analysis of the aquatic macroinvertebrate community in the Rinearson Creek system prior to restoration activities

Project completion report to the Cascade Environmental Group


Aeshnidae (darner) dragonfly nymph and Corixidae (water boatman), taxa in the Rinearson system

Submitted to: Kimberly Biafora
Restoration Ecologist | GIS Specialist
Cascade Environmental Group

Submitted by: Celeste A. Searles Mazzacano, Ph.D.
Staff Scientist | Aquatic Conservation Director
The Xerces Society for Invertebrate Conservation

The Xerces Society
for Invertebrate Conservation

Protecting the life that sustains us

Table of Contents

Summary

This report describes the benthic macroinvertebrate communities of the Rinearson Creek system (City of Gladstone, Clackamas County, Oregon) and assesses baseline biological conditions prior to implementing restoration activities. Aquatic macroinvertebrate samples collected from selected habitats in Rinearson Pond, Rinearson Creek, and Meldrum Bar Channel in late May 2015 were identified to the lowest practical taxonomic level (generally genus) and analyzed using standardized biotic assessment models developed for the state of Oregon (PREDATOR and IBI). Analyses of multiple additional taxonomic and biological traits were done to better characterize the macroinvertebrate community and potential stressors, including: community similarity analysis; diversity and abundance of indicator taxa for fine sediment conditions and temperatures; and distribution of functional feeding groups (FFGs) and habit (locomotion) types.

PREDATOR and IBI models indicated severely impaired biological conditions among all habitats sampled, with the Rinearson Creek community having the highest O/E and IBI score, and a better IBI-based condition (moderately disturbed) compared to the other two sites (severely disturbed). However, because flow conditions, substrate type, and the time of year in which sampling was done place these samples outside of the experience of the models, these results are not accurate; the model results are presented only as a basis for future comparison, as restoration activities may alter substrate and flow conditions in the future such that PREDATOR and IBI are applicable.

Multiple additional taxonomic and biological measures were examined. All measures indicated a macroinvertebrate community shaped by degraded habitat conditions; dominated by common cosmopolitan taxa tolerant of sediment, temperature, and disturbance; and more characteristic of lentic (standing) than lotic (flowing) waters, including aquatic earthworms (Oligochaeta), scuds (Amphipoda), and non-biting midges (Chironomidae). The invasive species New Zealand Mud Snail (*Potamopyrgus antipodarum*), established for over two decades in the Northwest, was also found in Rinearson Creek at low abundance. The EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera), widely regarded as a touchstone for high-quality flowing water conditions, were almost entirely lacking; the Rinearson Creek community had a very low abundance of two caddisfly (Trichoptera) genera but lacked mayflies (Ephemeroptera) and stoneflies (Plecoptera), and no EPT taxa were present in the pond or channel.

The macroinvertebrate community among all the sampling sites has been shaped by warm temperatures, elevated fine sediments, and reduced habitat complexity. These data provide a framework within which community changes subsequent to restoration activities can be evaluated. Recommendations for future work include continued monitoring within a biologically relevant time frame post-restoration; conducting macroinvertebrate sampling during the late summer/early fall index period used to develop the Oregon bioassessment models; and quantifying additional abiotic and habitat features that influence macroinvertebrate community composition such as water temperature, diel dissolved oxygen patterns, and substrate composition and embeddedness. Continued monitoring as restoration projects are completed will document impacts on aquatic biota and facilitate assessment of changed biological and ecological conditions resulting from restoration.

Introduction

Biological monitoring and stream restoration

Freshwater ecosystems are severely impacted by human activities, and 45% of US waters are classified as endangered or impaired (USEPA, 2004). Determining the ecological success of stream restoration projects requires baseline and post-project monitoring of biotic communities (biomonitoring), and an analysis of how observed changes in community composition relate to stream ecosystem functions (Bernhardt et al., 2005). Because biomonitoring evaluates the condition of biological communities inhabiting a water body, such as plants, amphibians, algae, diatoms, or invertebrates, it provides data about stream function or "health" that physical and chemical data alone do not address (Rosenberg & Resh, 1993; Karr & Chu, 1999). The structure of these biological communities changes in response to habitat impairment, based on individual species' sensitivity or tolerance to different stressors. The communities assessed must generate a biological "signal" based on human impacts that can be detected apart from the "noise" of normal variation in space and time (i.e. changes in season or stream order). Benthic macroinvertebrates (BMIs) are a useful assemblage for biomonitoring because they are critical to the food web, are confined to water for most or all of their life cycle, respond in a known way to a range of human-induced stressors, have a short generation time that allows changes in community structure to be detected rapidly, are ubiquitous and abundant, and their sampling and identification is relatively straightforward, standardized, and cost-effective.

Many restoration projects are undertaken with the assumption that improved physical habitat automatically increases faunal biodiversity, which in turn restores impaired or lost ecological processes, i.e. "the field of dreams hypothesis" (Palmer et al., 1997). However, a variety of reach- and catchment-specific influences must be considered when evaluating project outcomes (Roni et al., 2002; Bond & Lake, 2003; Palmer et al., 2005; Lake et al., 2007). Restoration can improve habitat and water quality at the reach level, but streams experience watershed-wide stressors that site-specific activities may not completely remediate (Booth & Jackson, 1997; Bohn & Kershner, 2002; Bond & Lake, 2003). The composition and mobility of the regional pool of colonists also affects post-restoration changes in biological communities (Bond & Lake, 2003; Blakely et al., 2006). Thus, it is important that data be obtained prior to restoration to provide information on baseline BMI community composition at a site and create a framework within which subsequent community changes can be evaluated.

Invertebrate-based biotic assessment techniques

Assessment of aquatic invertebrate communities is frequently conducted via two major analytical approaches: predictive models and multimetric Indices of Biological Integrity (IBI).

Predictive models

Predictive models compare the macroinvertebrate community at a sampling site to the community at previously sampled reference or best available-condition streams in the same region with similar physical, chemical, and biological characteristics (Wright *et al*., 2000). The PREDATOR model (Predictive Assessment Tool for Oregon; Hubler, 2008) was generated for two major regions in Oregon: Marine Western Coastal Forest (Willamette Valley and Coast Range ecoregions; MWCF model) and Western

Cordillera and Columbia Plateau (Klamath Mountain, Cascades, East Cascades, Blue Mountains, and Columbia Plateau ecoregions: WCCP model). The model calculates the ratio of taxa observed at a site to taxa that are expected (O/E) based on comparison to community data obtained previously in a large number of reference (least-disturbed) sites with similar natural characteristics. In general, a site O/E value of less than one indicates a loss of common reference taxa, and values greater than one reflect taxa enrichment, potentially in response to pollution or nutrient loading. The model also generates O/E scores for individual taxa at a sampling site, allowing specific taxa loss and replacement to be assessed.

There are a few caveats that accompany the use of PREDATOR. Because the models were developed from samples taken in riffle habitats in cobble- and gravel-bottomed streams, they will not provide an accurate assessment of the biological condition of low-gradient streams with more glide/pool habitat and/or with substrate dominated by finer sediments. Also, because PREDATOR was developed using data sets from reference samples taken from late June through early October, the model will flag any samples taken outside of a specific index period (earlier than June 20) as unsuited for analysis.

Multimetric biotic indices

Biological indices rate a combination of community attributes (metrics) that have been shown to respond predictably to human-induced stressors (Karr & Chu, 1999). Metrics used in most IBIs fall into four classes: richness (i.e., # taxa), tolerance (i.e., # or % tolerant or intolerant taxa), composition (i.e., dominance of top taxa), and trophic (i.e., % shredders, ratio of shredders to collectors). Individual metrics are scored and summed to generate a total IBI value that reflects the biological condition of a site. Multimetric biological indices have been developed in Oregon for use with macroinvertebrate stream taxa identified to genus and species (Level 3 assessment; OWEB, 2003; see Table 1). A suite of metrics have also been developed for a family-level IBI (Level 2 assessment), but identification to genus is preferred, as a single family often contains individual genera that differ in tolerances and response to disturbance. The Oregon IBI was developed from a smaller dataset than the PREDATOR models and unlike PREDATOR, does not consider regional differences (Hubler, 2008 and pers. comm.).

Table 1. *OR DEQ Level 3 Invertebrate-based Index of Biotic Integrity (IBI)*

	Scoring criteria		
Metric	**5**	**3**	**1**
Taxa richness	>35	19-35	<19
Mayfly richness	>8	4-8	<4
Stonefly richness	>5	3-5	<3
Caddisfly richness	>8	4-8	<4
# sensitive taxa	>4	2-4	<2
# sediment-sensitive taxa	≥2	1	0
Modified HBI	<4.0	4.0-5.0	>5.0
% tolerant taxa	<15	15-45	>45
% sediment-tolerant taxa	<10	10-25	>25
% dominance top taxon	<20	20-40	>40

The ranges used to calculate the scaled score of each metric were determined based on community composition in reference streams. A higher scaled score (5) is given to metric ranges typical of a healthy stream, while a lower scaled score (3 or 1) reflects values associated with degraded conditions. Some metrics are thus positive (a higher raw value corresponds to a higher scaled score) while others are negative (a higher raw value corresponds to a lower scaled score). Scaled scores for all metrics are summed to generate single value that reflects the level of impairment at the site; on a possible scale of 10-50, site impairment may be assigned as severe (<20), moderate (20-29), slight (30-39), or none (>39).

The first four metrics in the IBI are based on the rationale that a less disturbed, healthier stream system has more biodiversity with higher overall taxa richness (Norris & Georges, 1991; Barbour *et al*., 1996) and greater diversity of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). The EPT are often a focus of bioassessment metrics as they are widely considered to be the most sensitive to changes in flow, temperature, and sediment, although individual genera differ in their sensitivities. The % dominance of the top (i.e. most abundant) taxon in the sample is another diversity-related metric. A healthy system is expected to have a more balanced composition, and a large abundance of a small number of taxa is indicative of impaired conditions and environmental stressors, as the macroinvertebrate community becomes dominated by one or a few more tolerant groups (Plafkin *et al*., 1989; Barbour *et al*., 1999). The remaining metrics reflect the diversity and dominance of groups that are sensitive to or tolerant of warm temperatures and increased sediment loads. Sensitivity to organic enrichment is measured by the modified Hilsenhoff Biotic index (MHBI; Hilsenhoff, 1987), which ranges from 1 to 10, with lower values indicating greater sensitivity. MHBI is calculated as the weighted mean of MHBI scores for all individual taxa in the sample for which MHBI values have been assigned.

Rinearson Natural Area monitoring project

The Rinearson Natural Area in Gladstone, Oregon is slated to undergo substantial restoration to improve fish passage and enhance channel and floodplain conditions. The aquatic macroinvertebrate community at three sites—Rinearson Creek, a large pond created by a dam on the creek, and Meldrum Bar Channel—was assessed to provide baseline data prior to restoration activities.

Methods

Aquatic macroinvertebrate sampling

In spring 2015, Xerces Aquatic Conservation staff conducted a site visit to discuss monitoring plan design and train Cascade Environmental staff in standardized OR DEQ protocols for stream sampling (OWEB, 2003). Xerces provided equipment for sampling done by Cascade Environmental on 26-27 May 2015 in Rinearson Creek, Rinearson Pond, and Meldrum Bar Channel. At each site, individual 1 ft^2 D-frame kicknet sets were composited into a single sample and preserved in 80% ethanol in 0.5 L Nalgene jars.

Samples were processed and identified by Cole Ecological, Inc. Each sample was spread in a 30-cell Caton tray (Caton, 1991) and randomly sub-sampled to a target count of 500 individuals. Fixed-count sub-sampling is done to provide an unbiased representation of the complete sample; identification of every organism is cost-prohibitive and not required to provide accurate measures of taxa richness, relative abundance, and other attributes, and a target number of 500 adequately represents sample taxa diversity (Barbour & Gerritsen, 1996; Li et al., 2001; King & Richardson, 2002) Organisms were identified to genus where possible (insects, crustaceans, and mollusks), or to genus/species group (Chironomidae) or class (Oligochaeta [aquatic earthworms]). Individuals too immature for diagnostic characters to be present and/or clearly visible were left at family level. Functional Feeding Group (FFG) and tolerance values were assigned based on datasets from OR DEQ (Hubler, unpublished data) and Merritt et al. (2008).

Macroinvertebrate community analysis

Predictive and multimetric models

Because the Rinearson sites differ in many respects from reference streams used to generate the Oregon PREDATOR and IBI models (i.e. having low flow, ponded water, sand- and sediment-dominated substrate, and no riffles), use of the models is inappropriate for this habitat type. In addition, the May sampling date was outside of the experience of the PREDATOR model, such that the model would not provide output; therefore, data were entered into the model with an artificial sampling day number that corresponded to June 20, the earliest date within the model's experience. Because planned restoration activities may alter substrate and flow conditions in the future such that these models are more applicable, PREDATOR (MWCF model) and IBI scores were calculated to provide a basis for future comparisons. They are presented here with the caveats described above.

Temperature and sediment optima

Macroinvertebrate community composition can be shaped by water temperatures and the amount of fine sediment in the substrate. OR DEQ developed a dataset of optima values for individual taxa for seasonal maximum temperature and percent fine sediments (i.e. the temperature or %FSS under which a taxon can maximize its abundance). Temperature and sediment optima of the macroinvertebrate communities were examined to assess differences and determine whether the current community composition is reflective of sediment or temperature stressors, and the weighted means of the optima were calculated for each sample. The presence or absence of taxa considered by OR DEQ to be indicators (i.e. taxa with the strongest responses to environmental gradients) of cool or warm temperatures and high or low fine sediment conditions was also noted (Huff et al., 2006; see Appendix 1 for a list of OR DEQ indicator taxa).

Taxonomic and ecological trait analysis

Multimetric and multivariate biomonitoring models routinely examine taxonomic differences among biotic communities, as the identity of species in the community serves as a surrogate for their attributes that are affected by changing environmental conditions (Southwood, 1977). The ubiquity of the EPT metric, which looks at richness and/or abundance of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), taxa considered as a whole to be the most sensitive to increased temperature, sedimentation, and pollution, is a prime illustration. However, only a subset of taxonomic traits is used in any IBI, and additional investigation of community taxonomy is often informative.

Ecological traits, which include measureable properties such as trophic guild, body size, or number of generations per year, are receiving more attention as a way to assess site conditions in conjunction with taxonomic traits (Pollard & Yuan, 2010; Culp et al., 2011; van den Brink et al., 2011; Lange et al., 2014). Ecological traits are less spatially constrained, as they are not limited by regional species pools, and they have additional potential to not only monitor impairment at a site, but also to assign mechanistic linkages between ecological traits of a community and environmental stressors (Culp et al., 2011). The physical features of a habitat shape the biological traits of the macroinvertebrate community (Southwood, 1977), such that changes in physical habitat will not only change the identity of community members (i.e. taxonomic changes) but also the biological traits filtered by the habitat (i.e. functional changes). Thus, examining a combination of taxonomy- and ecology-based traits provides a more sensitive assessment of changes in macroinvertebrate assemblages following restoration or other changes in habitat (Mendez, 2007; Arce et al., 2014).

To incorporate ecological traits into bioassessment of Rinearson Creek, the trophic guilds (functional feeding group, FFG) and habit (locomotion) of taxa within each sample were analyzed. Designation of a taxon as a predator, scraper, shredder, collector-filterer, or collector-gatherer was assigned by Cole Ecological according to OR DEQ datasets (Hubler, unpublished). Habit (burrower, sprawler, clinger, swimmer, diver) was assigned according to Merritt et al. (2008). The richness, relative diversity, and relative abundances of taxa with different ecological traits was determined for each sample.

Community Similarity Analysis

Additional analyses to detect patterns in macroinvertebrate community composition were done using the PRIMER v6 ecological community statistics software package (Clarke & Warwick, 2001). CLUSTER analysis was conducted on a Bray-Curtis similarity matrix of square-root transformed abundance data to investigate macroinvertebrate community similarity between sites. SIMPER analysis was used to elucidate the taxa that contributed the most to between-site community similarities. Shannon Diversity Index (H’) was calculated using the DIVERSITY analysis.

Results & Discussion

Predictive and multimetric models

PREDATOR

PREDATOR and IBI scores are presented with the reminder that neither is appropriate for use with the Rinearson Creek sites in their current condition, as they differ substantially from the cobble-bottomed riffles in which the models were developed, and sampling was done outside of the model index periods. They are presented here as a benchmark against which future conditions may be measured.

For the PREDATOR Marine Western Coastal Forest model (MWCF), site observed/expected (O/E) scores correlate with biological condition as follows: $\leq$ 0.85 = most disturbed; 0.86 - 0.91 = moderately disturbed; 0.92 – 1.24 = least disturbed; and > 1.24 = enriched. The PREDATOR scores for all three sites indicated severe disturbance (Table2), a reflection of the current degraded habitat conditions as well as low flow rates and channel gradients, and early time of year.

Table 2. *PREDATOR O/E scores for Rinearson Natural Area sites (MWCF model)*

Metric	Rinearson Pond	Rinearson Creek	Meldrum Bar Channel
O/E score	0.194849	0.243395	0.194913
Condition	severely disturbed	severely disturbed	severely disturbed

IBI

Site IBI scores showed a similar pattern (Table 3) and correlated well with PREDATOR O/E scores (r^2 = 0.749). However, while Rinearson Pond and Meldrum Bar Channel scored as severely impaired, the Rinearson Creek score indicated moderate disturbance. Somewhat surprisingly, the score for the pond, a lentic site, was at the upper end of the range for severe impairment (i.e. close to the severe/moderate transition), while Meldrum Bar channel, a more lotic site, received the lowest possible IBI score. This likely reflects greater abundance and variety of vegetation in and around the pond site and greater substrate heterogeneity compared to the channel.

Table 3. *IBI scores for Rinearson Natural Area sites*

	Rinearson Pond		Rinearson Creek		Meldrum Bar Channel	
Metric	**Raw value**	**Scaled score**	**Raw value**	**Scaled score**	**Raw value**	**Scaled score**
taxa richness	30	3	29	3	18	1
mayfly richness	0	1	0	1	0	1
stonefly richness	0	1	0	1	0	1
caddisfly richness	0	1	2	1	0	1
# sensitive taxa	0	1	2	3	0	1
# sediment-sensitive taxa	0	1	0	1	0	1
% dominance top taxon	29.2	3	26.7	3	57.2	1
% tolerant taxa	38.7	3	11.7	5	59.7	1
% sediment-tolerant taxa	24.1	3	4.3	5	57.2	1
MHBI	6.5	1	5	3	5.7	1
TOTAL		***18***		***26***		***10***
Impairment	**Severe**		**Moderate**		**Severe**	

Almost no other macroinvertebrate community data from this system are available for comparison. An assessment of multiple streams in an NPDES monitoring study (Cole, 2014) included a sample from a glide in Rinearson Creek at a reach upstream (N 45.3822, W 122.6038) of that sampled in this study; this represented the first macroinvertebrate sampling done by the city of Gladstone. Cole (2014) presented the same warnings about reliance on PREDATOR and IBI scores for this system, but it is worth noting that the PREDATOR O/E score for that reach (0.242) was almost identical to the creek O/E score in this study (0.243). The IBI score obtained in the Cole (2014) study was substantially lower (14), even though taxa richness was nearly twice that seen in the present study. However, % tolerant taxa, % sediment tolerant taxa, and MHBI were all higher in the Cole (2014) Rinearson Creek sample, and unlike the current study, no caddisfly taxa were found.

The IBI scores for all sites in this study do not fully reflect site condition, but values for the individual metrics are informative. Note that there are currently no established models to evaluate the macroinvertebrate community in Oregon's wetlands (Mazzacano, 2011), which renders assessment of the Rinearson Pond sample more difficult. All metric values indicate severely degraded conditions in Meldrum Bar Channel, with extremely low community diversity, an absence of sensitive taxa, and high proportions of sediment-, temperature-, and disturbance-tolerant groups. The low diversity of the channel community was further reflected in the high degree of dominance by the top taxon, with over half of the invertebrates collected comprised of highly tolerant aquatic earthworms (Oligochaeta).

The Rinearson Pond community also lacked sensitive taxa, which is more typical in a lentic habitat, but pond diversity was 50% higher than that of the channel and equivalent to the diversity in Rinearson Creek. While the pond had the highest MHBI score (indicating large numbers of taxa tolerant to organic pollution) as well as substantial numbers of Oligochaeta, community dominance and the proportions of tolerant taxa were almost half that seen in the channel community. The pond community was dominated by the crustacean *Crangonyx*, a common tolerant genus of amphipod (scud) that feeds on detritus in shallow waters and is an important prey item for many fish.

The Rinearson Creek community was the only one that contained any EPT (two caddisfly genera in different families) or sensitive taxa (two genera of chironomid midge in the sub-family Orthocladiinae). The creek community also had the lowest values for MHBI, proportions of tolerant taxa, and community dominance, with the most abundant taxon, the chironomid midge *Polypedilum*, a genus in the more tolerant Chironomini tribe, comprising only about a quarter of the total community.

Temperature and sediment

Indicator taxa

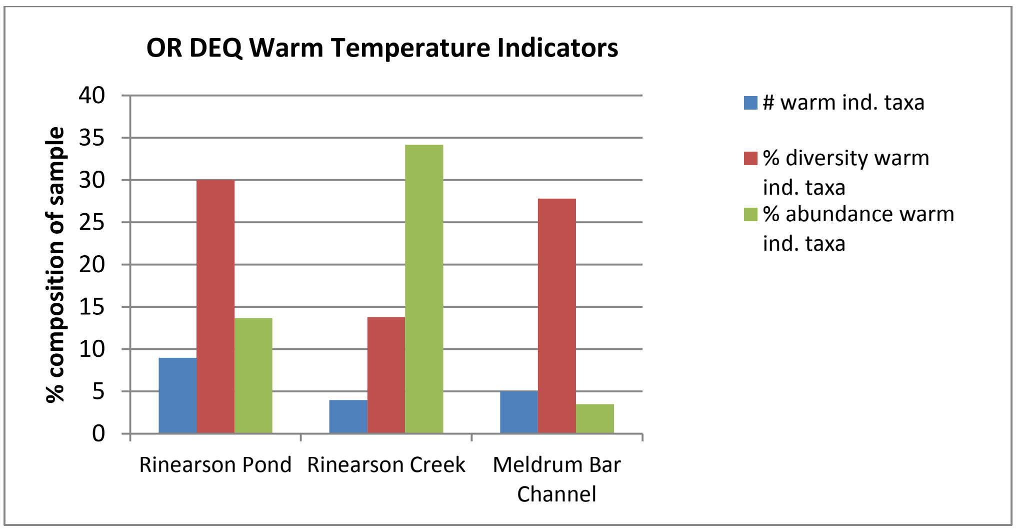
DEQ attribute tables were used to determine the presence of temperature (warm/cool) and sediment (low/high) indicators in the community at each sampling site. No site had taxa considered to be either cool temperature or low sediment indicators (see Appendix 1 for a complete list of OR DEQ indicator taxa), but warm temperature and high sediment indicators were present at all sites.

Rinearson Creek had the lowest total number and relative diversity of warm indicator taxa but the highest relative abundance. One-third (34.2%) of the creek community consisted of warm temperature indicators (Figure 1A), including multiple genera of non-biting midges (Chironomidae) in the tribe Chironomini and two types of snails: *Juga* (rock snails) and *Physa* (pond snails). These taxa are also high sediment indicators, and are widespread, tolerant organisms common in slow-moving, warm, silty waters. The higher relative diversity of warm indicators in both the pond and channel was due primarily to the presence of many genera of non-biting midges in the Chironomini tribe (10 of the 29 genera of chironomids in the complete data set belong to this tribe). Chironomini tolerance is best illustrated by the member genus *Chironomus*, known as bloodworms for their red coloration, due to a hemoglobin-like compound in their blood that enables them to extract oxygen from poorly oxygenated waters.

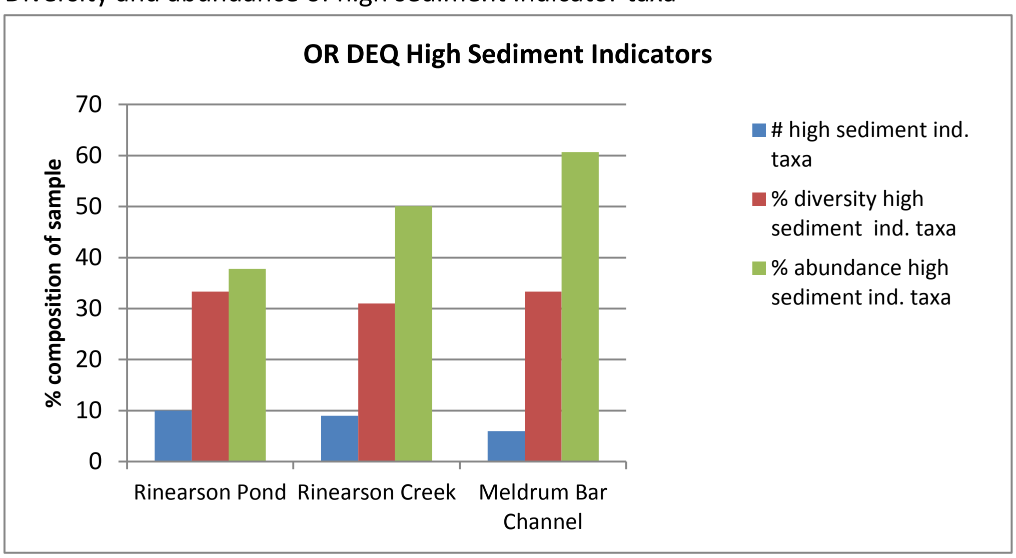
The number of high sediment indicator taxa was roughly similar between sites (Figure 1B) and also similar to the number of warm temperature indicator taxa at each site. However, high sediment indicator taxa were more dominant in the communities, with 31-33% of the total taxa at each site comprised of high sediment indicators present at high abundances (38-61% relative abundance). The community at Meldrum Bar Channel was dominated by segmented worms (Oligochaeta), where these tolerant sediment burrowers comprised 57% of the total community abundance.

Figure 1. *Presence, relative diversity, and relative abundance of OR DEQ indicator taxa*

A. Diversity and abundance of warm temperature indicator taxa



B. Diversity and abundance of high sediment indicator taxa



The high diversity of warm temperature and high sediment indicator taxa in Rinearson Pond is expected, as the macroinvertebrate community of lentic systems is necessarily adapted to warmer, slower, less oxygenated water. However, the extremely high relative abundance and relative diversity of warm indicator taxa in Rinearson Creek and Meldrum Bar Channel respectively, and the high relative diversity and abundance of high sediment indicators in the community at both sites suggests impaired conditions.

Community optima

OR DEQ has also assigned temperature and sediment optima (temperature and % FSS under which a taxon can maximize its abundance) to the majority of taxa in the state database. These values were used to calculate the abundance-weighted mean of the temperature and sediment optima for the macroinvertebrate community at each sampling site. Mean community temperature optimum was similar among all sampling sites, ranging from 17^{o}C at Meldrum Bar Channel to 18^{o}C and 18.5^{o}C for the Rinearson Pond and Rinearson Creek communities, respectively. For reference, the temperature optima of OR DEQ cool temperature indicators range from 12.2 – 15.6^{o}C while the optima of warm indicator taxa range from 17.9 – 21.1^{o}C, and the DEQ inferred stressor threshold is 18.2^{o}C.

Between-site differences for the weighted mean of % FSS optima were more dramatic. The community at Meldrum Bar Channel had the lowest mean sediment optimum (10% FSS), followed by Rinearson Pond (15.7% FSS) and Rinearson Creek (19.6% FSS). For reference, the optima of OR DEQ low sediment indicators range from 2 – 6% FSS; those of high sediment indicator taxa range from 10 – 25% FSS, and the DEQ inferred stressor threshold is 15% FSS.

These results indicate that temperature and sediment stressors are playing a role in shaping the macroinvertebrate community at these sites, especially in Rinearson Creek.

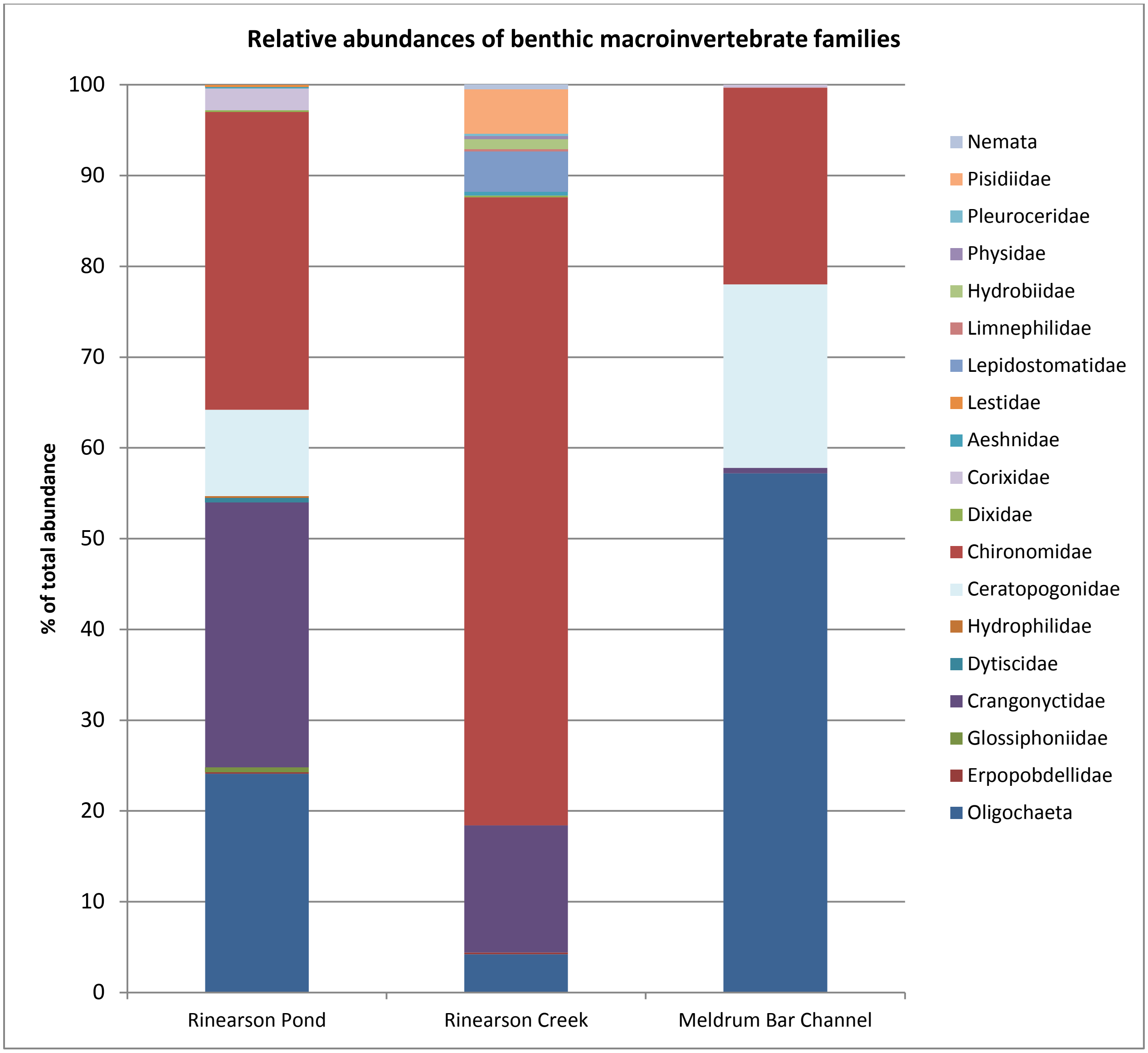
Taxonomic and ecological trait analyses

Unique taxa

Forty-nine unique taxa in 19 families or classes were collected among all three sampling sites (Figure 2). Only six of these taxa (12.2%) were present at all of the sites sampled, representing common, tolerant, cosmopolitan groups including aquatic earthworms, amphipods, and several genera of non-biting midges in the subfamily Chironominae. Taxa richness was similar between Rinearson Pond (29 taxa) and Rinearson Creek (30 taxa); diversity was much lower in Meldrum Bar Channel (18 unique taxa). These differences are also reflected in Shannon diversity index (H') values, which were similar in the pond and creek samples (H' = 3.13 and 3.17, respectively) and much lower in the channel (H' = 2.57).

Nine of the 30 taxa (30%) in the Rinearson Pond sample occurred only at that site, including many typical pond denizens, such as two of the three odonate (dragonfly and damselfly) genera in the complete dataset (*Anax*, undoubtedly *A. junius*, Common Green Darner, and *Archilestes*, undoubtedly *A. californica*, California Spreadwing; both are common at ponds and slow-moving streams) and the only aquatic beetles in the dataset (*Laccophilus*, a genus of predaceous diving beetle [Dytiscidae]; and *Berosus*, a genus of water scavenger beetle [Hydrophilidae]). Other taxa unique to the pond community were the tolerant glossiphoniid leech *Helobdella stagnalis* and four genera of non-biting (chironomid) midges in the sub-family Chironominae, all with high temperature and fine sediment optima.

Figure 2. *Relative abundances of benthic macroinvertebrate families among Rinearson samples. Note that Oligochaeta were identified only to class and Nemata only to phylum.*



The community in Rinearson Creek had more site-restricted taxa, with 14 of the 29 taxa (48.3%) in the creek community found only in that sample. The majority were Mollusca (snails and bivalves), including the rock snail (Pleuroceridae) genus *Juga*, common in many streams and tolerant of slower flow and human disturbance; *Physa* pond snails, common in slow, low-elevation waters; and hydrobiid pebble snails, moderately tolerant and, like *Juga*, generally found in streams rather than wetlands; and the only bivalves in these samples, the sediment-tolerant pisidiid fingernail or pea clams. Unfortunately, the mollusk community of Rinearson Creek also included three individuals of *Potamopyrgus antipodarum*, New Zealand Mud Snail (NZMS). This tiny (4-6 mm) invasive snail was first seen in the US in the Snake River in Idaho in 1987; it spread into Oregon waters by 1994, when it was found at the mouth of the Columbia River (Benson et al., 2015). Likely introduced accidentally via import of game fish or in ballast water, NZMS is now found throughout the west and in the Great Lakes. Many taxa unique to Rinearson Creek were among the more sensitive groups within the complete dataset and more associated with flowing water. These included the only Trichoptera among all samples, the long-horned (lepidostomatid) caddisfly *Lepidostoma*, whose larvae build square-sided cases from pieces of leaves and bark, and the Northern caddisfly *Psychoglypha,* which makes cylindrical cases from bits of plant and mineral material, as well as an *Aeshna* nymph, a genus of mosaic darner dragonfly.

In contrast, only four of the 18 taxa (22.2%) in the Meldrum Bar Channel community were unique to that sample; all were chironomid midges (three genera in the Orthocladiinae sub-family and one genus in the sub-family Chironominae).

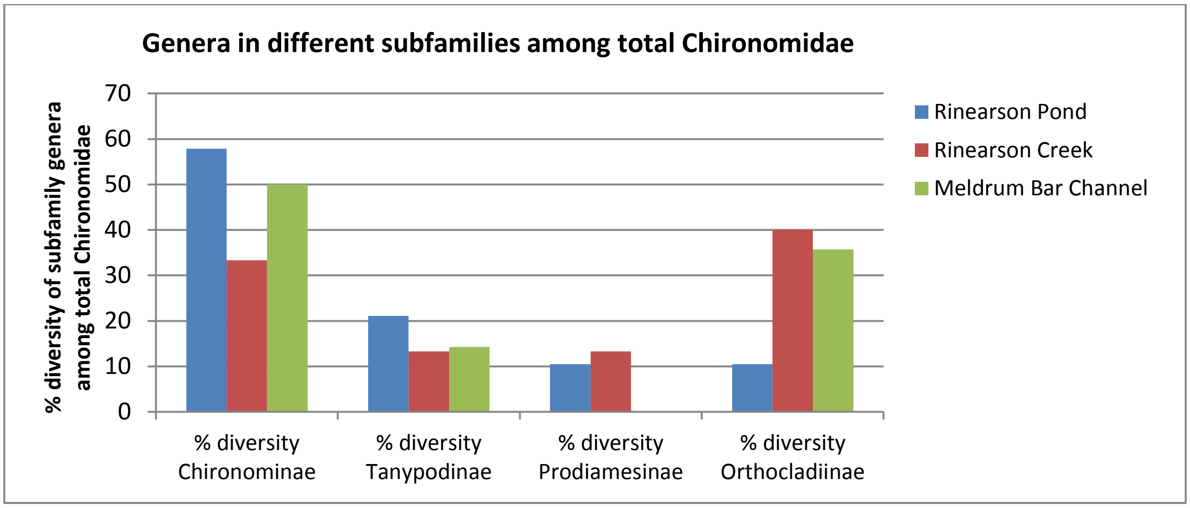
Chironomidae (non-biting midges)

The family Chironomidae (non-biting midges) comprises a huge diversity of species found in almost every type of aquatic habitat. Larvae are usually confined to surface layers of soft sediments, though some may burrow into the hyporheic zone, colonize the surface of wood or macrophytes, or burrow into rotting wood (Pinder, 1986). Chironomids are often broadly characterized as highly tolerant, but species differ widely in their sensitivity to stressors, from cosmopolitan groups tolerant of warm water, low oxygen, and soft sediment, to sensitive habitat-restricted inhabitants of mountain springs (Pinder, 1986; Merritt et al., 2008). Because of their wide range of sensitivities, when considered as a family in many IBIs a high diversity of Chironomidae is associated with better habitat health. In contrast, increasing relative abundance of Chironomidae is associated with impaired conditions, on the assumption that tolerant types have become more numerous.

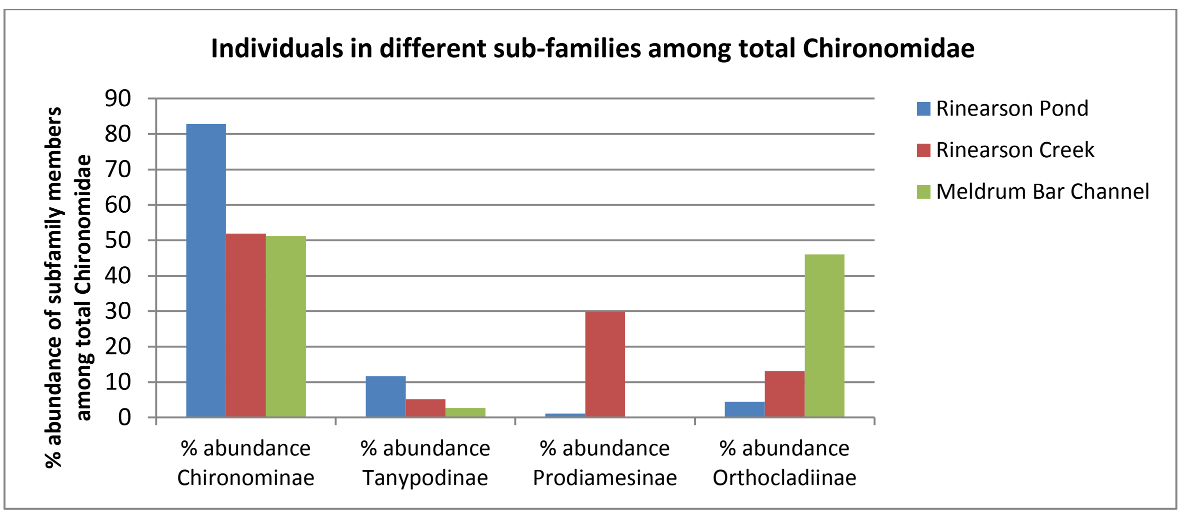
Chironomids accounted for the greatest diversity among all sites, with a total of 28 genera representing four of the seven North American subfamilies (Chironominae, Orthocladiinae, Tanypodinae, and Prodiamesinae). Chironomid taxa are expected to dominate the fauna in lentic environments, and the relative diversity of Chironomidae was indeed greater in Rinearson Pond (63.3% of total taxa diversity) than in Rinearson Creek (51.7% of total taxa diversity), although individuals were more abundant in the creek sample (relative abundance of 69.2% in the creek and 32.8% in the pond). However, this group dominated the diversity in Meldrum Bar Channel, with 77.8% of the total taxa comprised of chironomid genera, although individuals were present in lower numbers (relative abundance of chironomids in Meldrum Bar channel sample = 21.7%).

Because this family spans a wide range of sensitivities, chironomids are often examined at the level of subfamily. Tanypodinae genera are uncommon in samples and are usually found in cold springs, brooks, and streams, where larvae are often associated with mosses. Tanypodinae are active predators and unlike other chironomid subfamilies, larvae do not build sand tubes or other retreats. Only four Tanypodinae genera were present in the Rinearson samples, with the greatest abundance and diversity in the pond sample. Prodiamesinae, represented in the Rinearson samples by two genera (both found in the pond and creek samples), are associated with springs, streams, ponds, and the littoral zone of lakes. Orthocladiinae and Chironominae are less specialized and inhabit all types of aquatic habitats, and are thus more common and abundant in samples; both subfamilies were well-represented in these samples (Figure 3). The ability to tolerate a wide pH range (i.e. 6-9), lower dissolved oxygen, and increased acidity is seen more frequently in the Chironominae, particularly the Chironomini tribe, due to the presence of hemoglobin in their bodies (Jernelov et al., 1981; Pinder, 1986). Rock and gravel substrates tend to be dominated by Orthocladiinae, while sand and silt sediment are dominated by Tanypodinae and Chironominae. The number of chironomid genera belonging to the different subfamilies differed substantially among the sites (Figure 2). As expected, the highest relative abundance and diversity was seen for the Chironominae among all samples. Members of this more tolerant subfamily dominated the pond sample, with over 80% of the chironomid community comprised of Chironominae.

Figure 3. *A. Relative diversity of chironomid subfamilies among total Chironomidae*



B. Relative abundance of chironomid subfamilies among total Chironomidae



Community Composition

A hierarchical CLUSTER analysis of a Bray Curtis similarity matrix of square root-transformed taxa abundances revealed the closest relationship between the Rinearson Pond and Meldrum Bar Channel communities (51.5% similarity). The Rinearson Creek community was more similar to the pond community (39.4% similarity) than to the channel (22% similarity). The same four taxa contributed the most to differences between both the pond and creek and the channel and creek samples. Two of the four were abundant in creek samples but absent or nearly so from the channel and pond communities: *Prodiamesa*, a chironomid midge in the Prodiamesinae subfamily that sprawls or burrows in erosional (riffle) and depositional (pool) habitats; and *Polypedilum*, a chironomid midge in the Chironominae subfamily that is a climber and clinger associated with hydrophytes. The other two taxa accounting for the greatest difference between creek and pond/channel samples are tolerant sediment burrowers present in greater abundance in the pond and channel compared to the creek: Ceratopogoninae (biting midges), which were absent from the creek sample; and Oligochaeta (aquatic earthworms), whose abundance was an order of magnitude lower in the creek sample than in the pond and channel.

Trophic Guilds

Because food sources and availability play a large role in structuring aquatic macroinvertebrate communities, examining different trophic guilds (functional feeding groups [FFGs]) can be informative. The proportion of different FFGs varies naturally based on stream order, reach location, and differences in inputs of allochthonous (terrestrial-derived, i.e. leaves, seeds, wood, carcasses, feces) and autochthonous (stream-derived, i.e. photosynthesis by primary producers, decomposition of dead organisms, feces) nutrients into the stream (Vannote et al., 1980). However, FFG distributions are further influenced by surrounding land uses, hydrologic alterations, and excess nutrients, sediment, or contaminants.

The main FFGs of aquatic macroinvertebrates include shredders, collectors, scrapers, and predators (reviewed in Wallace & Webster, 1996). Shredders (SH) rely on terrestrial organic input such as leaf litter and wood (coarse particulate organic matter, CPOM, >1 mm diameter), and are often a dominant FFG in headwater reaches, especially where there is substantial riparian shading. Collectors include gatherers (CG), which take in fine particulate organic matter (FPOM, <1 mm diameter) deposited on surfaces and sediment, and filterers (CF), which take in suspended particles of FPOM. Scrapers (SC), also called grazers, rasp algae and diatoms off mineral and organic surfaces, and are thought to become dominant where primary production is maximized. Predators (PR), which consume other animals either by engulfing them or using piercing mouthparts to suck out body contents, remain relatively steady with stream order as a component of the community.

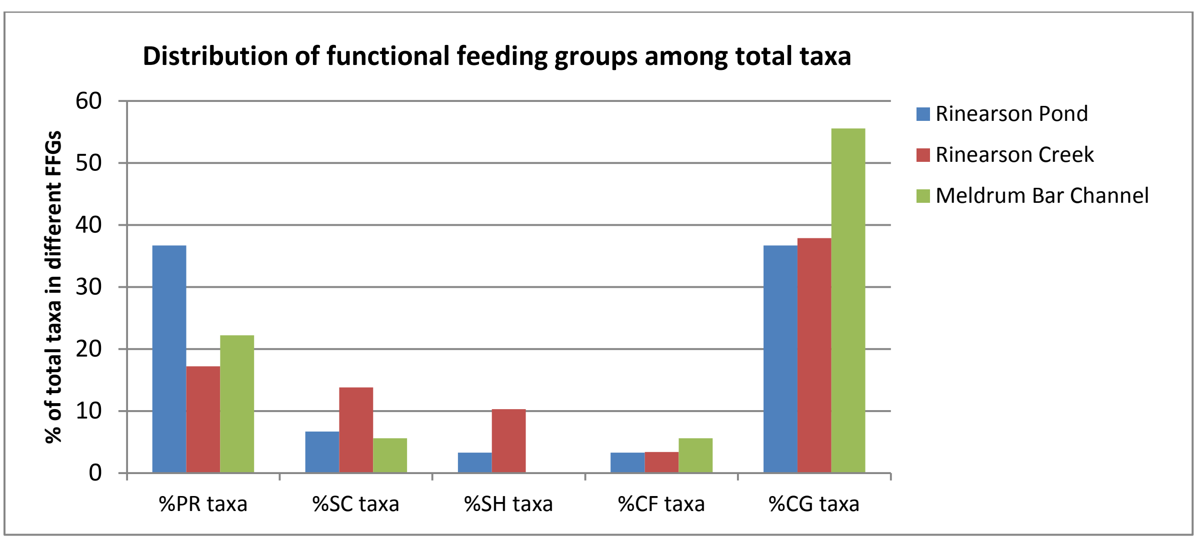
Gatherers (CG) are often an abundant component of the stream biota and are important prey for invertebrate and vertebrate predators. Because they are generalist feeders with a fairly broad food range, they can be more tolerant of disturbances that might alter food availability. The community at all sampling sites was dominated by CG taxa, which had both the highest relative diversity and relative abundance of all FFGs in all three samples (Figure 4). The majority of CG taxa were chironomid midges; 17 of the 28 chironomid genera present among the samples were gatherers. Gatherers can dominate under conditions of organic enrichment, but may decrease if pesticides or other toxins that bind to

FPOM particles are also present (Barbour et al., 1996). Filterers (CF), which also ingest FPOM, were present in much lower proportions then gatherers. The only CF taxon in the sample set was the chironomid midge *Micropsectra/Tanytarsus*, which was present in all three samples but with greatest relative abundance at Rinearson Pond. Filterers tend to me more abundant in riffles, so the low numbers of CF taxa may reflect the paucity of this habitat type in the sampled reaches. The difference in proportions of CG and CF could also reflect a difference in the quantity of suspended vs. settled FPOM.

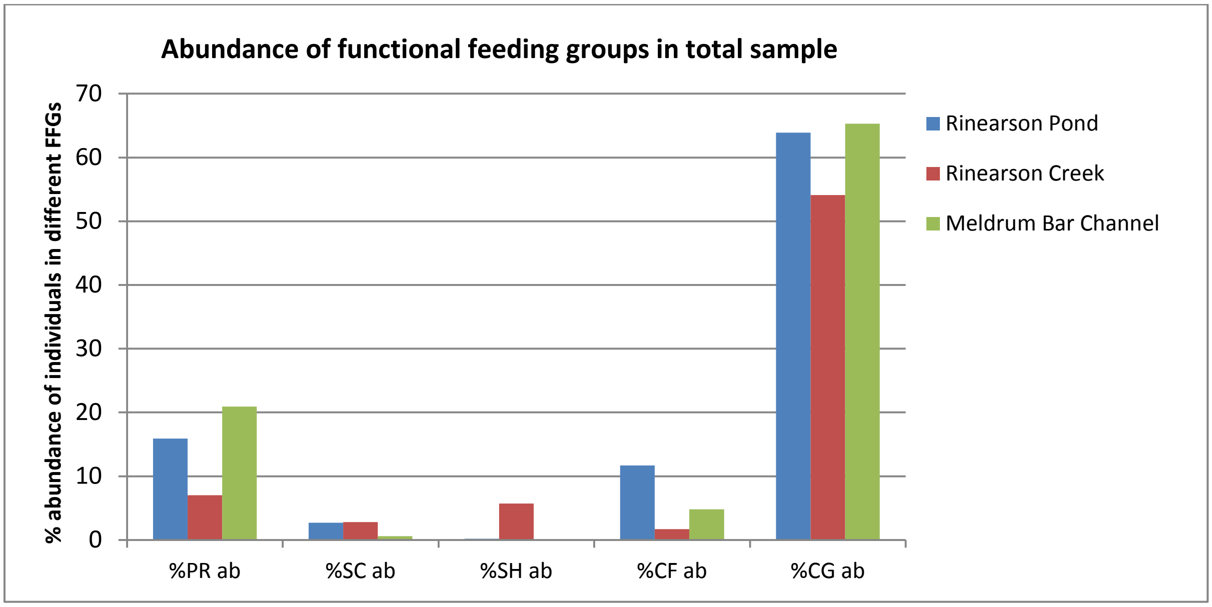
Predator taxa accounted for the 2nd highest community diversity and abundance, comprised primarily by dragonfly and damselfly taxa, several genera of chironomid midges in the subfamily Tanypodinae, and a few leech and aquatic beetle taxa. Because predators rely on an abundant food base, and different life stages of a single taxon may require prey of different sizes, their proportion within a community is expected to be lower at more disturbed or impaired sites.

Scrapers and shredders were present at lower overall diversity and abundance. Rinearson Creek had greater SH and SC diversity and abundance compared to the pond and channel communities, but the community in Meldrum Bar Channel lacked SH taxa and had only a single SC taxon (*Phaenopsectra*, a chironomid midge in the Chironominae subfamily). The majority of scrapers were comprised of snail taxa, while shredders were represented by the two caddisfly taxa found only in the creek sample, and a chironomid midge in the subfamily Orthocladiinae (*Brillia*). Scrapers require abundant periphyton, and since filamentous algae and mosses can interfere with their ability to feed, their proportions may be lower in impaired habitats. Shredders include detritivores and herbivores that may consume both living and dead tissue. Their reliance on CPOM as a food resource makes them particularly sensitive to riparian conditions and surrounding land uses that impact allochthonous inputs to the stream, and their low abundance and diversity is likely due in part to the lack of an intact riparian zone, especially in the creek and channel reaches. Because shredders are more specialized in their feeding and less tolerant of disturbance, their proportions are also expected to be lower in more impaired habitats.

Figure 4. *A. Proportion of total taxa in each sample comprised by each FFG. PR, predator; SC, scraper; SH, shredder; CF, collector-filterer; CG, collector-gatherer.*



B. Relative abundance of taxa in different FFGs

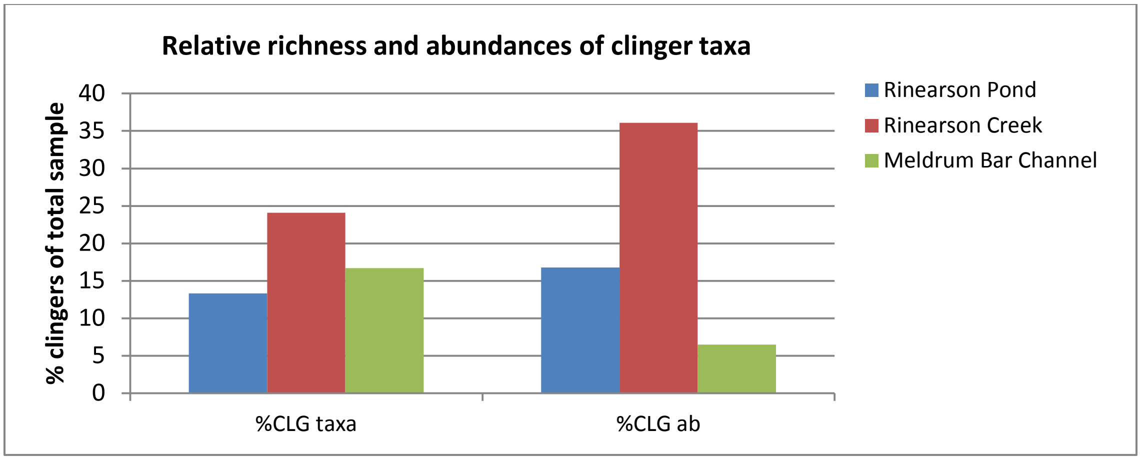


Habit

Habit describes an organism's locomotion, and includes categories such as swimmer (SW), burrower (BU), clinger (CLG), climber (CLB), sprawler (SP), and diver (DI) (Merritt et al., 2008). Flow rate, hydrology, and substrate characteristics can all affect habit types in the macroinvertebrate community, but less work has been done in the use of habit as an ecological trait for stream bioassessment. Using habit as an assessment measure is also complicated by the fact that some taxa may have multiple habits and/or different habits at different life stages. However, two habit-based traits have been found to correlate more closely with habitat disturbance: proportions of clingers; and swimmers.

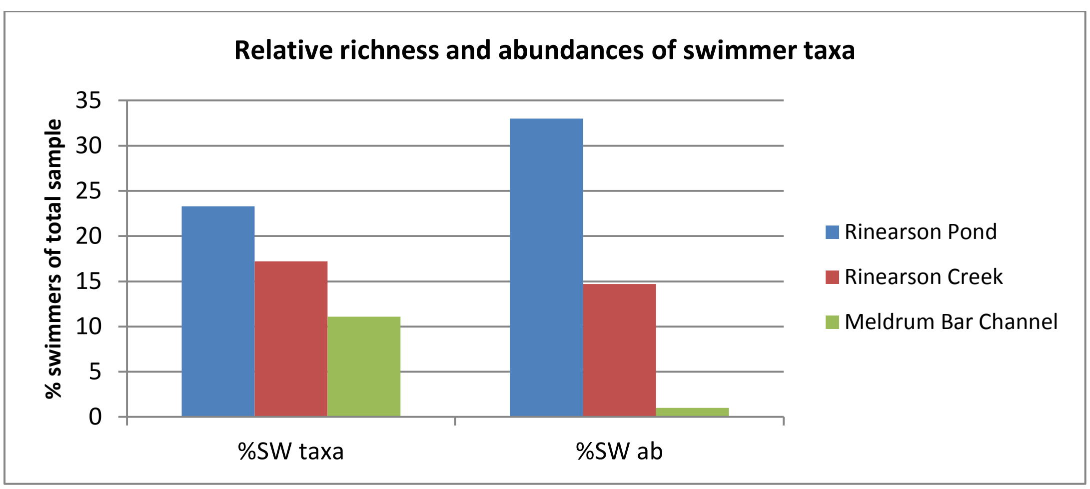
Clinger taxa build fixed retreats or have physical adaptations such as claws, flattened body shape, or sucker-like structures that help them cling to mineral or organic surfaces in flowing waters. Increased sedimentation may lead to a decrease in clingers, as the spaces and surfaces these organisms exploit fill in and become unavailable (Pollard & Yuan, 2010). The Rinearson Creek community had twice as many clinger taxa (seven genera) compared to the pond and channel samples (four and three genera, respectively), comprised mainly of chironomid midge and caddisfly genera. Relative diversity and abundance of clinger taxa was also greater in the creek community (Figure 5). While the absence of riffle habitat among all the sites likely contributed to low numbers of clingers, which are adapted to faster-flowing waters, it is worth noting that the relative abundance of clingers in the pond site was three times that in the channel, suggesting that habitat impairment as well as flow is affecting this component of the community in Meldrum Bar Channel.

Figure 5. Proportion of clinger taxa (% CLG taxa) and individual abundance (% CLG ab) in Rinearson samples



Swimmers inhabit lotic and lentic waters; they do not swim constantly, but alternate short bursts of swimming with periods of clinging to submerged rocks or plants. Swimmers may be a useful measure of habitat impairment, as their higher mobility is considered to be a positive adaptation in unstable or disturbed environments (Tullos, 2009; Pollard & Yuan, 2010). However, diversity and abundance of swimmers was not revealing in this case. The Meldrum Bar Channel community had the lowest relative diversity of swimmer taxa, with very few individuals (Figure 6), while the Rinearson Pond sample had the highest relative diversity and abundance of swimmers, including amphipods, aquatic bugs and beetles, and some genera of chironomid midges. The greater abundance and diversity of swimmers in the pond community may reflect the greater abundance of submerged and emergent plants in this habitat.

Figure 6. Proportion of swimmer taxa and individual abundance in Rinearson samples



Conclusions and next steps

This study represents the first attempt to delineate the benthic aquatic invertebrate communities of the Rinearson Creek system and describe baseline biological conditions prior to implementation of restoration activities. PREDATOR O/E and multimetric IBI scores indicated severely impaired biological conditions among all habitats (pond, creek, and channel), with the Rinearson Creek sample having the highest O/E and IBI score, and a better IBI-based condition (moderately disturbed) compared to the other two sites (severely disturbed). Because the Rinearson sampling sites differ significantly from the reference streams in which the PREDATOR and IBI models were developed (cobble-bottomed streams with riffle/run habitat), and because samples were taken during a season outside of the index period in which the models were developed, these model scores are not accurate. However, they are presented here as they may be useful for comparison if restoration activity ultimately creates riffle habitats more suitable for model application.

Due to the fact that use of existing models was not appropriate, and because additional community analyses are often more revealing, multiple different taxonomy- and ecology-based traits were examined and compared among the sampled communities. These traits can also be examined in future years of monitoring to assess potential restoration-related changes, even if use of O/E or IBI models remains inappropriate. All of these measures revealed severely impacted communities with high tolerance for sediment, disturbance, and slow-flow conditions. All communities were dominated by common, cosmopolitan, tolerant taxa adapted to higher temperature and fine sediment loads as well as slower-moving waters. Of the more sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera), only Trichoptera (caddisflies) were found, and were present only in the creek sample with very low diversity and abundance. Many aspects of the current macroinvertebrate community among all sampling sites correspond to "urban stream syndrome", where multiple development- and stormwater-related stressors contribute to reduced taxonomic diversity and increased dominance of common tolerant species (Walsh et al., 2005). Continued monitoring as restoration projects are completed will provide documentation of impacts on aquatic biota and enable assessment of changes in biological and ecological conditions resulting from restoration.

Recommendations for future biomonitoring efforts post-restoration include:

- Continue monitoring and analysis of the benthic macroinvertebrate community for a t least 2-3 years post-restoration. Assessment of the biological effectiveness of most stream restoration projects is limited by a lack of monitoring, an absence of baseline community data obtained prior to restoration, and/or a post-restoration monitoring timeframe that is inadequate to detect meaningful community changes (Bernhardt et al., 2005, 2007; Jahnig et al., 2010). In order to be meaningful, biomonitoring of restored habitats requires data on biotic communities present at the site prior to restoration, and a biologically relevant time frame for post-restoration monitoring. Stressors that impair habitats and filter biological communities generally operate over a period of years, and it is unrealistic to expect that community recovery will be instantaneous. Restored habitats may even select for taxa tolerant of disturbance for a period of time, as channel reconfiguration and other activities alter food and habitat resources.

Furthermore, changes in macroinvertebrate community composition are influenced not only by characteristics of the restored stream but also by the proximity and composition of source populations that can colonize improved habitats, and the degree of connectivity and/or presence of dispersal barriers between source and restored habitat (Bond & Lake, 2003; Petersen et al., 2004; Blakely et al., 2006; Sundermann et al., 2011; Tonkin et al., 2014). This project represents an excellent and necessary first step in implementing an ecologically valid biomonitoring program.

- Conduct macroinvertebrate sampling for continued monitoring during the OR DEQ standard index period of late summer to early fall. Although it would represent a change from the sampling period used in this study, sampling later in the season facilitates better taxonomic resolution (as individuals are more mature and thus more easily identified to genus or species), and falls within the index period used to develop the PREDATOR and IBI models (June 20 early date cutoff), rendering use of those models in the future more feasible.

- Quantify abiotic factors that can affect macroinvertebrate community composition and impact biological conditions, such as water temperature, diel dissolved oxygen patterns, and selected nutrients. Other habitat measures such as pebble counts and substrate embeddedness (i.e. USEPA, 2007) could provide more information about substrate and sediment characteristics that are influencing the structure of macroinvertebrate communities at these sites.

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Appendix 1. OR DEQ indicator taxa for temperature and fine sediment stressors

Values in parentheses indicate temperature (°C) or sediment (% fine sediment) optima value for each taxon.

Taxon	Temperature indicator	Fine sediment indicator
Prosimulium	Cool (12.2)	---
Baetis bicaudatus	Cool (12.3)	---
Zapada columbiana	Cool (12.9)	---
Neothremma	Cool (12.9)	---
Parapsyche elsis	Cool (13.5)	Low (4)
Caudatella	Cool (13.6)	Low (4)
Megarcys	Cool (13.6)	Low (4)
Visoka	Cool (13.7)	---
Epeorus grandis	Cool (14.2)	Low (2)
Yoraperla	Cool (14.2)	---
Ephemerella	Cool (14.4)	---
Drunella coloradensis/flavilinea	Cool (14.5)	---
Doroneuria	Cool (14.5)	---
Despaxia	Cool (14.5)	---
Turbellaria	Cool (14.6)	---
Ironodes	Cool (14.9)	---
Drunella doddsi	Cool (15.2)	Low (3)
Ameletus	Cool (15.2)	---
Rhyacophila Brunnea Gr.	Cool (15.5)	Low (4)
Cinygmula	Cool (15.5)	Low (6)
Micrasema	Cool (15.6)	---
Diphetor hageni	Warm (17.9)	---
Antocha	Warm (18.3)	---
Hydropsyche	Warm (18.5)	---
Juga	Warm (18.6)	High (15)
Chironomini	Warm (18.8)	High (10)
Zaitzevia	Warm (19.0)	High (9)
Optioservus	Warm (19.6)	High (12)
Dicosmoecus gilvipes	Warm (20.6)	---
Physa	Warm (21.1)	High (21)
Arctopsyche	---	Low (2)
Rhyacophila Hyalinata Gr.	---	Low (3)
Rhyacophila Angelita Gr.	---	Low (3)
Drunella grandis	---	Low (3)
Epeorus longimanus	---	Low (4)
Rhithrogena	---	Low (5)
Rhyacophila Betteni Gr.	---	Low (5)
Glossosoma	---	Low (5)
Baetis tricaudatus	---	Low (6)
Oligochaeta	---	High (10)
Paraleptophlebia	---	High (11)
Tanypodinae	---	High (12)

Ostracoda	---	High (17)
Hydroptila	---	High (17)
Lymnaeidae	---	High (18)
Cheumatopsyche	---	High (20)
Sphaeriidae	---	High (21)
Coenagrionidae	---	High (25)

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Abutilon theophrasti	Velvetleaf	B	**B**	N	Y	N
Acer platanoides	Norway maple	B	-	N	Y	N
Acroptilon repens	Russian knapweed	A*	B	N	Y	N
Ailanthus altissima	Tree-of-heaven	B	-	N	Y	N
Alliaria petiolata	garlic mustard	B	B/T	N	Y	N
Amorpha fruticosa	indigo bush	B	B	N	Y	N
Arctium minus	Common burdock	C	-	Y	Y	N
Arrhenatherum elatius	Tall oatgrass	C	-	N	Y	N
Betula pendula	cutleaf birch	C	-	Y	Y	N
Brachypodium sylvaticum	false brome	A*	B/T	Y	Y	N
Bromus tectorum	Cheatgrass	C	-	N	Y	N
Buddleja (Buddleia) davidii	butterfly bush	B	B	Y	Y	N
Callitriche stagnalis	Pond water starwort	C	-	N	N	Y
Carduus pycnocephalus and C. tenuiflorus	Italian thistle or slender flowered thistle	A*	B	N	Y	N
Carex pendula	Pendant sedge	A	-	N	Y	N
Centaurea diffusa	Diffuse knapweed	B	B	N	Y	N
Centaurea pratensis (C. debeauxii ssp. thuillieri)	Meadow knapweed	C	B	N	Y	N
Centaurea stoebe ssp. micranthus (C. biebersteinii)	Spotted knapweed	B	B	N	Y	N
Chondrilla juncea	Rush skeletonweed	B	B/T	N	Y	N
Cirsium arvense	Canada thistle	C	B	Y	Y	N
Cirsium vulgare	Common thistle	C	B	Y	Y	N
Clematis vitalba	wild clematis	C	B	N	Y	N
Conium maculatum	Poison-hemlock	C	-	N	Y	N
Convolvulus arvensis	field bindweed	C	B/T	Y	Y	N
Convolvulus sepium	Lady’s-nightcap		-	N	Y	N
Cortaderia jubata	Jubata grass	A*	B	N	Y	N

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Crataegus monogyna	English hawthorn	C	-	Y	Y	N
Cyperus esculentus	yellow nutsedge	-	B	Y	Y	N
Cytisus scoparius	Scotch broom	C	B	N	Y	N
Daphne laureola	Spurge laurel	B	B	N	Y	N
Daucus carota	wild carrot	C	-	Y	N	Y
Dipsacus fullonum	teasel	C	B	Y	Y	N
Echium plantagineum	Paterson's curse	A*	A/T	N	Y	N
Egeria densa	S. American waterweed	B	B	N	Y	N
Fallopia bohemica	Bohemian knotweed	B	-	N	Y	N
Foeniculum vulgare	fennel	C	-	N	Y	N
Geranium lucidum	Shining geranium	C	B	N	Y	N
Geranium robertianum	herb-Robert	C	B	Y	Y	N
Geum urbanum	European avens	C	-	N	Y	N
Hedera helix	English ivy	C	B	Y	Y	N
Hedera hibernica	Irish ivy	C	-	N	Y	N
Heracleum mantegazzianum	giant hogweed	A*	A/T	N	Y	N
Hieracium aurantiacum	Orange hawkweed	A*	A/T	N	Y	N
Hieracium laevigatum	Smooth hawkweed	B	-	N	Y	N
Hieracium pilosella	Mouse-ear hawkweed	B	A	N	Y	N
Hieracium pratense (H. cespitosum)	(formerly listed as Yellow hawkweed)	A*	A/T	N	Y	N
Hieracium vulgatum (H.lachanelii)	Common hawkweed	B	-	N	Y	N
Hypericum perforatum	St. John's wort	C	B	Y	Y	N
Hypochaeris radicata	hairy cat's ear	C	-	Y	N	Y
Ilex aquifolium	English holly	C	-	Y	Y	N
Impatiens capensis	spotted jewelweed	C	-	Y	N	Y
Impatiens glandulifera	Policemen's helmet	A*	B	N	Y	N

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Iris pseudacorus	yellow flag iris	B	B	Y	Y	N
Juncus effusus v. effusus	soft rush	B	-	Y	N	Y
Lactuca serriola	prickly lettuce	C	-	Y	N	Y
Lamiastrum galeobdolon	Yellow archangel	A	B	N	Y	N
Lapsana communis	nipplewort	C	-	Y	N	Y
Leucanthemum vulgare	oxeye daisy	C	-	Y	N	Y
Ligustrum vulgare	Privet	C	-	N	Y	N
Linaria dalmatica ssp. dalmatica	Dalmation toadflax	B	B/T	N	Y	N
Lotus corniculatus	birds foot trefoil	C	-	Y	N	Y
Ludwigia hexapetala (Jussiaea uruguayensis)	Water primrose	A	B	N	Y	N
Lunaria annua	Money plant	B	-	N	Y	N
Lythrum portula	spatulaleaf purslane	B	-	Y	N	Y
Lythrum salicaria	purple loosestrife	B	B*	Y	Y	N
Melilotus alba	sweetclover	C	-	N	N	Y
Melissa officinalis	Lemon balm	C	-	N	N	Y
Mentha pulegium	pennyroyal	C	-	Y	N	Y
Myriophyllum aquaticum	Parrots feather	B	B	N	N	Y
Myriophyllum spicatum	Eurasian watermilfoil	C	B	N	N	Y
Nymphaea odorata	Fragrant water lily	C	-	N	N	Y
Onopordum acanthium	Scotch thistle	A*	B	N	Y	N
Parentucellia viscosa	Yellow glandweed	C	-	N	N	Y
Phalaris aquatica	Harding grass	A	-	N	Y	N
Phalaris arundinacea	reed canarygrass	C	-	Y	Y	N
Phragmites australis (introduced var. only)	Common reed	A*	A	N	Y	N
Phytolacca americana	Pokeweed	A	-	N	Y	N
Polygonum convolvulus	Climbing bindweed	B	-	N	Y	N

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Polygonum cuspidatum (Fallopia cuspidata)	Japanese knotweed	B	B*	Y	Y	N
Polygonum polystachyum (Persicaria wallachii)	Himalayan knotweed	B	B	N	Y	N
Polygonum sachalinense (Fallopia sachalinensis)	Giant knotweed	B	B	N	Y	N
Populus alba	White poplar	B	-	N	Y	N
Potamogeton crispus	curly leaf pondweed	C	-	N	N	Y
Potentilla recta	Sulphur cinquefoil	C	-	N	Y	N
Prunus avium	sweet cherry	C	-	Y	Y	N
Prunus laurocerasus	English laurel	C	-	Y	Y	N
Prunus lusitanica	Portugal laurel	C	-	Y	Y	N
Pueraria lobata	Kudzu	A*	A/T	N	Y	N
Ranunculus ficaria (formerly listed as Chelidonium majus)	Lesser celandine	B	B	N	Y	N
Ranunculus repens	creeping buttercup	C	-	Y	N	Y
Robinia pseudoacacia	black locust	C	-	Y	Y	N
Rosa eglanteria	Sweetbriar rose	C	-	N	Y	N
Rosa multiflora	Multiflora rose	C	-	N	N	Y
Rubus armeniacus	Himalayan blackberry	C	B	Y	Y	N
Rubus laciniatus	cutleaf blackberry	C	-	Y	Y	N
Senecio jacobaea	tansy ragwort	C	B/T	Y	Y	N
Silene coronaria	Rose campion	C	-	N	Y	N
Silybum marianum	Blessed milk thistle	A*	B	N	Y	N
Sisymbrium officinale	Hedge mustard	C	-	N	Y	N
Solanum dulcamara	bittersweet nightshade	C	-	N	Y	N
Solanum nigrum	Garden nightshade	B	-	N	Y	N
Sonchus arvensis, S. asper, S. oleraceus	perennial sowthistle	C	-	Y	N	Y

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Taeniatherum caput-medusae	Medusahead	C	B	N	Y	N
Tamarix ramosissima	Salt cedar	A*	B/T	N	Y	N
Tanacetum vulgare	common tansy	C	-	Y	N	Y
Trifolium arvense	Hare’s foot clover	C	-	N	N	Y
Trifolium pratense	red clover	C	-	Y	N	Y
Trifolium repens	white clover	C	-	Y	N	Y
Trifolium subterraneum	Subterraneum clover	C	-	N	N	Y
Ulex europaeus	Gorse	A*	B/T	N	Y	N
Utricularia inflata	Swollen bladderwort	A	-	N	Y	N
Verbascum blattaria	moth mullein	C	-	N	N	Y
Verbascum thapsus	common mullein	C	-	Y	N	Y
Verbena bonariensis	tall verbena	A	-	N	Y	N
Vicia cracca	tufted vetch	C	-	N	N	Y
Vicia villosa	Hairy vetch	C	-	N	N	Y
Vinca major	periwinkle (large leaf)	C	-	N	N	Y
Vinca minor	periwinkle (small leaf)	C	-	N	N	Y

***Required eradication/EDRR species**