Action Effectiveness Monitoring for the Columbia River Estuary Habitat Restoration Program

Final Report to the Bonneville Power Administration

Project Number: 2003-011-00
Contract Number: 51120
Performance/Budget Period: September 15, 2010 – December 31, 2011
Annual Report

Technical Contact: Jina Sagar
Research Scientist
Lower Columbia Estuary Partnership
811 SW Naito Parkway, Suite 410
Portland, Oregon 97204
Phone: (503) 226-1565 x 239
jsagar@lcrep.org

BPA Project Manager: Anne Creason
Policy Analyst
Bonneville Power Administration
905 NE 11th Avenue
Portland, Oregon 97208
Phone: (503) 230-3859
amcreason@bpa.gov

May 2012

Action Effectiveness Monitoring for the Columbia River Estuary Habitat Restoration Program

Annual Report for Project Number: 2003-011-00, Contract Number: 51120

Jina P. Sagar*
Sean Y. Sol[1]
O. Paul Olson[1]
Kate H. Macneale[1]
Paul M. Chittaro[1]
Lyndal L. Johnson[1]
George L. Kral[2]
Melissa A. Rowe Soll[2]
Janelle M. St. Pierre[3]
Rita M. Beaston[3]
Sarah Holman[3]
April S. Cameron[4]
Micah Russell[4]
April Silva[4]
Matthew Schwartz*

Prepared by the Lower Columbia Estuary Partnership*
with support from the Bonneville Power Administration

Lower Columbia Estuary Partnership
811 SW Naito Parkway, Suite 410
Portland, OR 97204

[1] Northwest Fisheries Science Center, NOAA-Fisheries
[2] Ash Creek Forest Management, Inc.
[3] Scappoose Bay Watershed Council
[4] Columbia River Estuary Study Taskforce

List of Figures

List of Tables

List of Appendices

1.0 Executive Summary

The Lower Columbia Estuary Partnership's mission is "to preserve and enhance the water quality of the estuary to support its biological and human communities." The Habitat Restoration Program's goal is to enhance, protect, and restore tidal wetlands and other key habitats in the lower Columbia River and estuary. This program provides a coordinated, ecosystem-based approach to implement restoration actions by many partners in the lower Columbia River and estuary and allows partners to leverage off resources and expertise of each other.

The Bonneville Power Administration (BPA) has supported the Estuary Partnership's Habitat Restoration Program for eight years. The focus of BPA's support is the development and implementation of habitat restoration projects designed to benefit Endangered Species Act listed salmonids. The Effectiveness Monitoring Program administered by the Lower Columbia Estuary Partnership (Estuary Partnership) implements Action Effective Monitoring (AEM) to address RPA 60 in the 2007 Draft BiOp based on the Estuary RME plan. This Effectiveness Monitoring Program will focus on projects sponsored by the Estuary Partnership's Habitat Restoration Program.

This annual report documents AEM efforts implemented by the Estuary Partnership under BPA Project Number: 2003-011-00, Contract Number: 51120.

The Estuary Partnership contracted NOAA Fisheries (NOAA), Ash Creek Forest Management (ACFM), Scappoose Bay Watershed Council (SBWC), and Columbia River Estuary Study Taskforce (CREST) to conduct pilot AEM at four sites (Mirror Lake, Sandy River Delta, Scappoose Bottomlands, and Fort Clatsop) in spring 2010/2011. These AEM sites represent different restoration activities (culvert enhancement to improve fish passage, large wood installation, re-vegetation, cattle exclusion, and culvert removal for tidal reconnection), habitats (bottomland forest, riparian forest, emergent wetland, and brackish wetland), and hydro-geomorphic reaches of the river (Reaches H, G, F, and A, ranging from tidal freshwater in Reach H, or the Columbia River George, to saltwater intrusion in Reach A, near Astoria, Oregon).

<u>Summaries of AEM Results</u>

- NOAA Fisheries sampled fish and macroinvertebrates from May to October 2011 at 5 locations at the Mirror Lake restoration site to describe site usage by fish, condition and stock of collected juvenile salmonids, and abundance and biomass of macroinvertebrates (**Section 3.0 Fish-passage Improvement and LWD Monitoring AEM at Mirror Lake**). The Lake site was sampled through December 2011 to detect the potential downstream movement of juvenile coho salmon from Youngs Creek.
    - Coho, Chinook, and steelhead were observed at Mirror Lake, below culvert, Youngs Creek, Latourell Creek and the confluence in varying amounts throughout the sampling season. Increased coho density at Youngs Creek and Latourell Creek suggest that restoration actions, such as placement of large woody debris at these sites, may be improving habitat conditions for coho salmon.
    - For the first time, Chinook salmon were present above the Lake at the confluence site, which suggests that under some conditions, such as high water years, the confluence area may provide feeding and rearing habitat for out migrating juvenile Chinook salmon entering the Mirror Lake Complex from the mainstem Columbia.

- ACFM returned to 5 restoration sites to collect data at 185 vegetation plots across 259 acres at the Sandy River Delta and Mirror Lake restoration sites to assess the success of invasive vegetation removal and native vegetation plantings at these restoration sites (**Section 4.0 Planting Success AEM at Mirror Lake and Sandy River Delta**).

- At the Sandy River Delta sites, density of native woody plants (stocking) increased or remained stable. From 2008 individual plant growth has increased, as indicated by change in high-vigor plants, from 10% to 48%, along with a continuing decline in suppression to 10%. The ratio of trees to total woody plants trended downward, possibly indicating recruitment of shrubs via rhizomes and natural seeding. When compared to the reference site, native woody stem densities of bare-ground restoration units show gradual but expected trends toward target conditions.
- At Mirror Lake, installed plants from 2010 to 2011 showed a continued downward trend from 74% to 53%. The decrease in plant survival and vigor are attributed to herbivore damage and competition/suppression from noxious weeds due to limited maintenance funds.

- Following vegetation plantings and cattle exclusion at the Scappoose Bottomlands restoration area, SBWC deployed two loggers to monitor water temperature and depth, collected photo-points at 7 sites to assess landscape change, assessed planting success in 64 plots, and collected vegetation community data in 3 tidal wetland ponds at Hogan Ranch. Fish monitoring was concluded 2010 at Hogan Ranch due to landowner concerns and 2011 will be the last year for habitat and vegetation monitoring. (**Section 5.0 Vegetation and Habitat AEM at Scappoose Bottomlands**).
  - Over the 2004-2011 study period of the Hogan Ranch Ponds the largest parameter change observed was a significant decrease in E. coli levels in all ponds. Decreases in turbidity and conductivity were also observed during this time and both decreases can be attributed to cattle exclusion from the ponds. Seasonally high water temperatures during late spring and summer in the ponds and creeks suggest these areas do not provide ideal habitat for salmonids during these times.
  - In Scappoose Creek, over the four year study period, no large changes in the streams seasonal or inter-annual water chemistry were observed between sites. During this time the only water quality parameter that consistently did not meet the prescribed salmon habitat water quality standards was temperature which occurred during summer low flow months (late July-September). However, after July, juvenile salmonids are expected to have already migrated through this stream and not be threatened by exposure (ODEQ 2003).
  - In 2011 the plant communities of all the ponds showed a significant shift in composition due to prolonged summer flooding. Major changes to the plant composition post cattle exclusion include restoration of Pond 3 to a wapato dominate wetland. This change has enhanced native food resources for water fowl and other wildlife in this wetland area. Alterations to the hydrology of Ponds 1 and 2 (though not a direct part of this restoration effort) has resulted in an increase in the wetted area and aquatic plant communities of these ponds.
  - In 2011 plant species vigor and survival was lower than previous years on both Wilson/LaCombe and Hogan Ranch properties because of stress caused by the extreme high water levels from April-July. Monitoring indicates the remaining native plantings are in good condition with high vigor.
  - The overall survival rate of plantings in 2011 on the Wilson/LaCombe property was 61% when adjusted for plants missing between the 2010 and 2011 surveys. This is comparable to the survival on plantings on this site from 2009 (adjusted survival 61%) and 2010 (adjusted survival 73%). On Hogan Ranch the overall survival was 58% this is low compared to previous year's survival of 89-83% and can be attributed to impacts from abnormally long inundation (high water) and high loss from herbivory.

- CREST collected habitat (sediment accretion, channel cross-sections, and photo-points), fish, and macroinvertebrate data at the Fort Clatsop restoration and reference sites, for the fourth year. In 2009, CREST began collecting water quality data at Ft. Clatsop restoration and reference sites. Fish and macroinvertebrates were sampled monthly between March and July at the Fort Clatsop site (**Section 6.0 Salmon, Salmon Prey, and Habitat AEM at Fort Clatsop South Slough & Alder Creek**.)

- The modification in fish sampling methods in 2011 increased catch totals and provided a more accurate representation of the fish density, abundance, and composition.
- The South Slough restoration site expressed a greater diversity of unmarked juvenile salmonids, while the reference site at Alder Creek had a greater diversity of native, non-salmonid, species in the by-catch.
- In 2011, 4 species of juvenile salmon were observed at South Slough, and 2 species at Alder Creek; Chinook and coho were observed at both sites while chum and cutthroat were only observed at South Slough.
- Chinook demonstrated a preference for isopods and chironomids; isopods were favored at Alder Creek, chironomids were selected more at South Slough. Coho primarily selected isopods and chironomids at both sites. Coho demonstrated a wider range of prey selectivity, suggesting they may be more opportunistic feeders, and Chinook more selective.
- Sediment accretion revealed an increase in sediment deposition in the adjacent floodplain at both Sough Slough (+4cm) and Alder Creek (+5cm). Changes in channel morphology were smaller between 2010 and 2011 than in previous years.
- Reconnection of tidal influence to South Slough has resulted in a restored tidal signature to the site. South Slough had more optimal water quality conditions for salmon than Alder Creek; however, key differences in landscape characteristics are likely a contributing factor. South Slough is deeper, particularly after tidal reconnection, and is fed by a consistent source of cold fresh water year round.

2.0 Background on Estuary Partnership's Action Effectiveness Monitoring

The Lower Columbia Estuary Partnership's mission is "to preserve and enhance the water quality of the estuary to support its biological and human communities." As part of this mission, the Estuary Partnership manages an umbrella Estuary Ecosystem Restoration Program that supports state, federal and local government restoration objectives. The Habitat Restoration Program's goal is to enhance, protect, and restore tidal wetlands and other key habitats in the lower Columbia River and estuary. This program provides a coordinated, ecosystem-based approach to implement restoration actions by many partners in the lower Columbia River and estuary and allows partners to leverage off resources and expertise of each other. The Estuary Partnership's Comprehensive Conservation and Management Plan, completed in 1999 and updated in 2011, calls for enhancing, protecting, creating, or reclaiming 19,000 acres of wetland habitat, including at least 3,000 acres of tidally influenced habitat, by 2014. The Estuary Partnership has catalogued more than 16,614 acres of lower Columbia River habitat that have been acquired, protected, or restored throughout the region since 1999. Estuary Partnership funding has supported approximately 60 restoration projects, which have resulted in the restoration of 3,325 acres of habitat.

The regional restoration program developed by the Estuary Partnership and its partners for the lower Columbia River is made up of six major components: 1) a competitive bid process to evaluate, prioritize and fund individual restoration projects; 2) a "top-down" restoration prioritization strategy that identifies priority areas for protection and restoration; 3) a restoration inventory database that tracks identified actions in a GIS-based system; 4) outreach and coordination efforts such as the Estuary Partnership's Science Work Group (SWG), quarterly project development coordination meetings, annual technical conferences, etc. to grow our regional partnership and ensure coordination and best available science is being used; 5) a technical assistance program that allows us to support restoration partners to identify and develop larger and more complex projects; and 6) an adaptive management framework that includes ecosystem monitoring to track the overall health of the lower river and an action effectiveness monitoring program to identify which actions are working best and how to improve other actions. This report concentrates on component 6 that is funded through this contract. Results of components 1, 3, 4 and 5 funded through this BPA contract are provided in a separate report (E. Haas, 2012).

The Bonneville Power Administration has supported the Estuary Partnership's Habitat Restoration Program for eight years. The focus of BPA's support is the development and implementation of habitat restoration projects designed to benefit Endangered Species Act listed salmonids. During this contract period, the Estuary Partnership provided funding for five restoration projects, which when complete, will result in the restoration or enhancement of 0.5 miles and 285.5 acres of habitat. Also, the Estuary Partnership provided technical assistance funding to help initiate development of five additional projects. Additionally, the Estuary Partnership collaborated with a variety of government, non-profit, and private entities to identify and develop restoration projects, share information about restoration projects, and identify ways to improve regional restoration efforts. By hosting quarterly project development coordination meetings and regular Science Work Group meetings, the Estuary Partnership provided a forum for project funders and practitioners to share knowledge about restoration projects. The Estuary Partnership continued to work closely with the Bonneville Power Administration, as well as the United States Army Corps of Engineers, to implement actions identified in the 2008 Biological Opinion for the Federal Columbia River Power System.

To that end, the 2008 Draft Biological Opinion for the Federal Columbia River Power System (Draft 2008 BiOp) highlights the importance of estuarine habitat restoration for anadromous fish (Reasonable and Prudent Alternatives [RPA] 36-38). These restoration RPAs are to be implemented in conjunction with action effectiveness monitoring (AEM) identified in RPA 60. AEM is needed to "evaluate the effects of selected individual habitat restoration actions at project sites relative to reference sites and evaluate post-restoration trajectories based on project-specific goals and objectives" (NMFS, 2007).

In preparation for the Draft 2008 BiOp, the plan for "Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program" (Estuary RME) was prepared for the Bonneville Power Administration (BPA) by the Pacific Northwest National Laboratory (PNNL) in conjunction with National Oceanic and Atmospheric Administration (NOAA) Fisheries and the US Army Corps of Engineers (USACE) with the collaboration of the Lower Columbia Estuary Partnership (Johnson et al. 2008) as part of the Estuary and Oceanic Subgroup (EOS). The plan provided a framework to evaluate progress towards understanding, conserving, and restoring the estuary to benefit ESA listed salmonid species and outlines recommendations for AEM.

The Effectiveness Monitoring Program administered by Lower Columbia Estuary Partnership (Estuary Partnership) implements AEM to address RPA 60 in the 2007 Draft BiOp based on the Estuary RME plan. This Effectiveness Monitoring Program will focus on projects sponsored by the Estuary Partnership's Habitat Restoration Program. On-the-ground AEM efforts collect the data needed to assess the performance and functional benefits of restoration actions in the LCRE. The goal of this effort is to provide the Estuary Partnership, primary funding agencies (BPA and Environmental Protection Agency [EPA]), restoration partners (e.g., USACE and Columbia River Estuary Study Taskforce [CREST]), and others with information useful for evaluating the success of restoration projects. Such evaluations supported by AEM facilitate improvements in project design and management, increase the success of restoration projects for ESA listed salmonids, and address RPA 60 of the 2007 Draft BiOp.

The Estuary Partnership's objectives for the Effectiveness Monitoring Program are to:

- Improve restoration techniques to maximize impact of habitat restoration actions and better track long term project success
- Identify how restoration techniques address limiting factors for salmonids
- Determine the impact of restoration actions on salmon recovery at the site, landscape, ecosystem scale
- Use intensive monitoring to inform extensive monitoring efforts to improve multi-scale AEM

To meet AEM program objectives, the Estuary Partnership are engaged it the following tasks:

- Implementing AEM as outlined in the Estuary RME plan (Johnson et al. 2008) and following standardized monitoring protocols (e.g., Roegner et al. 2009) where applicable
- Developing long-term datasets for restoration projects and their reference sites
- Increasing consistency in monitoring methods and data management and sharing between projects
- Disseminating data and results to facilitate improvements in regional restoration strategies
- Developing of a regional cooperative effort by all agencies and organizations participating in restoration monitoring activities to maximize the usefulness of monitoring data

Additionally, the Estuary Partnership aims for the Effectiveness Monitoring Program to complement our existing Ecosystem Monitoring Program (BPA project # 2003-007-00). The Ecosystem Monitoring Program implements monitoring activities to characterize undisturbed emergent wetlands and assess juvenile salmonid usage of those habitats. Several sites monitored by the Ecosystem Monitoring Program are included in the Estuary Partnership's Reference Site Study funded by BPA. Since the Ecosystem Monitoring Program monitors many parameters likely to be included in AEM (e.g., vegetation, water quality, and salmon), the collection of comparable datasets by the two programs (where possible) will fill data gaps and add to our understanding of habitat conditions and juvenile salmonids in the lower river.

2.1 Site Selection

In January 2008, the Estuary Partnership and the Estuary and Oceanic Subgroup (EOS) identified sites for pilot AEM. The Estuary Partnership presented a sample of restoration projects supported with BPA funds as potential sites (Figure 1). Projects included a variety of restoration activities implemented in different habitats and reaches of the river. EOS members recommended selecting sites to represent different restoration activities, habitats, and geographic reaches of the river. Other recommended considerations included:

- Baseline monitoring was conducted at the restoration site.
- Re-vegetation AEM in different habitats would provide useful data and be low in cost relative to AEM for projects such as like tidal reconnection.
- If possible, AEM should occur at sites where restoration actions are apt to continue for multiple years (indicating a financial investment in the project area).
- AEM at sites sponsored by BPA and partners would provide collaboration opportunities.
- Some (but not all) project managers would have the capacity to implement AEM in 2008.

EOS members recommended 4 projects for AEM (Mirror Lake, Sandy River Delta, Scappoose Bottomlands, and Fort Clatsop; highlighted rows in Table 1 and green dots in Figure 1 were first sampled in 2008 and 2009. These AEM sites represent different restoration activities (culvert enhancement to improve fish passage, large wood installation, re-vegetation, cattle exclusion, and culvert removal for tidal reconnection), habitats (bottomland forest, riparian forest, emergent wetland, and brackish wetland), and geographic reaches of the river (Reaches H, G, F, and A, ranging from tidal freshwater in Reach H, or the Columbia River Gorge, to saltwater intrusion in Reach A, near Astoria, Oregon).

Table 1. Sample of Estuary Partnership restoration projects funded by BPA presented as potential sites to EOS members. Recommended AEM sites are highlighted in gray.

Project Name	Restoration Activity	Year(s) When Restoration Occurred	Habitat Type	Reach	Baseline Monitoring
Mirror Lake	Improve fish passage; Large wood installation; Native plant revegetation	2007 – Present	Bottomland hardwood forest	H	Yes
Sandy River Delta	Native plant revegetation	2004 – 2006	Riparian forest	G	No
Stephens Creek	Floodplain reconnection; Native plant revegetation	2007 – Present	Floodplain	G	Yes
Salmon Creek	Large wood installation	2007 – Present	Riparian	F	TBD
Malarkey Ranch	Culvert removal	2004 – 2005	In stream	F	Yes
Scappoose Bottomlands	Cattle exclusion; Invasive removal; Native plantings	2004 – Present	Emergent wetland	F	Yes
Alder Creek	Culvert removal	2005 – 2006	In stream	F	Yes
Lewis River	Native plant revegetation	2007 – Present	Riparian	E	TBD
Sharnelle Fee	Dike breach	2005 – Present	Tidally influenced wetland	A	Yes
Lewis and Clark	Dike breach	2004 – 2006	Tidal estuarine habitat	A	Yes
Fort Clatsop	Culvert removal and bridge installation	2005 –Present	Brackish wetland	A	Yes

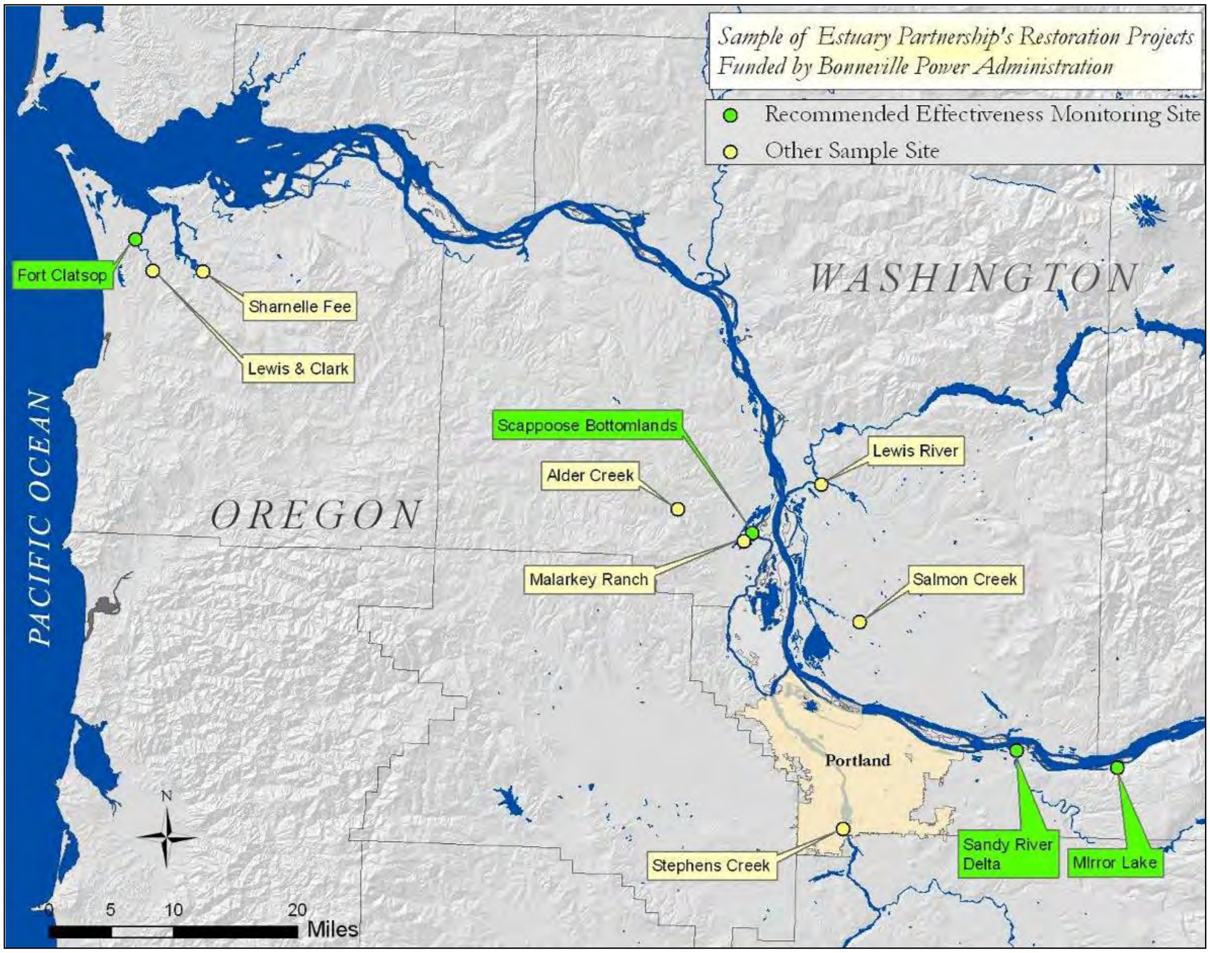


Figure 1. Sample of Estuary Partnership restoration projects funded by BPA presented as potential sites to EOS members. Sites that EOS members recommended for AEM are denoted by the green dots and boxes.

3.0 Fish-passage Improvement and LWD AEM at Mirror Lake

3.1 Site Description

The Mirror Lake project area is a part of Rooster Rock State Park, and is separated from the Columbia River by Interstate 84. The lake is used for fishing and recreation and the area contains some high quality emergent wetland habitats at its downstream end. Further upstream, wetland and riparian habitats are dominated by reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus discolor*), and other non-native species. These areas were historically subject to annual flooding from the Columbia River. Although the upstream connection to the site was severed by the freeway, a culvert under I-84 still allows for backwater from the Columbia to flood the site; however, flows are likely somewhat restricted compared to historical conditions. Modifications to the Columbia's hydrograph are the primary hydrologic impact to this site.

The area is currently undergoing restoration, and as part of the Estuary Partnership's Effectiveness Monitoring Program, NOAA Fisheries investigated prey availability, fish assemblages, and juvenile salmon habitat usage of the Mirror Lake area. As part of this effort, NOAA Fisheries focused on the following five work elements:

1.) A survey of prey availability and habitat use by salmon and other fish at site;
2.) Taxonomic analyses of prey in salmon stomach contents in order to identify prey types at the Mirror Lake project area. NOAA Fisheries will use these data to examine the effects of restoration activities on salmon diets;
3.) Analyses of otoliths for determination of growth rates;

4.) Analyses of biochemical measures of growth and condition (e.g., whole body lipid content);
5.) Compilation of data and annual report preparation.

Table 2 lists the coordinates of each site and Figure 2 illustrates the five areas of focused fish sampling at the Mirror Lake project area as described below.

Culvert: This site is located immediately below the I-84 culvert and adjacent areas opposite the boat launch and associated docks (Figure 2, Figure 3A, B). The area immediately below the culvert had very little to no vegetation associated with the banks or bottom. The banks are steep, and rocky, areas consisting of pebbles to small boulders. Bottom sediment was the same. The adjacent areas are dominated by grasses, with a steep bank (1.5 meter) that drops off quickly. The bottom sediments are composed of very soft mud. In the summer of 2008, boulders were added to the culvert at I-84 to improve water flow for salmon passage.

Lake: This site is on the open water part of the lake near the I-84 culvert (Figure 2, Figure 3C). The area is dominated by grasses from the high water mark to the low water edges, and by shrubs and blackberry vines along the bank above and at very high water levels. The lake substrate consists of consolidated to soft-packed mud, with aquatic vegetation later in the season. The lake is fed by waters from Latourell Creek and Youngs Creek. Its water level varies seasonally depending on the elevation of a beaver dam at its outlet (upstream of the I-84 culvert) and backwater from the Columbia River that inundates the site during spring runoff.

Table 2. Coordinates of the sites sampled at Mirror Lake in 2011.

Site Name	**Latitude**	**Longitude**
Culvert	45° 32.606'N	122° 14.878'W
Lake	45° 32.562'N	122° 14.703'W
Confluence	45° 32.620'N	122° 13.727'W
Latourell Creek	45° 32.590'N	122° 13.190'W
Youngs Creek	45° 32.735'N	122° 12.275'W

Figure 2. Photo showing areas of fish collection at Mirror Lake. Photo provided by Google Earth.

Youngs Creek: This site is located upstream of the Mirror Lake site (Figure 2, Figure 3 D). The creek varies from about 1.5 meters wide at low water level to about 5 meters at high water. The riparian area is dominated by reed canarygrass to the edge of the creek bed and in immediately adjacent areas, with a steep drop (1.5 meters) from the edge of the creek bank. Bottom sediment is composed of very soft mud. From mid-June to late summer, the creek banks are overgrown with tall grasses, which overhang the banks, providing shade and cover for stream inhabitants. Between 2004 and 2007, before monitoring was initiated, a failing culvert (dam) at this site was replaced with a 70 ft. bridge to give salmon species access to upstream spawning areas. Prior to restoration activities, very little large woody debris existed at this site and grasses provided the only available cover. To improve this situation, invasive plants along the creek were removed and native willows and cottonwoods were planted. In summer of 2008, large woody debris was added to Youngs Creek to improve salmon habitat.

Confluence and Latourell Creek: In 2011, these two new sites first sampled in 2010 were sampled again. Both sites were surveyed intermittently for salmon observation. The Confluence site (Figure 3 E) is located at the confluence of Latourell Creek and Youngs Creek, downstream of the Youngs Creek Site. Latourell Creek (Figure 3 F) is located 100 m downstream of Latourell Lake. Physical characteristics of both sites are similar to Youngs Creek. The bottom sediment is composed of very soft mud, and the banks are overgrown with tall grasses. The Confluence, which is slightly wider and shallower than Youngs Creek, was sampled in May, and July, and September, while Latourell Creek was sampled once in September.

Figure 3. Photos of fish sampling sites at the Mirror Lake project area. A) Culvert at high water, B) Culvert at low water, C) Lake, D) Youngs Creek, E) Confluence and F) Latourell Creek.

3.2 Methods

3.2.1 Fish Sampling

Fish were collected at the Mirror Lake Complex sites from early May 2011 through October 2011, with the exception of the Lake site, where sampling continued through December in order to detect potential downstream movement of juvenile coho salmon (*Oncorhynchus kisutch*) from Youngs Creek. However, not all sites were sampled every month. Sampling permit issues prohibited sampling at all sites in April. Extremely high water from May to June precluded sampling at the Culvert in June and at Youngs Creek in May and June. The Confluence was sampled intermittently throughout the sampling season, though not as regularly as the Culvert, Lake and Youngs Creek. Because it is difficult to access, Latourell Creek was sampled only once, in September. Additional details on sampling effort are provided in the Results section.

Due to variation in topography, accessibility, and water levels among the restoration sites, several types of gear were used to sample the Mirror Lake sites. Fish were collected using a Puget Sound beach seine (PSBS) (37 x 2.4 m, 10 mm mesh size), a modified PSBS (MPSBS, shortened to 7.5 x 2.4 m, 10 mm mesh size), or a modified block net (MBN) where the middle portion of the PSBS was used as a block net and a second net (2 x 1.5m, 10 mm mesh size) was used as a fish chase net. PSBS sets were deployed using a 17 ft. Boston Whaler or 9 ft. inflatable raft. The MPSBS was deployed on foot in shallow water where efficient boat deployment was not possible. The MBN was used to sample fish in small stream channels where fishing with the PSBS or MPSBS was not efficient or feasible. Up to three sets were performed per sampling time as conditions allowed.

Sampled fish were identified to the species level and counted. Salmonid species (up to 30 specimens) were measured (fork length in mm) and weighted (in g), and checked for adipose fin clips to distinguish between marked hatchery fish and unmarked, presumably wild fish. At each sampling event, NOAA Fisheries recorded the coordinates of the sampling locations, the time of sampling, water temperature, weather, habitat conditions, and vegetation.

When Chinook salmon (*Oncorhynchus tshawytscha*) were present, up to 30 individual juvenile Chinook salmon were collected for necropsy at each field site at each sampling time. Salmon were measured (to the nearest mm) and weighed (to the nearest 0.1 g), then sacrificed. The following samples were collected from the field-sampled fish: stomach contents for taxonomic analysis of prey, whole bodies (minus stomach contents) for measurement of lipids and persistent organic pollutants (POPs), fin clips for genetic stock identification, and otoliths for aging and growth rate determination. Because sufficient fish were not available or could not be collected within the limits or our collection permit, bile for measurement of metabolites of polycyclic aromatic hydrocarbons (PAHs) and stomach contents for measurement of PAHs and POPs were not collected in 2011. Necropsy samples were not collected for coho salmon or other salmonid species because our permits did not authorize this type of sampling for these species.

Samples for chemical analyses were frozen and stored at –80°C until analyses were performed. Samples for taxonomic analyses were preserved in 70% ethanol. Fin clips for genetic analyses were collected and preserved in alcohol, following protocols described in Roegner et al. (2009). Otoliths for age and growth determination were also stored in alcohol. The number and type of samples collected at each site and sampling time are listed in Table 3.

3.2.2 Prey Sampling

For the invertebrate prey sampling, the objective was to collect aquatic and terrestrial invertebrate samples and to identify the taxonomic composition and abundance of salmonid prey available at sites when juvenile salmonids were collected. These data will be compared with the taxonomic composition of prey found in stomach contents of fish collected concurrently. Because juvenile Chinook salmon were the target species for diet analyses, prey sampling in 2011 was limited to the Culvert and Lake sites, where juvenile Chinook salmon were typically present.

In 2011, NOAA Fisheries conducted the following types of invertebrate collections at the Culvert and Lake sites in the Mirror Lake project area:

1) Open water column Neuston tows (2-3 tows at each site at each sampling time). These tows collect prey available to fish in the water column and on the surface of open water habitats. For each tow, the net was towed for a measured distance of at least 100 m. Invertebrates, detritus, and other material collected in the net were sieved, and invertebrates were removed and transferred to a labeled glass jar or Ziploc bag. The jar or bag was then filled with 95% ethanol so that the entire sample was covered.

2) Emergent vegetation Neuston tows (2-3 tows at each site at each sampling time). These vegetation tows collect prey associated with emergent vegetation and available to fish in shallow areas. For each tow, the net was dragged through water and vegetation at the river margin where emergent vegetation was present and where the water depth was < 0.5 m deep for a recorded distance of 10 m. The samples were then processed and preserved in the same manner as the open water tows.

3.2.3 Sample Analyses

Genetic analysis
Genetic stock identification (GSI) techniques (see Manel et al. 2005) were used to investigate the origins of juvenile Chinook salmon using the Mirror Lake Complex sites, as described in Teel et al. (2009) and Roegner et al. (2010). The stock composition of juveniles was estimated with a regional microsatellite DNA data set (Seeb et al. 2007) that includes baseline data for spawning populations from throughout the Columbia River basin (described in Teel et al. 2009). The overall proportional stock composition of Mirror Lake samples was estimated with the GSI computer program ONCOR (Kalinowski et al. 2007), which implemented the likelihood model of Rannala and Mountain (1997). Probability of origin was estimated for the following regional genetic stock groups (Seeb et al. 2007; Teel et al. 2009): Deschutes River fall Chinook; West Cascades fall Chinook; West Cascades Spring Chinook; Middle and Upper Columbia Spring Chinook; Spring Creek Group fall Chinook; Snake River Fall Chinook; Snake River Spring Chinook; Upper Columbia River Summer/Fall Chinook; and Upper Willamette River Spring Chinook. West Cascades and Spring Creek Group Chinook are Lower Columbia River stocks.

Lipid Determination
As part of our study we determined lipid content in salmon whole bodies. Lipid content can be a useful indicator of salmon health (Biro et al. 2004), and also affects contaminant uptake and toxicity (Elskus et al. 2005). Studies show that the tissue concentration of a lipophilic chemical that causes a toxic response is directly related to the amount of lipid in an organism (Lassiter and Hallam, 1990; van Wezel et al. 1995); in animals with high lipid content, a higher proportion of the hydrophobic compound is associated with the lipid and unavailable to cause toxicity.

Prior to analyses, salmon whole body samples from the field were composited by genetic reporting group and date and site of collection into a set of composite samples, each containing 3-5 fish each. The total amount of extractable lipid (percent lipid) in these composite samples was determined by Iatroscan and lipid classes were determined by thin layer chromatography with flame ionization detection (TLC/FID) (Ylitalo et al. 2005).

Otolith Analyses
To determine recent growth, microstructural analysis was conducted on otoliths extracted from juvenile Chinook at the Lake and Culvert sites. Specifically, sagittal otoliths are being embedded in Crystal Bond© and polished in a transverse plane using 30-3µm lapping film. Using Image Pro Plus© (version 5.1), with a media cybernetics (evolution MP color) digital camera operating at a magnification of 20 x, NOAA-Fisheries will determine the average fish daily growth rate (i.e., mm of fish length/day) for three time periods: a) the last 7 days of their life, b) the last 14 days of their life, and c) the last 21 days of their life (total otoliths analyzed = 131; left sagittal otoliths were used). Average daily growth (DG, mm/day) was determined using the Fraser-Lee equation:

$$La = d + [(Lc - d)/Oc] \times Oa$$

$$DG = [(Lc - La)/a]$$

where La and Oa represents fish length and otolith radius at time a (i.e., last 7, 14, or 21 days), respectively, d is the intercept (13.563) of the regression between fish length and otolith radius, Lc and Oc are the fish length and otolith radius at capture, respectively. The results of these analyses will be appended to the report when completed.

Chemical Contaminants in Whole Bodies and Stomach Contents
Composite whole body samples were extracted with dichloromethane using an accelerated solvent extractor. The sample extracts were cleaned up using size exclusion liquid chromatography and analyzed by gas chromatography/mass spectrometry (GC/MS) for PCB congeners, PBDE congeners, and organochlorine (OC) pesticides including DDTs, hexachlorocyclohexanes (HCHs), chlordanes, aldrin, dieldrin, mirex, and endosulfans, as described by Sloan et al. (2004, 2006). Summed PCBs were determined by adding the concentrations of 45 congeners (PCBs 17, 18, 28, 31, 33, 44, 49, 52, 66, 70, 74, 82, 87, 95, 99, 101/90, 105, 110, 118, 128, 138/163/164, 149, 151, 153/132, 156, 158, 170/190, 171, 177, 180, 183, 187, 191, 194, 195, 199, 205, 206, 208, 209). Summed DDT levels (∑DDTs) were calculated by summing the concentrations of p,p'-DDT, p,p'-DDE, p,p'-DDD, o,p'-DDD, o,p'-DDE and o,p'-DDT. Summed chlordanes (∑CHLDs) were determined by adding the concentrations of heptachlor, heptachlor epoxide, g-chlordane, a-chlordane, oxychlordane, cis-nonachlor, trans-nonachlor and nonachlor III. Summed hexachlorocyclohexanes (∑HCHs) were calculated by adding the concentrations of a-HCH, b-HCH, g-HCH, and lindane.

To adjust for the influence of lipid on toxicity, we normalized whole body contaminant concentrations for lipid, and relied primarily on lipid-normalized data to evaluate potential health effects of toxicants on juvenile salmon. Wet weight data are also presented to facilitate comparison with other studies, and to evaluate risks to predators who consume salmon that have accumulated toxicants.

Fish Community Characteristics, Catch per Unit Effort, and Fish Condition Calculations. Fish species diversity was calculated using the Shannon-Weiner diversity index (Margaley 1958):

$$H' = -\sum_{i=1}^{S} (p_i \ln p_i)$$

Where

S = the number of species. Also called species richness;

pi = the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community.

Catch per unit effort (CPUE) was calculated as described in Roegner et al. (2009), with fish density reported in number per 1000 m^2.

For all salmonid species, Fulton's condition factor (K) (Fulton 1902; Ricker 1975) was calculated as an indicator of fish health and fitness, using the formula:

$$K = [\text{weight (g)}/\text{fork length (cm)}^3] \times 100$$

3.3 Results

3.3.1 Water level and its effect on fishing

At all sites, water level increased from April through June and declined thereafter. Figure 4 shows the water depth measured below Bonneville Dam on the Columbia River during this time period. During the spring runoff (April through July), water levels at the Mirror Lake sites coincided with Columbia River water levels. After early July, water levels at the Mirror Lake sites were more constant and influenced by the elevation of the beaver dam at the I-84 culvert and flows from Latourell and Youngs Creeks.

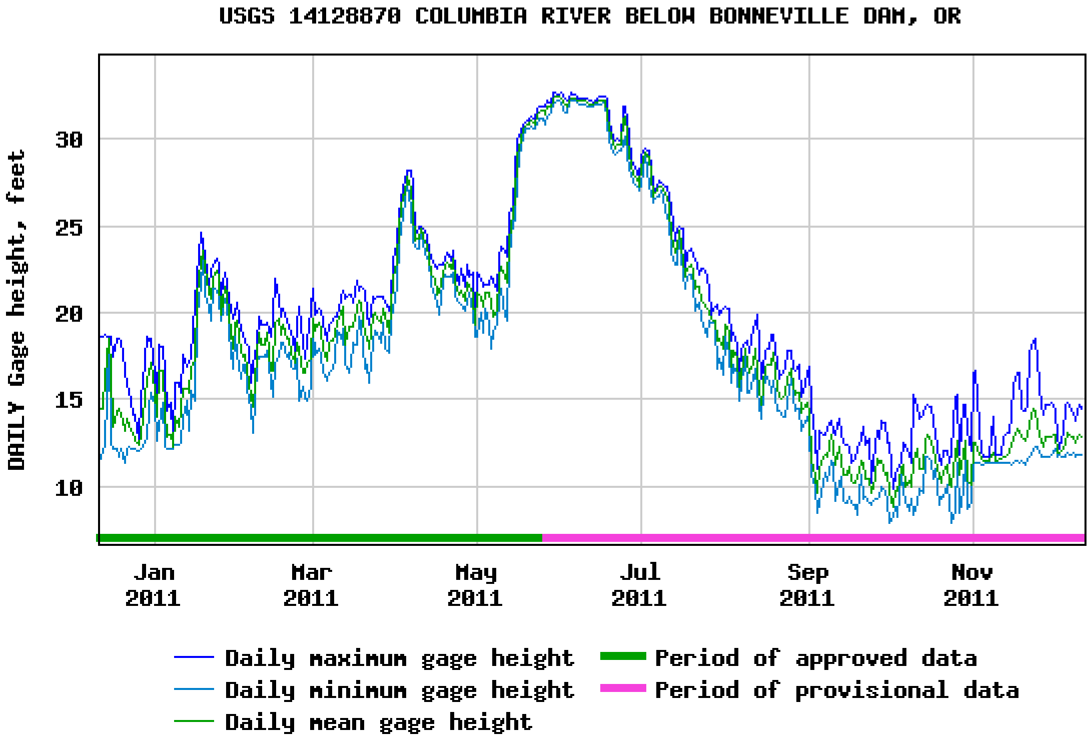


Figure 4. Water depth (ft) below the Bonneville Dam (Lat 45° 38'00", long 121° 57'33"). Data provided by USGS.

The rise and fall of water levels prohibited effective sampling of the Mirror Lake sites as described below.

- Culvert. At mid to higher water, the area immediately below the culvert and two adjacent areas were sampled with the PSBS. At extreme low water, bottom substrate, which was comprised of very soft mud, prevented successful beach seining with the PSBS, and consequently no sampling was possible in September.

- Lake. This site was successfully fished in early and late May, June and July using the PSBS; from late August through December, water levels receded while the growth of aquatic vegetation increased. Low water levels and increased vegetation cover made site access difficult and prohibited the use of the PSBS (Figure 6), thus the MPSBS was used then to sample the site from late August through December.

Figure 5. Fishing at high water with PSBS (note the absence of vegetation in water) vs site at low water (full of vegetation)

- Youngs Creek. The site was successfully fished in late July through October using the MBN. The water level was extremely high in May and June, which prevented use of the MBN to fish this site (Figure 7).

Figure 6. Fishing with modified block net at lower water vs. sampling at relatively higher water levels (photograph from 2008).

Table 3 lists the total number of fishing attempts that were accomplished at each site by month for the 2011 sampling season. Because of the extended sampling season at the Lake section, this site had the most attempts completed (20) of all Mirror Lake sites, followed by the Culvert (9), Youngs Creek (8), the Confluence (4) and Latourell Creek (2). Table 4 lists all the samples that were collected from juvenile Chinook, including otoliths, stomach contents for diet analysis, fin clips for stock determination and whole bodies for contaminant analysis.

Table 3. Fishing attempts made at Mirror Lake Complex site in 2011.

	month								
site	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
Culvert	a	1	b	2	2	2	2	0	0
Lake	a	2*	1	2	3	3	3	3	3
Confluence	a	1	b	1	0	2	0	0	0
Latourell Creek	a	b	b	0	0	2	0	0	0
Youngs Creek	a	b	b	2	2	2	2	0	0

* denotes sites where the site was sampled in early May and late May.
[a] denotes sites where sites were not sampled due to sampling permit issues.
[b] denotes sites where sites were not sampled due to extreme water levels

Table 4. Samples collected from juvenile Chinook salmon at Mirror Lake in 2011 as part of the Effectiveness Monitoring Program.

Site	Date	Number of fish	% Hatchery (marked)	Otoliths (taxonomy)	Stomach contents taxonomy (diet)	Body chemistry	Fin clips (genetics)
Culvert	05/5/12	25	16.0	11	6	11	25
Lake	05/5/12	26	46.2	11	11	11	26
	06/28/12	3	0	3	3	3	3
Total		54	29.6	25	20	25	54

3.3.2 Water Temperature

Intersite differences in water temperature were observed (Figure 7). These differences were likely associated with habitat conditions and time of sampling at a particular site. Typically, NOAA Fisheries sampled the Lake in the morning, Youngs Creek in the mid-morning through midafternoon, and the Culvert later in the afternoon. At all of the sampling sites, water temperature generally increased from May through August, although a slight decrease in water temperature was observed at the June sampling, which coincided with an increase in water level at the Mirror Lake project area. The water temperature was similar at most sites (14-15°C) in May, with the Confluence being slightly lower (12.6°C). Temperatures increased at the Lake and Culvert site, reaching a maximum of 21°C in July and August. An increase in water temperature was also observed at Youngs Creek, but water temperature remained lower, reaching a maximum of 13.5°C. The water temperature at Youngs Creek remained very stable from May through September (13-13.5°C), but dropped to 9.5°C by October. The limited temperature measurements from the Confluence and Latourell Creek were intermediate between water temperatures at Youngs Creek and the Lake and Culvert sections at the same sampling times.

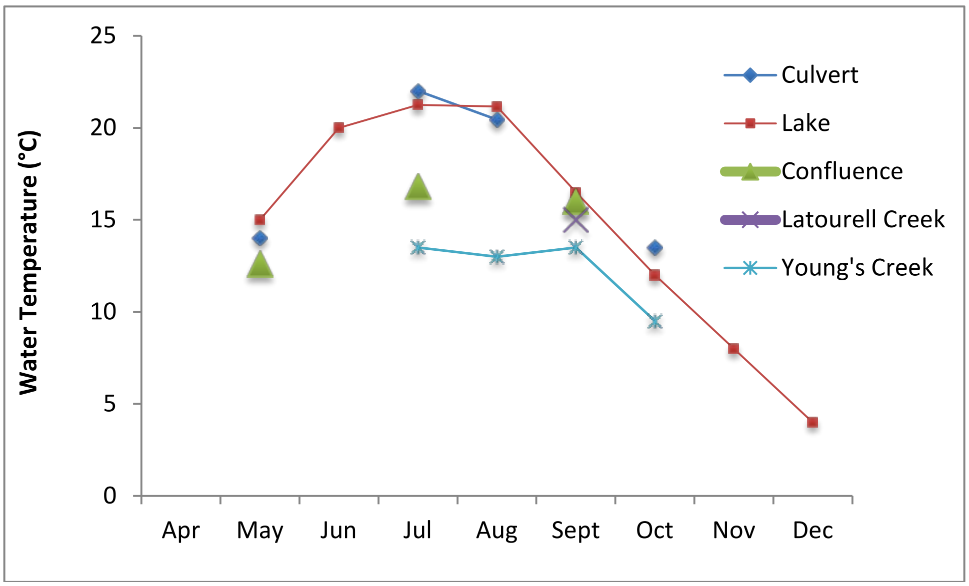


Figure 7. Water temperature (°C) at Mirror Lake sites at the time of fish collection in 2011.

3.3.3 Fish Community Composition and Species Diversity

As in prior years, all five Mirror Lake sites were utilized by fish (Table 5). However, the number and type of fish present varied with time and site (Table 5, Figure 8,
Figure 9, and Figure 10). A complete list of all species and their common and scientific names, as well as their taxonomy grouping, can be found in Appendix A. For comparison purposes, the November and December data for the Lake site are not included in most Figures and Tables summarizing results over the sampling season, but are shown in Table 4.

Total fish (all species combined) catch per unit effort (CPUE) per 1000 square meters varied widely from site to site (Figure 8). Total fish CPUE was highest at Youngs Creek, lowest at the Culvert and Lake sections, and intermediate at both the Confluence and Latourell Creek (Figure 8). CPUE increased from the start of the sampling season to a peak in July (Figure 9) and then decreased until the end of the sampling season at all sites except Latourell Creek (sampled only once).

Coho salmon was the dominant species captured at Youngs Creek (Figure 10). At Latourell Creek, three-spine stickleback (*Gasterosteus aculeatus)* was the dominant species with significant numbers of coho and pumpkinseed also present. The Confluence was heavily dominated by stickleback with much lower numbers of other species. Catches at the Lake were generally dominated by stickleback (Figure 10) with much lower numbers of banded killifish *(Fundulus diaphanous)* and common carp (*Cyprinus carpio*). At the Culvert, stickleback was the dominant species, while Northern pikeminnow (*Ptychocheilus oregonensis*), yellow perch (*Perca flavescens*), carp and killifish were also common, but salmon species, including Chinook and coho salmon, made up significant proportions of the catch in certain months. For instance, Chinook comprised 17% and 25% of the catch in early May at the Lake and Culvert sites, respectively, but then decreased to none captured at either site by July (Table 5).

Table 5 shows the percentage of each species caught at each site by the month of capture. The percentages of species collected varied somewhat for the Culvert and the Lake, as counts of killifish, stickleback, and other species fluctuated between sampling events. At Youngs Creek, juvenile coho salmon and stickleback (beginning in August) were consistently collected (though at varying levels) while steelhead (*Oncorhynchus mykiss*) were detected only in August and October. In addition, juvenile carp were detected at Youngs Creek for the first time (Table 5 and Figure 2). At the Confluence, stickleback were consistently collected, while coho salmon were captured in all months except July, and killifish, carp and chiselmouth (*Crocheilus alutaceus*) were observed in all months except May. Additionally, Chinook salmon were captured for the first time at the Confluence. Latourell Creek was sampled in September only, so no temporal comparisons can be made.

Table 5. Total number of each species captured as a percentage of the total number of all individual fish captured. It should be noted that data at the Lake site includes the extended sampling period (May through December) in 2011.

Site	date	Total number of fish captured	Species Count -	Chinook	coho	steelhead	Stickleback	killifish	sculpin sp	n. pikeminnow	yellow perch	pumpkinseed	bullhead sp	crappie sp	common carp	bluegill	peamouth	chiselmouth	sucker sp	golden shiner	smallmouth bass	mosquitofish	walleye	American shad	tui chub	lake chub
Culvert	5/5/11	240	5	24.8	29.8	0.0	42.0	0.0	0.0	0.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7/26/11	1768	8	0.0	0.0	0.0	60.4	9.5	0.0	26.6	0.1	1.6	0.0	0.0	1.2	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.2	0.0	0.0
	8/28/11	544	10	0.0	0.0	0.0	4.2	10.5	0.0	0.6	0.0	0.9	0.0	0.4	56.1	21.5	0.0	0.0	0.9	0.0	2.0	0.0	0.0	0.2	2.8	0.0
	10/17/11	630	8	0.0	0.0	0.0	88.4	1.4	0.5	0.0	0.0	0.3	0.2	0.3	0.0	2.9	0.0	4.9	0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Total	3182	18	2.1	2.5	0.0	54.3	7.1	0.1	13.5	0.2	1.0	0.0	0.1	11.4	4.8	0.0	1.2	0.3	0.0	0.6	0.0	0.0	0.1	0.5	0.0
Lake	5/5/11	305	3	17.4	0.0	0.0	82.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5/31/11	19	2	5.3	0.0	0.0	42.1	52.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6/28/11	541	4	0.6	0.2	0.0	97.0	1.7	0.0	0.0	0.0	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7/26/11	3462	9	0.0	0.0	0.0	88.1	3.6	0.0	2.3	0.0	0.7	0.0	0.0	3.8	0.0	0.0	0.4	0.4	0.2	0.5	0.0	0.0	0.0	0.0	0.0
	8/29/11	1825	12	0.0	0.0	0.0	91.3	1.7	0.1	0.1	0.0	2.4	0.0	0.0	0.9	0.8	0.7	0.9	0.4	0.0	0.5	0.0	0.0	0.0	0.2	0.0
	9/19/11	746	8	0.0	0.0	0.0	87.3	2.1	0.0	0.0	0.0	0.0	0.0	0.0	2.8	5.1	0.0	1.6	0.3	0.0	0.4	0.0	0.0	0.0	0.0	0.4
	10/17/11	465	3	0.0	0.4	0.0	93.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11/15/11	734	2	0.0	0.0	0.0	99.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12/6/11	542	1	0.0	0.2	0.0	99.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	8639	16	0.7	0.0	0.0	91.0	2.2	0.0	0.9	0.0	0.8	0.0	0.0	2.0	0.9	0.2	0.5	0.3	0.1	0.4	0.0	0.0	0.0	0.0	0.0
Confluence	5/4/11	118	3	7.6	7.6	0.0	84.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7/26/11	3263	6	0.0	0.9	0.0	92.5	1.4	0.4	0.0	0.0	0.0	0.0	0.0	2.2	0.1	0.0	2.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	9/19/11	1674	9	0.2	1	0	92.3	1.4	0.4	0	0	0	0	0	2.1	0.1	0	2.3	0.1	0	0	0.1	0			
	Total	5055	12	0.2	1.0	0.0	92.3	1.4	0.4	0.0	0.0	0.0	0.0	0.0	2.1	0.1	0.0	2.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Latourell Creek	9/19/11	958	11	0.0	36.1	0.0	63.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	958	11	0.0	13.7	0.0	64.7	1.8	0.3	0.1	0.0	9.2	0.0	0.0	2.9	2.9	0.0	3.4	0.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Youngs Creek	7/26/11	1080	4	0.0	80.7	0.0	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	8/30/11	1455	3	0.0	34.2	0.0	65.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9/19/11	1238	2	0.0	90.2	0.3	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10/17/11	920	3	0	53.3	0	46	0	0.1	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
	Total	5689	5	0.0	53.3	0.0	46.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

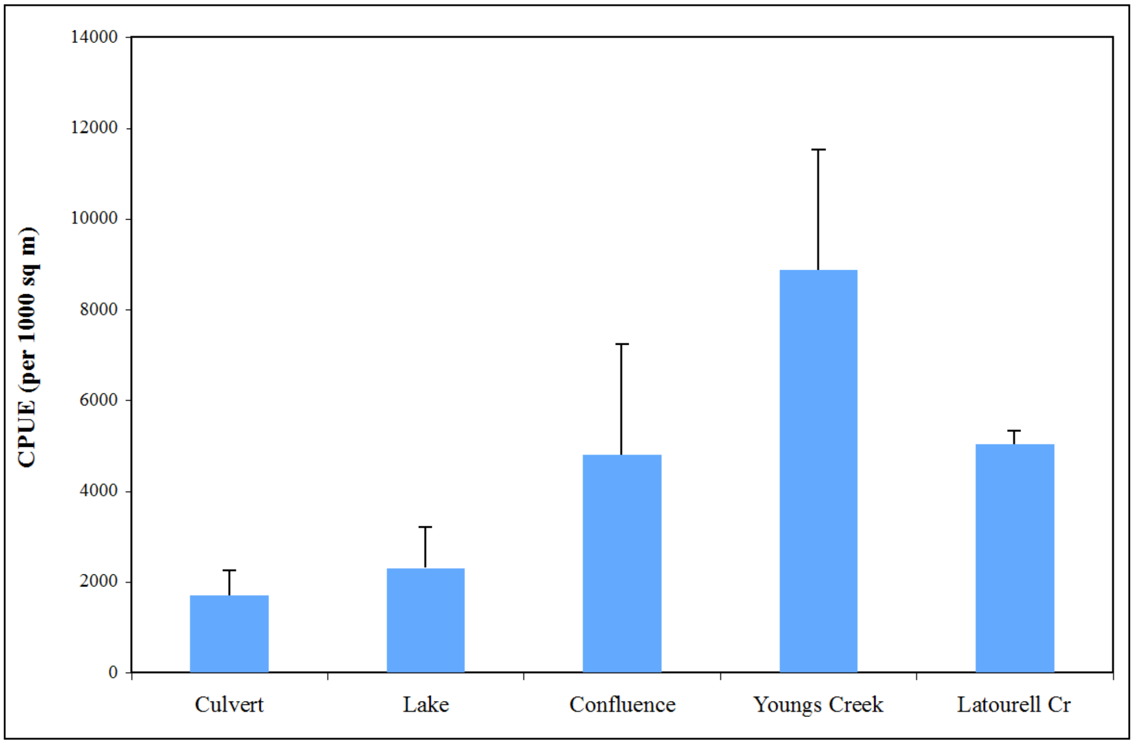


Figure 8. Mean total fish catch per unit effort (per 1000 m2) at Mirror Lake sites in 2011. Bars represent standard error of the mean.

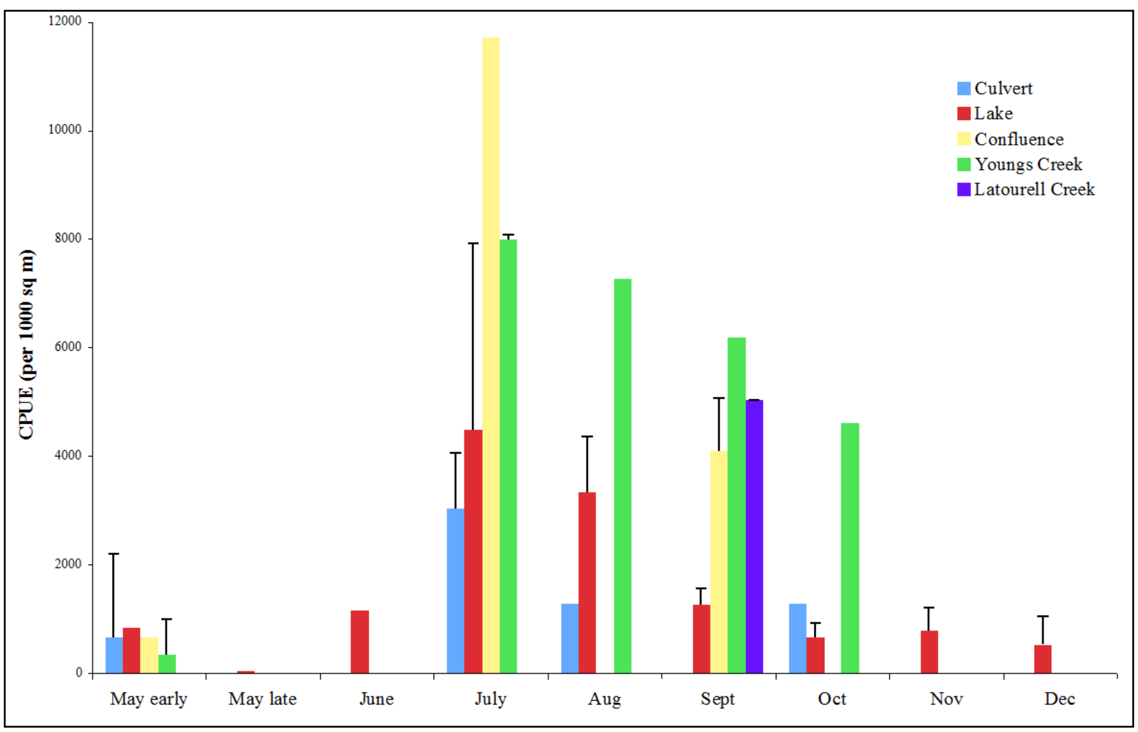


Figure 9. Mean catch per unit effort (fish per 1000 m^2) by month at all Mirror Lake sites in 2011. Bars represent standard error of the mean.

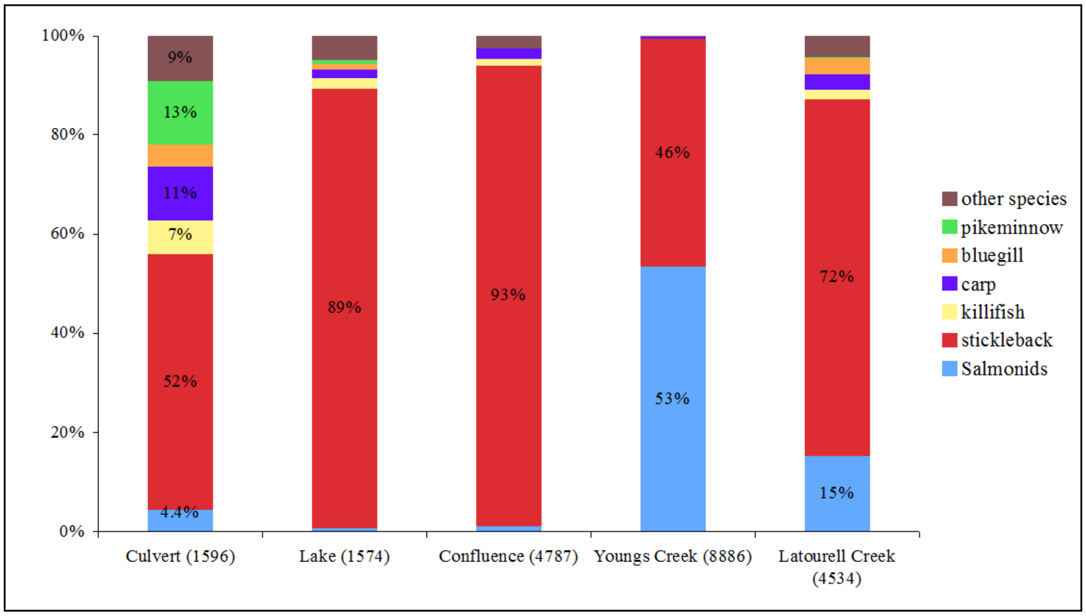


Figure 10. Percentage of each species in total catch at the Mirror Lake project area (n = total number of fish captured). This figure includes only data May-Oct for all sites including the Lake site. Additional catch data collected at the Lake site in November and December are shown in Table 5.

Species richness (the total number of species caught; Figure 11) was highest at the Culvert and Lake sites, where 18 and 16 species were observed, respectively, and lowest at Youngs Creek, where only 5 species were observed. Species richness was intermediate at the Latourell Creek and the Confluence, where 11 and 12 species were collected, respectively. Species diversity (Figure 10), as calculated by the Shannon-Wiener diversity index (Margalev 1958), was the lowest at the Confluence and Lake sections and (0.47 and 0.59, respectively) and highest at the Culvert (1.21). The low indices observed at the Confluence and the Lake sections were due to the high number of individuals from a few dominant species captured (Table 5). Stickleback comprised 89% or more of all fish captured at the Lake and Confluence sites, while other species comprised 2.6% or less of all fish captured (Figure 10), thus the cause of the low species diversity at these two sites. Species diversity was relatively high at the Culvert, Youngs Creek and Latourell Creek sites in comparison, due to more individuals of other species being captured than at the Lake and Confluence sites. For instance, three-spine stickleback at these three sites comprised 48-63% of all fish captured at these sites (Figure 10). Other species captured in relatively higher numbers were yellow perch (12%), pikeminnow (12%) and carp (10%) at the Culvert, coho salmon (53%) at Youngs Creek, and pumpkinseed (*Lepomis gibbosus*, 9%) and coho (13%) at Latourell Creek.

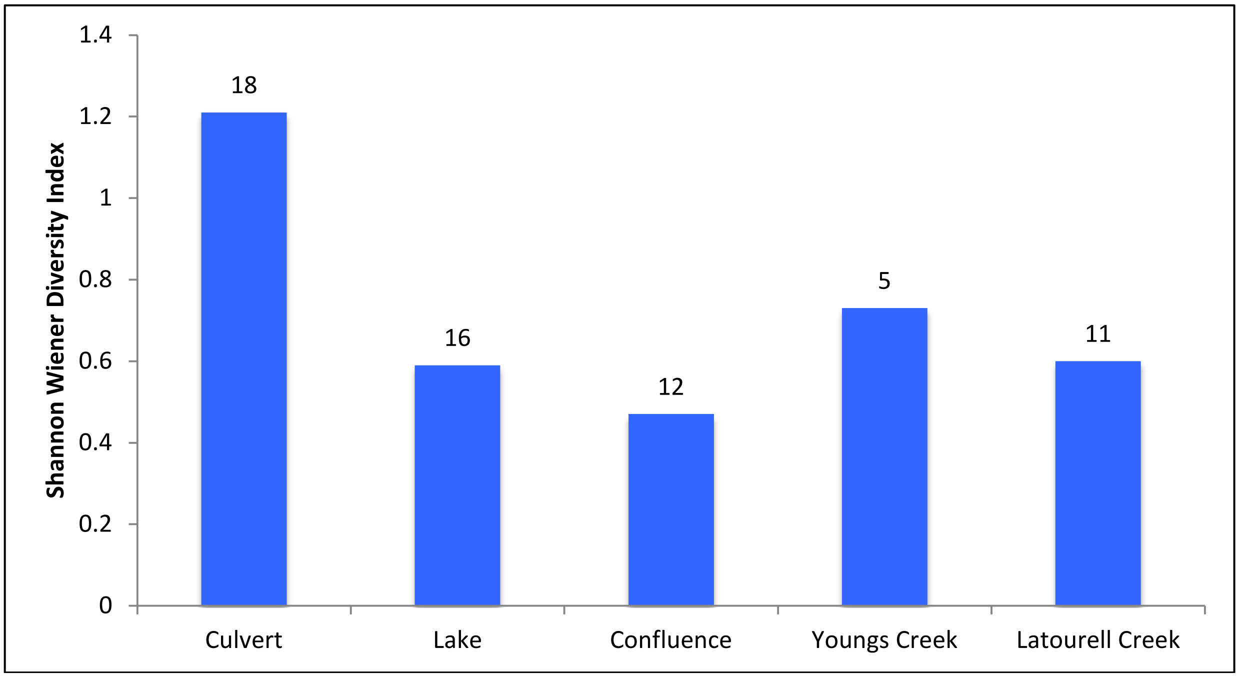


Figure 11. Fish species diversity (Shannon-Wiener Diversity Index) at Mirror Lake sites in 2011. Numbers above the bar represent numbers of species captured (Species Richness).

The proportions of non-native species (Figure 12) caught at the Culvert and the Lake differed as well, comprising roughly 34% of the species present at the Lake and 56% at the Culvert. At the Confluence, and Latourell Creek, non-native species were similar with 42% and 45% respectively, of the species captured, while at Youngs Creek, only 20% were non-native species. However, when compared by the total number of native vs. non-native individuals, native species were the dominant species at all sites, ranging from 66% of all fish captured at the Culvert to over 99% at Youngs Creek (Figure 12).

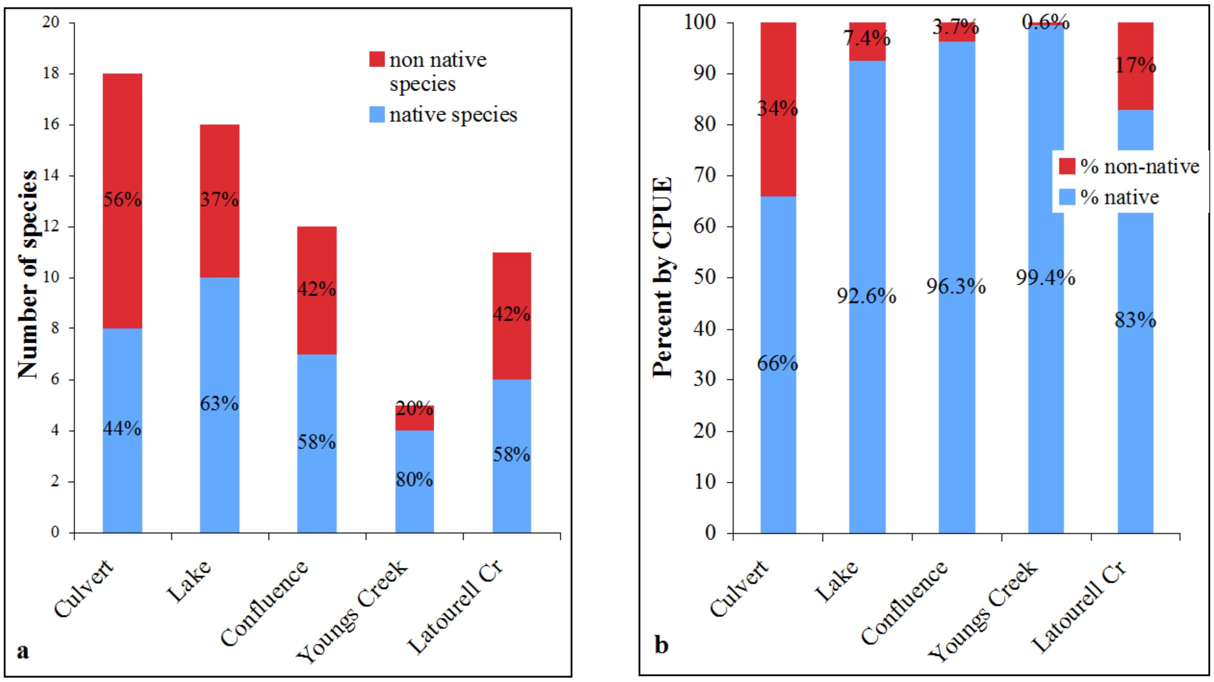


Figure 12. Number of native vs. non-native species at Mirror Lake sites in 2011, by number and percent of species captured, and by percent total catch per unit effort (CPUE) (fish per 1000 m^2).

3.3.4 Salmonid Catch Composition and Catch per Unit Effort

The proportions of salmonids (Figure 10) in the total catch for the Lake and the Culvert were 0.7% and 4.6%, respectively, while at Youngs Creek, the proportion of the total catch made up of salmonids was 53%. At the Confluence and Latourell Creek, proportions of salmonids were 1.2% and 13%, respectively.

Coho (2.5%) and Chinook (2.1%) salmon were the dominant salmonid species caught at the Culvert, with Chinook the dominant species at the Lake site (Figure 13). At all other sites, coho salmon made up the greatest percentage of the salmonid catch (Figure 13). Coho salmon were present at all of the sampling sites, whereas Chinook salmon were present at the Lake, Confluence and Culvert. Steelhead/trout were observed only at Youngs Creek, whereas chum salmon (*Oncorhynchus keta*) were not captured at any site in 2011, Since sampling did not begin until May in 2011, and no chum were captured after April in any prior sampling year at Mirror Lake sites or as part of the Ecosystem Monitoring Program, this is not an unexpected result.

Salmonid occurrence by month at the sampling sites is shown in Table 5. Chinook salmon were collected at the Culvert only in May, but at the Lake they were present in May and in low numbers in June. Coho salmon were found throughout the sampling season at Youngs Creek, but only in June, October and December at the Lake, and only in May at the Culvert. Coho were captured in May and September at the Confluence. Latourell Creek was sampled only in August, and a large number of coho salmon were found.

Catch per unit effort (CPUE, Figure 14) values for Chinook salmon at the Culvert and the Lake were 32 fish per 1000 m^2 and 14 fish per 1000 m^2, respectively. For coho salmon, CPUE was highest at Youngs Creek at 4,740 fish per 1000 m^2, and lowest at the Lake at 0.8 fish per 1000 m^2, with intermediate values at the Confluence (49 fish per 1000 m^2) and Latourell Creek (689 fish per 1000 m^2). CPUE for steelhead/trout at Youngs Creek was 4.1 fish per 1000 m^2.

The majority of juvenile Chinook captured at the Culvert site were marked hatchery fish (Figure 15). Roughly 45–55% of Chinook collected at the Lake and Confluence sites were marked. All coho captured at Mirror Lake sites in 2011 were unmarked fish.

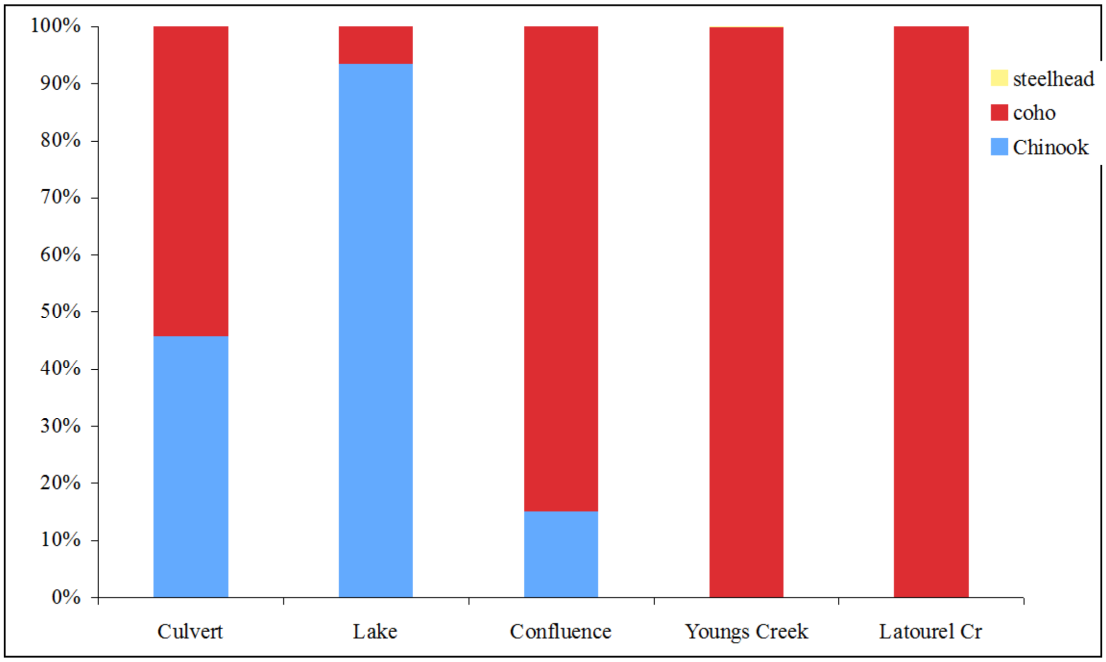


Figure 13. Proportions of different salmon species in 2011 catches at the Mirror Lake Complex sampling sites.

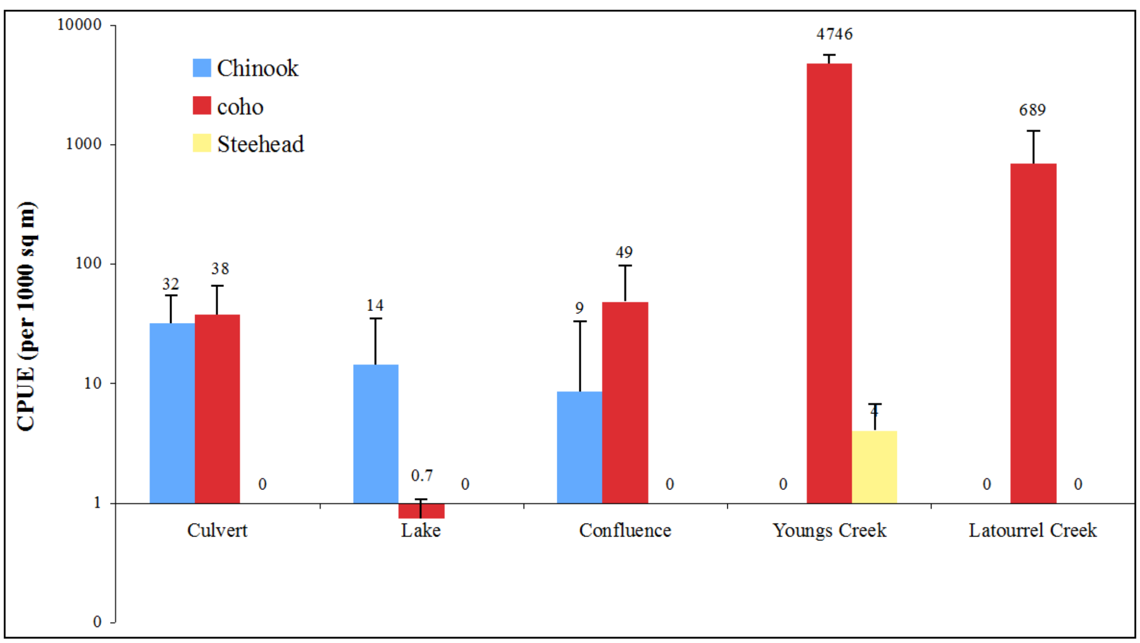


Figure 14. Density of salmonids captured in 2011 per 1000 sq. meters, as determined from catch per unit effort (bars above columns = Standard Error).

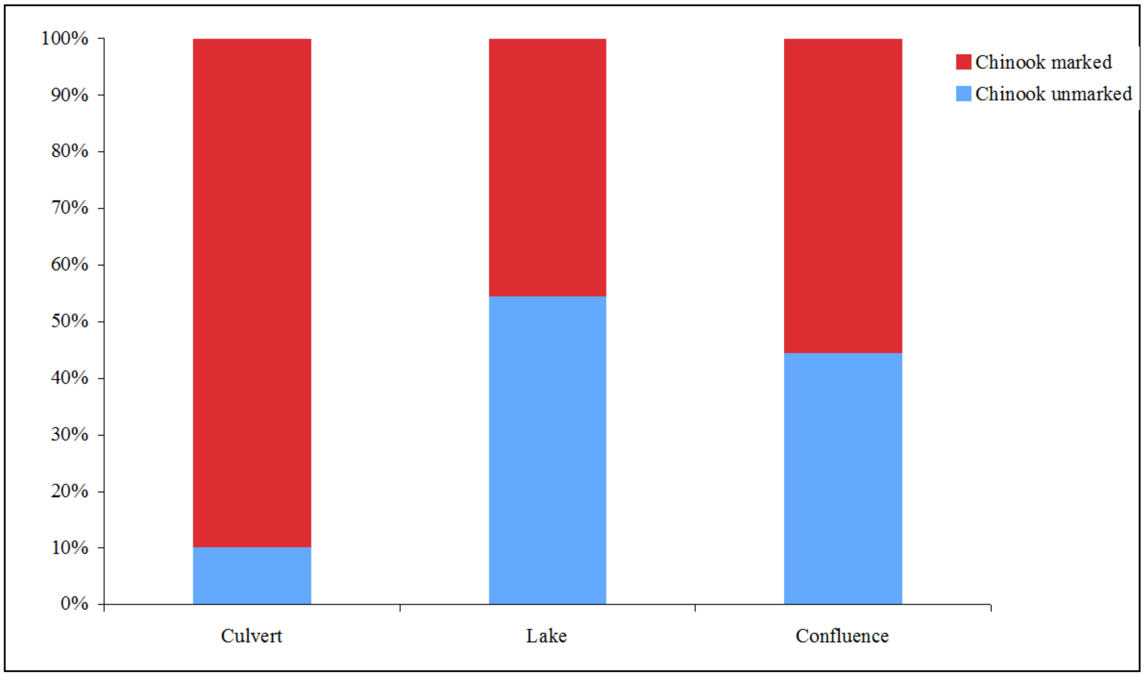


Figure 15. The percentages of marked vs. unmarked juvenile Chinook salmon captured at Mirror Lake sites in 2011.

3.3.5 Salmonid Size and Condition

All coho captured at Mirror Lake sites in 2011 were unmarked fish. The average length, weight and condition factor of coho salmon from the Mirror Lake sites are shown in Table 6. The size range of the coho salmon collected varied greatly throughout the sampling period, but there were significant differences in both length and weight among sampling sites ($p \leq 0.0001$) and by month ($p \leq 0.0001$). Length and weight of coho were highest at the Culvert and Confluence sites in May (Table 6) and lowest at Youngs Creek in September and the Lake in June. Coho length tended to increase at the Lake over time, though the number of fish sampled was too small for the trend to be statistically significant. Both length and weight were significantly lower in fish collected from the Confluence in September as compared to those collected in May. The length and weight of coho from Youngs Creek tended to be lower than at most of the other sites, and tended to decline between July and October. The condition factor (K) of coho salmon was lowest at the Culvert in May and highest at Youngs Creek in July, and was significantly lower at the Culvert than at Youngs Creek, Latourell Creek, or the Confluence ($p < 0.0001$). While K varied throughout the sampling period, no definite trend was observed.

The lengths, weights and condition factor of Chinook salmon caught at each site are shown in Table 7. The mean length and weight of the marked Chinook (74 ± 8 mm and 4.1 ± 1.3 g, n=18) were significantly higher ($p < 0.001$) than the mean length and weight of the unmarked Chinook (57 ± 9 mm and 2.0 ± 1.1 g, n = 33). However, overall mean condition factor (K) in unmarked Chinook (0.96 ± 0.12, n=33) and marked Chinook 1.0 ± .09, n=18) was not significantly different ($p = 0.2290$). For unmarked Chinook salmon, length, weight, and K were significantly lower at the Culvert than either the Lake or Confluence ($p \leq 0.0001$ for all parameters). However, for marked Chinook there were no significant differences among sites for K ($p = 0.2076$), weight ($p = 0.6584$) or length (p=0.3792).

Length, weight, and condition factor of steelhead/cutthroat trout are shown in Table 8. Steelhead/trout were captured only at the Youngs Creek site in 2011, and only in August and October. Due to the small sample size (2), statistics were not performed on these fish.

Table 6. Summary table showing number of unmarked coho salmon caught at each site for each month of sampling and average length, weight, and condition factor by site and sampling time. Values with different letter superscripts (e.g., ABC) are significantly different (One-way ANOVA, Tukey's HSD multiple range test, $p \leq 0.05$).

Site	Date	Number caught	Number measured	Fork length (mm)	Weight (g)	Condition factor
Culvert	05/05/11	71	15	134.9 ± 5.6^{A}	23.0 ± 2.8^{A}	0.93 ± 0.22^{C}
Lake	06/28/11	1	1	76.0^{BCD}	4.10^{BC}	0.93^{ABC}
	10/17/11	2	2	86.0^{BCD}	NA	
	12/06/11	1	1	109.0^{ABCD}	NA	
Confluence	05/04/11	9	9	132.6 ± 11.1^{A}	24.8 ± 7.0^{A}	1.03 ± 0.05^{ABC}
	09/19/11	42	31	96.7 ± 11.2^{B}	9.7 ± 3.2^{B}	1.05 ± 0.10^{AB}
Latourell Creek	09/19/11	131	35	94.2 ± 10.3^{BC}	9.0 ± 2.7^{BC}	1.05 ± 0.10^{AB}
Youngs Creek	07/26/11	1055	50	89.2 ± 9.2^{CD}	9.7 ± 12.1^{BC}	1.09 ± 0.10^{A}
	08/30/11	1174	60	88.3 ± 8.7^{CD}	7.3 ± 2.2^{C}	1.03 ± 0.06^{B}
	09/19/11	424	50	82.6 ± 13.5^{D}	6.4 ± 1.9^{C}	1.05 ± 0.12^{AB}
	10/17/11	831	54	87.5 ± 8.3^{CD}	NA	

Table 7. Summary table showing number of Chinook salmon caught at each site for each month of sampling, and average length, weight, and condition factor by site and sampling time). Values with different letter superscripts (e.g., A, B) are significantly different (One-way ANOVA, Tukey's HSD multiple range test, $p \leq 0.05$.

		Chinook (marked)				Chinook (unmarked)			
Site	Date	Number caught	Length (mm)	Mean wt (g)	Condition Factor	Number caught	Length (mm)	Mean wt (g)	Condition Factor
Culvert	05/05/11	3	79.3 ± 7.5^{A}	4.8 ± 1.6^{A}	0.93 ± 0.05^{A}	11	44.8 ± 11.8^{B}	0.96 ± 0.5^{B}	0.84 ± 0.08^{B}
Lake	05/05/11	11	71.8 ± 9.5^{A}	3.9 ± 1.5^{A}	1.02 ± 0.09^{A}	2	60.13 ± 16.6^{A}	2.71 ± 1.1^{A}	1.01 ± 0.10^{A}
	05/31/11	0	-	-		1	57^{AB}	2.1^{AB}	1.13^{A}
Confluence	05/04/11	4	75.5 ± 3.9^{A}	4.2 ± 0.4^{A}	0.97 ± 0.05^{A}	6	59.2 ± 4.8^{A}	2.1 ± 0.46^{AB}	1.00 ± 0.09^{A}

Table 8. Summary table showing number of unmarked steelhead/cutthroat caught at each site for each month of sampling and average length, weight, and condition factor by site and sampling time.

Site	Date	n	Length (mm)	Weight (g)	Condition factor
Youngs Creek	08/30/11	1	279	142	0.65
Youngs Creek	10/17/11	1	232	-	-

3.3.6 Genetic Stock Identification of Mirror Lake juvenile Chinook salmon

Due to the extended sapling season, genetic stock identification analyses of samples collected in 2011 are currently still being analyzed.

3.3.7 Lipid content of Mirror Lake juvenile Chinook salmon

Lipid analyses on samples collected in 2011 will be conducted when genetic stock information becomes available to composite the samples.

3.3.8 Growth rates of Mirror Lake Juvenile Chinook salmon as determined from otolith analysis

In 2011, otoliths from 25 Chinook were collected from Mirror Lake culvert and lake sites for growth rate estimation. Due to the extended sampling season, analysis of these samples is still currently in progress.

3.3.9 Contaminant concentrations in Mirror Lake juvenile Chinook salmon

In 2011 we collected 20 Chinook salmon body samples (14 from the Lake and 6 from the Culvert) for chemical analyses. No bile samples were collected in 2011 because of low sample sizes and small fish. The whole body samples will be analyzed when genetics data are available, as this information is needed to form sample composites.

Prey Availability. In 2011, prey availability surveys were conducted at the Mirror Lake sites by sampling with Neuston tows in open water and emergent vegetation (a total of 4 from the Culvert site, 8 from the Lake site and 0 from Youngs Creek). In addition, stomach contents from 9 Chinook were collected from the Culvert site and 14 from the Lake for Chinook diet analysis (Table 9). These samples are now being analyzed and results will be presented in a subsequent report.

Table 9. Summary table showing number of prey samples (open water and emergent vegetation tows) and stomach contents for diet analysis collected in 2011 at each site for each month of sampling.

Sites	May early	May late	June	July	August	Total
Culvert	4, 9	0, 0	0, 0	0, 0	0, 0	4, 9
Lake	4, 11	1, 0	3, 3	0, 0	0, 0	8, 14
Youngs Creek	0, 0	0, 0	0, 0	0, 0	0, 0	0, 0
Total	8, 20	1, 0	3, 3	0, 0	0, 0	12, 23

Horsetail/Oneonta pit tag array.

The newest generation of multiplexing pit tag receivers, the IS1001-MTS will be installed at the Horsetail /Oneonta Creek site culverts in the late Winter-early Spring 2012. This new receiver will power 10 antennas at the site (5 at each culvert end), and this project will be the first users of this new technology. Already, significant progress has been made in getting this system installed in the field, which should be noted is a huge challenge given the nature of the site. Considerable work has already been completed at the site to obtain all required permits, install anchor bolts and other infrastructure to facilitate attachment of antennas within the culverts. We have devised an installation plan that will provide secure attachment to the culverts and also protect the antennas from the high velocity flows, rock and woody debris and high water levels that will be encountered at this site. In addition, a prototype antenna has been built and tested in the lab and the performance exceeded our expectations. Planning is now underway to field test this antenna in late spring to investigate any possible interference from rebar within the concrete culvert walls and other potential sources of noise. If all goes well with the test, we plan to build and install all the antennas in late spring. Finally, the solar array required to power this system will be quite large, with approximately 80 sq. ft. of panels generating 1kW. Placement of the array is critical as it must receive as much solar exposure as possible and also be above the high water mark encountered during the spring runoff. This will require that the panels be pole mounted to a height of 10-12 feet above grade. Further, we need to position the array in a manner to obscure its viewing from both I84 and Hwy 30, as this site lies within the Columbia River Gorge Scenic area. The planning and permitting process to install the solar array is now underway and we hope to have it installed sometime in late spring. Given the above timeframes, we are optimistic that we will have the entire system completely installed and operational in late spring.

3.4 Discussion

The goal of the Mirror Lake salmon and prey sampling is to evaluate the effectiveness of site enhancements on salmonid prey availability, salmonid occurrence, and salmonid health and condition at the Mirror Lake Complex restoration sites. This is being accomplished by 1) comparing data on fish assemblages, prey types and abundance, salmon habitat occurrence, and salmon health indicators before and after the enhancements, and 2) comparing data from Mirror Lake with other relatively undisturbed monitoring sites in the Lower Columbia, such as the Ecosystem Monitoring sites in Reach H, to see whether the restoration activities are helping the sites to approach reference conditions. This report summarizes our monitoring results at the Mirror Lake Complex for 2011, and briefly compares them with our 2008-2010 findings. A more comprehensive multi-year synthesis report is now in preparation and will be provided in late spring. Genetic stock composition, prey availability and salmon diets, salmon lipid content, growth rates, and chemical contaminant concentrations are not discussed because the 2011 data are not yet available but will be provided in a subsequent report.

3.4.1 Fish Monitoring Findings for 2011

A major confounding factor in the 2011 sampling period was an altered sampling time frame. Due to permit issues, and exceptionally high water levels from May to July, sampling was limited at several of the Mirror Lake sites, notably at the Culvert and Youngs Creek. Because of both high (June) and low (September) water levels at the Culvert, this site could not be sampled in these months. High water levels at Youngs Creek prevented sampling until July. This makes comparisons with earlier years challenging. Our 2011 sampling also differed from previous years in that we extended the sampling season until October at Youngs Creek and the Culvert, and until December at the Lake site. This was done in part to compensate for the lack of sampling earlier in the season, and also in an attempt to determine when juvenile coho at Youngs Creek begin to out migrate.

Our sampling in 2008-2010 revealed clear distinctions among the Mirror Lake Complex sampling sites. The Lake and the Culvert, which are of a habitat type comparable to the emergent marsh habitats sampled as part of the Ecosystem Monitoring Program (e.g., Jones et al. 2008) and Tidal Freshwater Monitoring Project(Johnson et al. 2011) had relatively high species richness and diversity, with a variety of native and non-native resident fish species in catches, including stickleback carp, chiselmouth, killifish, and pumpkinseed. However, the proportion of salmonids in catches at these sites was typically low, with Chinook and coho salmon being the primary salmonid species found. Water temperatures at both sites were quite high in the summer months (up to 25-30^{o}C), likely creating an unfavorable habitat for juvenile salmon, which were rarely observed at either site after June.

Youngs Creek was very different from the Lake and Culvert sites, representing a more riparian habitat, with a narrow channel and more rapidly flowing water that was not clearly comparable to any of the Ecosystem Monitoring sites samples in Reach H. Our 2008-2010 sampling showed that this site supported a wild coho population, but was not utilized by Chinook or chum salmon. Water temperatures at this site remained relatively cool throughout the sampling season, generally remaining below 15^{o}C even in the summer. Species richness and diversity were lower at this site than at the Lake or Culvert sites, with fewer non-salmonid fish species. The Confluence and Latourell Creek sites, which were first sampled in 2010, were similar to Youngs Creek in physical habitat characteristics and in water temperature, and species richness and species composition at these sites were intermediate between Youngs Creek and the Lake and Culvert sites. Coho salmon were abundant at both sites, but did not make up as high a proportion of the catch as at Youngs Creek, and like Youngs Creek neither of the sites were utilized by Chinook or chum salmon.

In our 2011 sampling, the sites showed these same general characteristics, but there were a number of differences in fish community characteristics, and patterns of occurrence of salmon species, many of which can be attributed to the unusual high water year and altered sampling period. Comparisons for several factors, including species richness and diversity, dominant species, proportions of salmonids in catch, salmon densities, and salmon condition factor are summarized in Table 10, and discussed below.

First, the number of species present tended to be higher than in previous years at all of the sampling sites (Table 10). This was especially true at the Confluence and Latourell Creeks, where 11-12 species were found in 2011, as compared to 4-5 species in 2010. The percentage of non-native species present was also higher at these sites in 2011 (Table 10). The higher number of species and increase in non-native at the Confluence and Latourell Creeks may have been because the unusually high water levels allowed species from the mainstem Columbia that normally would not have access to these sites to reach them. The relatively high percentage of non-native species at all sites except Youngs Creek might be of great ecological concern because of the resulting changes to habitats, trophic structures, plant and animal communities, as well as disease and parasite distribution from non-native species (Strayer 2010, Taylor et al. 1984). In some cases there can be additional problems with hybridization with native species (Taylor et al. 1984). However, the number of non-native species is similar to other river systems in the Pacific Northwest (Gadomski and Wagner 2009, LaVigne et al. 2008). Also, the relatively high number of non-native vs. native species captured at several of Mirror Lake sites is offset by the low percentage of the total individual non-native vs. native fish in catches at these sites, as has been found in other studies (Roegner et al. 2010).

Table 10. Comparison of fish monitoring data in 2011 with earlier sampling at Mirror Lake Complex sites. Data for 2008-2010 are from Sol et al. (2009, 2010, 2011).

	Culvert		Lake		Confluence		Latourell Creek		Youngs Creek	
	2011	2008-2010	2011	2008-2010	2011	2010	2011	2010	2011	2008-2010
Species Richness	18	15-17	17	12-15	12	5	11	4	5	5-6
Species Diversity	1.44	1.97-2.12	0.59	0.78-1.79	0.47	0.65	1.24	0.72	0.73	0.21-0.79
% salmonids in total catch	4.4%	21%-29%	0.7%	3-4%	1.2%	40%	13%	52%	53%	68-86%
Dominant Species (% total catch)	Stickleback (52%)	Chiselmouth (28-36%) for 2008-2009; stickleback (48%) for 2010	Stickleback (89%)	Stickleback (26-73%)	Stickleback (93%)	Stickleback (57%)	Stickleback (72%)	Coho salmon (52%)	Coho salmon (53%)	Coho salmon (68%-84%)
Chinook CPUE (per 1000 m^2)	32	5-145	14	1-50	9	0	0	0	0	0
Coho CPUE (per 1000 m^2)	38	24-100	1[2]	0-11	49	374	689	434	4700	275-1700
Chinook K	0.93	0.89 -1.03	1.02	1.02-1.24	0.97	-	-	-	-	-
Coho K	0.93	0.90 -1.07	0.93	1.17-1.24	1.04	1.13	1.05	1.22	1.06	1.09-1.20
Maximum temperature	21°C	22-30°C	21°C	25-30°C	16.8°C (July)	12.6°C (May)	13°C (May)	15°C (Aug)	13.5°C	15-20°C
% native species	44%	50-53%	63%	50-53%	58%	80%	58%	100%	80%	100%
% marked Chinook	10%	9-19%	45%	0-29%	56%	-	-	-	-	-
% marked coho	0%	1.6-74%	0%	0%	0%	0%	0%	0%	0%	0%

Fish community composition also changed substantially at some sites in 2011. One of the most obvious differences was that the proportions of stickleback in catches were generally much higher in 2011 at all sites. The percentage of sticklebacks in the catches was especially high at the Lake site, where they made up 89% of the total catch, at the Confluence site, where they made up 93% of the total catch, and at Latourell Creek, where they made up 72% of the total catch. This predominance of sticklebacks at these sites is similar to other studies on the Columbia River (Roegner at al. 2010). Correspondingly, the proportions of salmonids in catches were generally lower in 2011 than in other years (Table 10). At the Lake, the proportion of salmonids in the catch was only 0.7% in 2011 vs. 3-4.6% in 2008-2010, while at the Culvert it was 4.4 % in 2011 vs. 21-29% in 2008- 2010. At the Confluence it was 1.2% vs. 40% in 2010, and at Latourell Creek, 13% vs. 52% in 2010. At Youngs Creek, the proportion of coho salmon, the only salmon species found at the site, in the total catch was 53%, compared to 68-96% in previous years.

With these changes in fish community composition, we also saw changes in species diversity at several sites (Table 10). For example, species diversity values at Latourell Creek (1.24) and Youngs Creek (0.73) in 2011 were among the highest levels recorded for those sites, because of the more even distribution of species as compared to other years. Species diversity at the Confluence, Lake, and Culvert sites decreased in 2011, likely because of the increased dominance of stickleback in catches at these sites.

The large differences between 2011 and previous years in fish community composition, species number, species diversity, and the percentages of salmonids in catches are partly due to the limited sampling early in the sampling season. Particularly at the Culvert and Lake, which support Chinook and sometimes chum salmon, sampling did not occur when out migrating juvenile salmonids are most prevalent. In fact, in the case of chum salmon, sampling was not initiated until May, when chum salmon have generally completed their outmigration (Johnson et al. 1997). Also, at all the sites, sampling was concentrated more in the summer months, when larger number of stickleback and other warm water species are likely to be present.

Another interesting change in 2011 was that Chinook salmon were found for the first time above the Lake site, at the Confluence, albeit at very low levels (less than 0.2% of the total catch and 18% of the salmonids). The fact that Chinook salmon were not found further upstream in either Youngs Creek or Latourell Creek, and that roughly 50% of the Chinook captured at the Confluence were of hatchery origin, suggests that these fish are entering the site from the mainstem of the Columbia, and are not the offspring of naturally spawning Chinook within the Mirror Lake Complex. Our observation of Chinook salmon at the Confluence is our first evidence that juvenile Chinook may use this area for feeding and rearing when conditions are suitable for them to access the site, such as in high water years.

Our extended late fall to early winter sampling at the Mirror Lake Complex sites showed that juvenile Chinook salmon were not using these sites during this time. However, a few juvenile coho were captured at the Lake site in October and December, suggesting that some of the Youngs Creek coho were beginning to move downstream in the late fall and early winter months. While peak coho smolt abundance in the Columbia Estuary typically occurs between April and June (Carter et al. 2009), pre-smolt juveniles could be moving earlier in the season from Youngs Creek to other tidal freshwater areas for rearing. This would be consistent with the fact that we have not observed them moving from Youngs Creek to the Lake and Culvert sites between April and June.

Salmon density, based on catch per unit effort (CPUE) data, is one of our major indicators of restoration effectiveness. At the Culvert and Lake sites, densities of Chinook and coho salmon in 2011 were relatively low, although within the range of values observed in previous years (Table 10). At the Confluence site, Chinook density was higher than in earlier years, as this species had not been found at the site before, but coho density was much lower (49 fish per 1000 m^2 as compared to 374 fish per 1000

m^2 in 2010). The low salmon densities at the Culvert and Lake sites were probably due to the limited sampling between April and June, when these species are most likely to use the sites. The reason for the lower density of coho salmon at the Confluence in less clear, but because of the limited time frame over which this site has been sampled, we do not have a very clear picture of the natural variability in coho density at the site.

In contrast to the Culvert, Lake, and Confluence sites, the coho CPUEs (densities) at Latourell Creek and Youngs Creek in 2011 were the highest yet observed. At Latourell Creek, coho CPUE in 2011 was 689 fish per 1000 m^2, as compared to 434 fish per 1000 m^2 in 2010. At Youngs Creek, coho density, estimated at 4,740 per 1000 m^2, was the highest density of any sampling year. This coho density was almost 3 times the level detected in 2008, when the density was 1,700 fish per 1000 m^2 (Sol et al. 2009). Coho returns from the prior spawning year (Fall 2010) do not account for this increase in juveniles at Youngs Creek, as the reported adult return at the Bonneville Dam was 120,429, below the 10-year average of 134,583 (http://www.fpc.org//). The increased coho densities at these two sites, especially in the absence of comparable increases throughout the rest of the system, suggest that the restoration activities carried out at Latourell and Youngs Creek, such as the addition of woody debris, may have improved the habitat for coho salmon.

As yet our information on salmon health and fitness at the Mirror Lake sites in 2011 is limited to condition factor (K). Overall, K tended to be in the lower range of observed values for both coho and Chinook salmon at most sampling sites (Table 10). Indeed, the mean values of K for coho salmon at both the Lake and Youngs Creek were the lowest values yet observed. Mean values of K for coho salmon were also lower in 2011 than in 2010 at the Confluence and Latourell Creeks. The reasons for the differences in K are not clear. At Latourell Creek and Youngs Creek, lower K could be associated with higher densities of coho salmon. The unusual conditions and high water levels, as well as the altered sampling period, may also have contributed to somewhat lower salmon condition in 2011.

3.5 Summary and Conclusions

In summary, our results for 2011 confirm our earlier observations that Youngs Creek and Latourell Creek, and to a lesser extent, the Confluence, appear to be important rearing areas for juvenile coho salmon, while the Culvert and Lake sites, and in some cases the Confluence, provide habitat for Chinook salmon from the mainstem Columbia. One of our most interesting findings was increased coho density at Youngs Creek and Latourell Creek, suggesting that restoration actions, such as placement of large woody debris at these sites, may be improving habitat conditions for coho salmon. Another particularly interesting finding was the presence of Chinook salmon above the Lake, at the Confluence site, for the first time. This finding suggests that under some conditions, such as during high water years, the Confluence area may provide feeding and rearing habitat for out migrating juvenile Chinook salmon entering the Mirror Lake Complex from the mainstem Columbia.

The extreme high water level in 2011 and resultant changes in our normal sampling season were associated with a number of changes in fish community composition. Both the Confluence and Latourell Creek sites had substantial increases in the number of species present in 2011, possibly because the high water levels allowed species not normally present to access the sites. We also observed a greater dominance of stickleback in catches at all sites, leading to a more even distribution of species, and a higher species diversity index, at some sites such as Youngs Creek, but a less even distribution of species and a lower species diversity index at other sites, such as the Lake. The proportion of salmonids in catches was generally lower than normal, because of limited sampling between April and July when Chinook salmon are most likely to be present at the Culvert and Lake site, and because of the very large number of sticklebacks at the sites, which tended to dominated catches.

While the data collected over the past four years of sampling suggest that the Mirror Lake complex is a valuable rearing area, especially for coho salmon, the 2011 sampling results highlight the variability in fish use that may be associated with changing water levels and climatic conditions.

4.0 Planting Success AEM at Mirror Lake and Sandy River Delta

For the fourth consecutive year, Ash Creek Forest Management LLC (ACFM) staff sampled vegetation monitoring plots across 259 acres at five restoration projects at the Sandy River Delta and at Rooster Rock State Park (Mirror Lake) in Multnomah County, Oregon (Table 11). A total of 185 plots were sampled using the rapid monitoring protocol in *Protocols for Monitoring Habitat Projects in the Lower Columbia River and Estuary* (Roegner, et al. 2009). A fifth, 140-acre restoration unit was monitored for the first time at the Sandy River Delta (Delta) on which 50 plots were sampled using the Roegner, et al (2009) comprehensive monitoring protocol.

Since 2002, these and other units at the Delta and Mirror Lake have been managed for the re-establishment of native plants and control of competing noxious and non-native vegetation. Resulting native plant cover is expected to contribute to improved riparian function through large wood recruitment, increased shade, bank stabilization and prey diversity. Anticipated effects on terrestrial resources include reduced edge, greater extent of hardwood forest cover and greater habitat complexity. The goal of continued monitoring at the Delta and Mirror Lake is to systematically assess the effectiveness of treatments on weed control, native plant establishment and habitat conditions.

Data collection and analyses yielded estimates of current stocking levels, native plant survival, suppression and vigor. Field observations provided essential information for adaptive management and include interplanting and continued noxious weed control. Anticipated costs of these ongoing stewardship treatments are expected to decline as native plant cover occupies increasing proportions of surveyed units.

The Delta and Mirror Lake exist within the active floodplain of the Columbia River and provide habitat critical to sustaining healthy aquatic life. Restoration and stewardship of native vegetation are essential to recovering and maintaining functional habitats for listed and rare native fish and wildlife in the Columbia region.

4.1 Survey Sites

In July and August 2011 ACFM staff returned to five restoration units that were first monitored in 2008, and established monitoring at an additional restoration unit. Trained staff surveyed six units totaling 399 acres. Roegner et al. Protocol for Rapid monitoring was used to survey the five units originally surveyed in 2008: Estuary Partnership's 15-acre "North bank Sandy Channel"; Estuary Partnership's 20-acre "South Bank/North Slough"; Estuary Partnership's and BPA's 40-acre "Southwest Quad" and US Army Corps of Engineers' 155-acre "Sundial Island North"- located at the Sandy River Delta - and the 29-acre "Mirror Lake" unit at Rooster Rock State Park. Roegner et al. Comprehensive protocol was used to survey the new monitoring unit, 140 acre "Columbia River Bank" (Figure 16 and Figure 17).

Table 11. Restoration Units

Site Name	Number of Acres	Surveyed prior to 2011
Sundial Island North	155	x
Southwest Quad	40	x
South Bank/North Slough	20	x
North Bank Sandy Channel	15	x
Mirror Lake	29	x
Columbia River Bank	140	

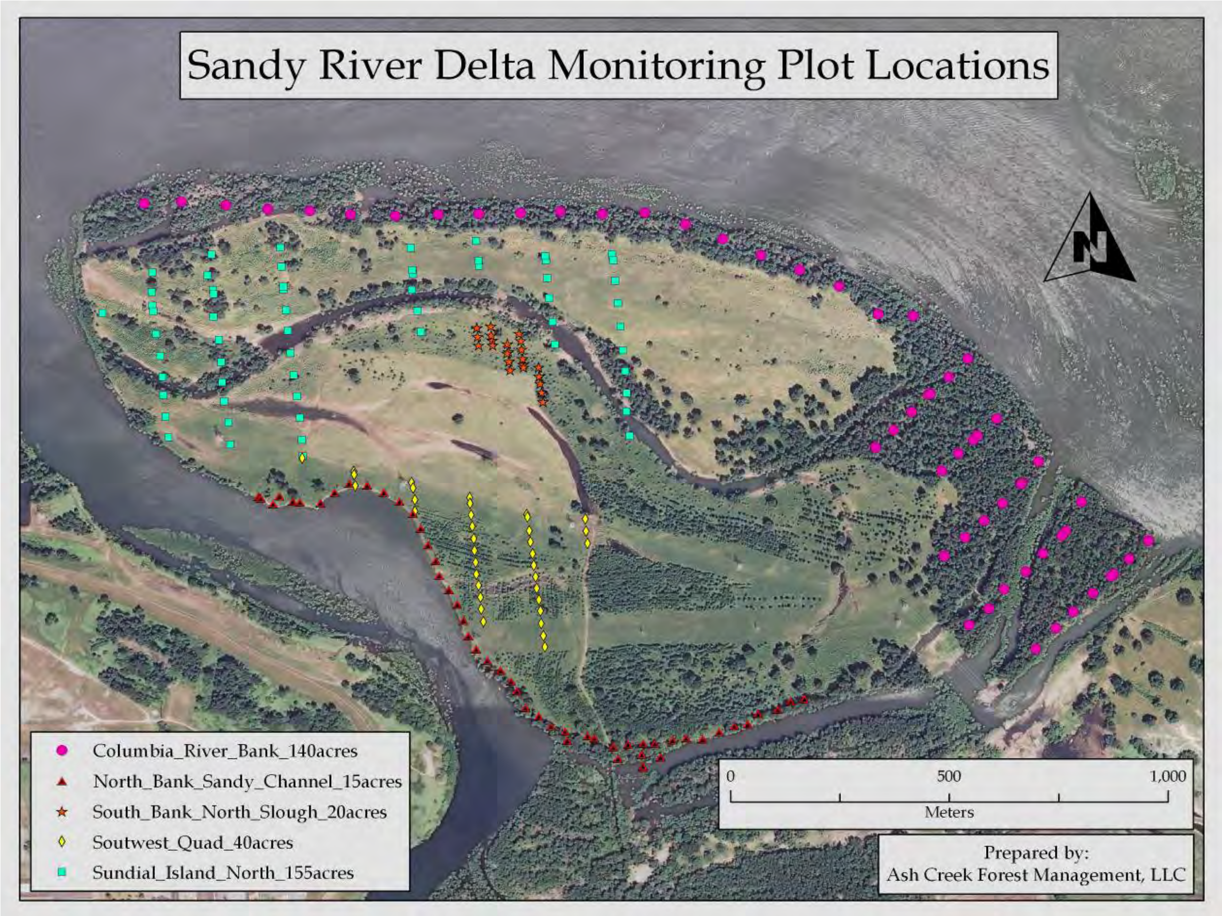


Figure 16. Monitoring plot locations, Sandy River Delta units.

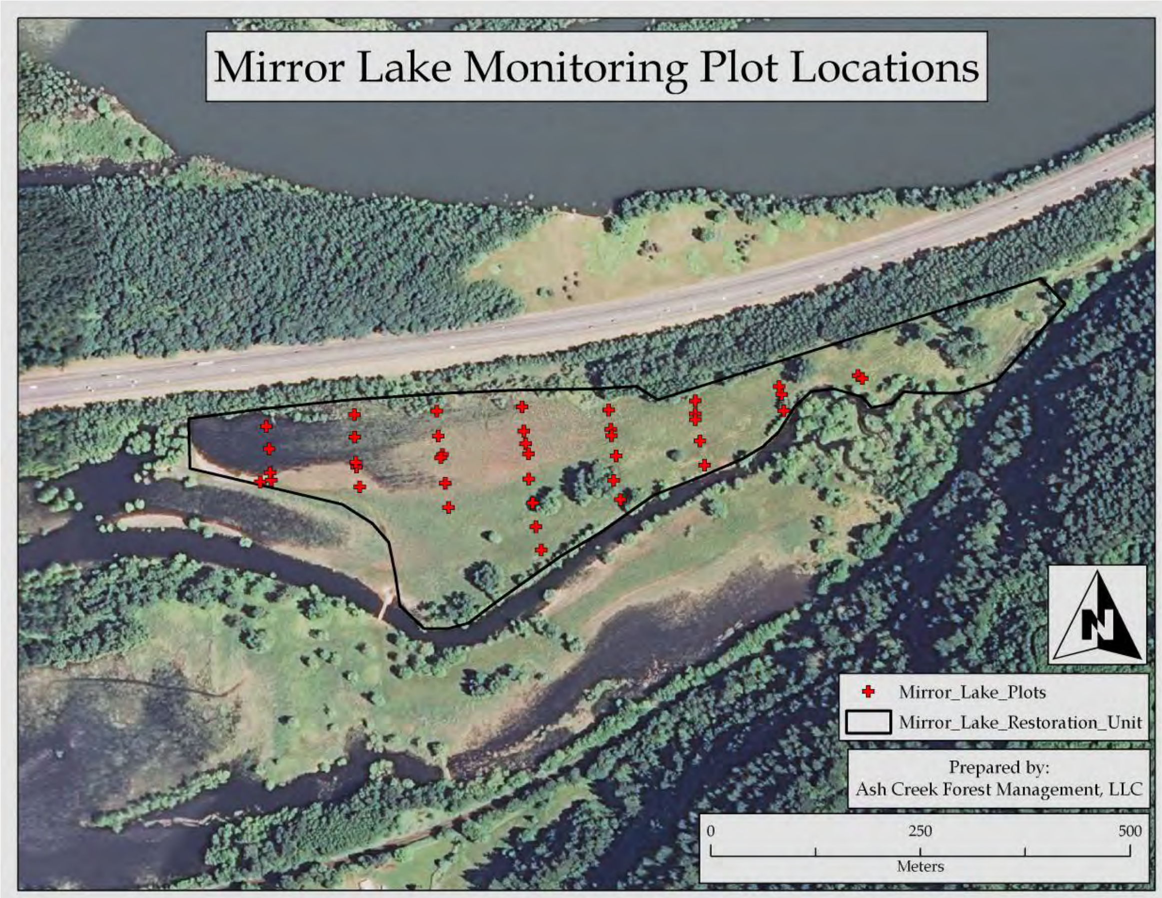


Figure 17. Mirror Lake Monitoring plot locations

Table 12. Woody species installed at Sandy River Delta and Mirror Lake

TREES	
Scientific name	Common name
*Abies grandis**	Grand fir
Acer macrophyllum	Bigleaf maple
Alnus rubra	Red alder
Crataegus douglasii	Black hawthorn
Fraxinus latifolia	Oregon ash
Populus balsamifera	Black cottonwood
Prunus emarginata	Bitter cherry
*Pseudotsuga menziesii**	Douglas-fir
Quercus garryana	Oregon oak
Rhamnus purshiana	Cascara
Thuja plicata	Western redcedar

*Planted at Mirror Lake only

SHRUBS	
Scientific name	Common name
Cornus stolonifera	Red-osier dogwood
Holodiscus discolor	Ocean spray
Mahonia aquifolium	Oregon grape
Lonicera involucrata	Black twinberry
Oemleria cerasiformis	Indian plum
Philadelphis lewisii	Mock orange
Physocarpus capitatus	Pacific ninebark
Ribes sanguineum	Redflowering currant
Rosa pisocarpa	Swamp rose
Rubus parviflorus	Thimbleberry
Rubus spectabilis	Salmonberry
Salix lasiandra	Pacific willow
Salix piperi	Piper willow
Salix scouleriana	Scouler willow
Sambucus cerulea	Blue elderberry
Sambucus racemosa	Red elderberry
Spiraea douglasii	Spiraea
Symphoricarpos albus	Snowberry

4.2 Methods

Sampling protocol followed *Protocols for Monitoring Habitat Projects in the Lower Columbia River and Estuary, (*Roegner et al, 2008 and 2009). First-year monitoring initiated on five units in 2008 and on the Columbia River Bank this year followed the Roegner et al. Comprehensive monitoring protocol. Permanent transects and plots were established at each unit and spaced according to unit size to ensure sampling of the entire restoration area. At the 15-acre North Bank Sandy River, plots were established along a changing azimuth to capture interior and edge habitat. On all units, one-third of total plots per unit were randomly chosen and marked as permanent with PVC, pink flagging and a pink marking whisker, and photos were taken to capture visual change over time. In 2009, 2010 and 2011, according to the Roegner et al. Rapid monitoring protocol, permanent plots were re-located, marked with blue flagging and sampled. All other plots along each transect were installed systematically at intervals pre-determined based on unit size. Where a plot center landed on or near a boundary, the plot was transformed into a 5.66 radius semicircle (noted in data). Where the middle of the woody plant (stem or stem cluster) was not within the plot radius, it was not included in the survey.

At each plot surveyed with the Rapid monitoring protocol, surveyors recorded woody vegetation by species and noted for each plant whether live or dead, natural or planted. Plant vigor, average height and suppression by weedy vegetation were also recorded. Invasive species were listed. At each plot surveyed with the Comprehensive monitoring protocol, surveyors measured all Rapid monitoring metrics, plus canopy cover with densitometer and herbaceous species within a one square meter area in each plot. Surveyors noted specific habitat features for plots falling within existing forested areas or exhibiting other atypical conditions.

For all units, the number of installed plants per hectare was calculated by dividing the total number of installed plants by number of hectares planted. Stocking of installed plants and percent survival were calculated as: Total number of live, installed plants counted on all sample plots (T) divided by number of plots sampled (n) to yield average of surviving, installed plants per plot (Tp); total per plot was multiplied by 200 (because a 4-m radius plot is $1/200^{th}$ ha) to estimate total number of live, installed plants per hectare (Th); this total was then divided by number of plants originally installed per hectare (i).

$$T / n = Tp$$
$$Tp * 200 = Th$$
$$Th / i = \%\ survival$$

Because natural recruitment is increasing on AEM units, we calculated total native plant stocking (per the same formula) and track these numbers as a measure of overall restoration effectiveness. We also estimate trends in natural recruitment by subtracting numbers of live installed plants from total live plants per plot.

4.3 Results

As summarized in Table 13, below, on all restoration units, we found a range of 1,500 to 5,200 live, woody installed plants per hectare, and survival rates of 53% to 122. In 2011 trees comprised 29% to 66% of live, woody plantings, down from 37% to 45% when first measured in 2008. When naturally occurring (non-planted) trees and shrubs were included, the total live, woody stems (total stocking) on all restoration units ranged from 2,100 to 9,900 per hectare.

Table 13. Plant survival and stocking by Restoration Unit

UNIT		Sundial Island North	Southwest Quad	South Bank/North Slough	North Bank Sandy Channel	Mirror Lake	Columbia River Bank	Reference Site
Original number of plants installed per hectare		2010	3840	2150	4610	3444	5241	0
Plots per unit								
	2008	50	30	20	50	38		30
	2009	50	37	22	50	33		
	2010	49	30	20	50	36		
	2011	51	31	21	50	47	49	
Live, installed plants per hectare								
	2008	1,228	3,240	1,540	2,588	3,100		0
	2009	1,509	2,627	2,086	N/A*	3,362		
	2010	2,400	3,246	2,450	N/A*	2,538		
	2011	1,541	2,568	2,619	N/A*	1,821	5,269	
Percent installed plant survival								
	2008	61%	84%	72%	56%	90%		
	2009	75%	68%	97%	N/A*	98%		
	2010	119%	86%	114%	N/A*	74%		
	2011	77%	67%	122%	N/A*	53%	101%	
Total live woody stems per hectare (Stocking)								
	2008	1,784	3,367	1,660	2,860	3,100		7,753
	2009	2,396	2,795	2,196	3,793	3,396		
	2010	2,514	3,453	2,630	4,312	2,591		
	2011	3,753	3,265	2,981	4,112	2,128	9,898	
Ratio trees to total woody plants								
	2008	75%	37%	75%	64%	51%		11%
	2009	60%	33%	88%	33%	40%		
	2010	78%	30%	71%	51%	49%		
	2011	37%	29%	66%	40%	45%	18%	

*NOT AVAILABLE: Planted and natural vegetation no longer reliably distinguishable.

Table 14, below, shows vigor of native plants averaged across all units and the potential impact of competing vegetation on vigor of installed plants. 'Low vigor' defines a plant that is severely suppressed or damaged; 'Medium vigor' indicates normal stress expected in recent plantings (discoloration of leaves, herbivory, etc.); and 'High vigor' describes plants that are in excellent condition and growing vigorously relative to species growth potential. Plants that are designated 'suppressed' are significantly shaded, crowded and/or overtopped by competing weedy vegetation. While 'suppressed' plants may eventually grow through competing weeds, and weed cover may provide some protection from browse, weeds still significantly affect growth and survival.

Table 14. Plant vigor and suppression

VIGOR	LOW	MEDIUM	HIGH
total live, installed trees and shrubs on surveyed plots	87	1,630	1,567
2008 ratio per rating	6%	87%	7%
2009 ratio per rating	2%	87%	11%
2010 ratio per rating	2%	88%	10%
2011 ratio per rating	3%	49%	48%
SUPPRESSED	**Yes**	**No**	
total live, installed trees and shrubs on surveyed plots	245	2,385	
2008 ratio per rating	25%	75%	
2009 ratio per rating	19%	81%	
2010 ratio per rating	26%	74%	
2011 ratio per rating	10%	90%	

The most dominant weed species found throughout the surveyed units were common teasel (*Dipsacus sylvestris*), Canada thistle (*Cirsium arvense*), reed canarygrass and Himalayan blackberry. Reed canarygrass and Himalayan blackberry were shown to have greatest impact on plant survival, vigor and suppression. Reed canarygrass is prevalent in sloughs, back channels and areas with partial tree canopies. Himalayan blackberry was observed throughout the surveyed units, mostly in low-statured, small patches or individual sprigs.

4.4 Discussion

Overall density of native woody plants (stocking) increased at Sundial Island North and South Bank North Slough; stocking fell slightly at SW Quad and N Bank Sandy Chanel and decreased consistently with multi-year trend at Mirror Lake. Plant vigor is markedly higher and suppression from weeds has declined from previous years. Ratio of trees to total woody plants trended downward, possibly indicating recruitment of shrubs via rhizomes and natural seeding.

As monitored restoration units mature, distinguishing between installed and natural native plants has become increasingly difficult. While there is value in independently assessing survival of installed plants, to do so reliably would require some means of marking or labeling plants during installation. More accurate analysis of restoration trends also could be achieved if monitoring with the same parameters as those described in Roegner et al. (2009) were established prior to restoration.

Similar difficulties in uniform data collection have resulted in outlier years that deviate from trends established and supported by a majority of the annually collected data. Randomized sampling of the highly variable and patchy floodplain forests at Mirror and the Delta, where a single planted stem can produce 50-100 clones within one to several years, can produce extreme plot data that skews overall trends in plant survival and stocking. Differences in surveyor interpretations of planted vs. natural also can contribute to discrepancies in data from year to year.

The overarching goal for restoration at the Delta and Mirror Lake units is the reestablishment of naturally reproductive, dense stands of floodplain forest species. This suggests that analysis of total native woody stems (stocking), rather than survival of installed woody plants, would provide an accurate indicator of restoration effectiveness and more comprehensive view of a unit's progress toward self-sustaining target conditions, as seen on an representative reference site. Analysis also should include examination of plot data to evaluate and remove extreme values that skew overall restoration trends per unit.

Sundial Island North (155 acres)
While installed plant survival appears to have fallen to 77%, trends in total stocking show a marked increase, from 1,228 per ha installed in 2007 to 3,753 per ha native woody stems measured in 2011. The uneven trend in installed plants – 2,400 per ha in 2010 declining to 1,500 per ha in 2011 – has occurred as total native woody plant stocking is increasing significantly. This suggests that distinguishing between planted and natural plants is becoming more difficult at Sundial Island North, a trend seen on all maturing restoration units.

The unexpectedly large increase in total stocking at Sundial North also is attributable to the patchy vegetation characteristic of recovering habitats at the Delta. These pockets of extremely dense stocking are emerging features of this restored landscape but are difficult to accurately assess. Three of 51 plots contain over 100 natural Pacific willow; removing these three plots from analysis brings overall stocking trends in line with earlier years, to approximately 2,700 stems per ha.

Southwest Quad (40 acres)
Originally restored in 2005 and interplanted before monitoring began in 2008, the Southwest Quad shows a small decrease in overall stocking since 2010. The prevalence of shrubs, which comprise 70% of overall stocking at this unit, reflects original project design, where shrubs were installed to accommodate BPA power line corridors on the unit.

South Bank/North Slough (20 acres)
South Bank/North Slough shows a greater than 100% woody plant stocking (122%) as compared to original restoration planting density. The increasing stocking is attributable to an increase in natural plant recruitment and may indicate that natural regeneration is occurring on the unit, attributable to decreases in weedy competition as the canopy increases and as plantings reproduce through natural seeding and vegetative growth. Additionally, stocking numbers were boosted by an interplanting in February 2010, where approximately 400 plants per hectare were installed to improve plant densities in understocked portions of the unit. The slowly declining tree to shrub ratio may indicate progress toward reference site conditions.

North Bank Sandy Channel (15 acres)
Originally installed in 2006, this riparian restoration project shows succession toward target, self-sustaining conditions in 2011, as indicated by increasing total woody plant stocking. Trends are attributable to decline in weedy competition, increased native seed production and development of multi-stem clones and rhizomatous spread of native trees and shrubs. Natural regeneration has made natural and installed plants indistinguishable in many areas. The 2011 shrub to tree ratio (40%) indicates recovery of healthy riparian conditions and progress toward reference site conditions.

The apparent, slight decrease in stocking from 2010 to 2011 may be a result of random plot placement in areas with lower woody plant representation, though bank erosion also may be affecting results. The unit's border along the current mainstem of the Sandy has been especially hard hit by erosion, and several permanent plot locations appear to have partially or completely eroded into the river. To date, our analysis has used the original unit size, as measured in 2008; calculations with fewer hectares would produce higher stocking and survival rates.

Mirror Lake (29 acres)
The lowest stocking rates compared to original planting density (53%) were found at the Mirror Lake unit, originally planted in 2008. Mortality rates are consistent with downward trends measured annually since monitoring began in 2008. Lack of funding for management has prevented important interplanting and weed control treatments that could shift the site toward increasing native plant stocking seen on all other units. The Mirror Lake site continues to offer challenges, particularly from animal activity (voles and elk). Vigor measurements reflect these stresses, with elevated low-vigor ratings (19%) compared to average for all units (3%). Suppression, however, is occurring on only 4% of woody plants sampled, which represents lower impact from weeds at Mirror Lake than the 10% average for all units. The relatively low presence of weed cover at Mirror Lake this year may attributable to the atypical flooding rather than post-restoration maintenance.

Columbia River Bank (140 Acres)
The most recent addition to the AEM program, the Columbia River Bank, has been planted, interplanted and managed for plant establishment/weed control for three years beginning in 2009. Year-1 Comprehensive monitoring shows excellent levels of survival with greater than 100% stocking relative to installed plant density. High stocking may be attributed to the intact forest canopy at CRB, which provides favorable growing conditions for trees and shrubs native to the Delta. Thorough site preparation also appears to have supported installed plant establishment and released native plants, seed and rhizomes. The highly variable density of native plants at the Delta also can result in unexpectedly high numbers of natural and installed plants relative to initial planting density. The apparent success on this unit shows how integral both intact forest canopy and thorough weed control are in the reestablishment of well-stocked and naturally reproductive floodplain forests.

4.5 Recommendations

Continued maintenance and stewardship of all sampled Sundial and Mirror Lake units is needed to achieve the goal of restoring naturally reproductive Columbia River floodplain forest and scrub. Additional vegetation management treatments are indicated for all units, shown in Table 15, below.

Sundial Island North (155 acres)
Mowing this unit remains necessary to control prolific invasive thistle populations, to expose voles to population-controlling raptor predation and to ensure consistency in future monitoring endeavors. Blackberry spot spray is essential for continued survival of installed trees and shrubs, at least until the unit achieves canopy closure. Fifteen acres in the easternmost portion of the unit are poorly stocked due to severe browse and weed competition and should be interplanted to ensure full canopy development. We recommend monitoring the success of the 2011 vole damage control installations, and applying additional installations, should these prove effective. In heavily damaged areas, we recommend interplanting to replace trees damaged or killed by voles to promote more rapid development of canopy cover at this unit.

Southwest Quad (40 acres)
Lack of consistent, intensive maintenance treatments at the Southwest Quad has led to significant populations of invasive weeds. Weed control is especially important here since the unit is intersected by the BPA power line corridor, where target is a dense layer of weed-resistant native shrubs. Interplanting to boost unmaintained native plant populations, plus blackberry and canary grass control, are needed to ensure full establishment under the power lines

South Bank/North Slough (20 acres) & North Bank Sandy Channel (15 acres)
Only minimal weed control effort is required on a biennial basis at this time.

Mirror Lake (29 acres)
Weed control and interplanting would be beneficial at the Mirror Lake unit. The low levels of invasives currently on site (attributable to the flooding this year) still should be managed, because treatments implemented in the near term are more efficacious than after noxious weeds reestablish to pre-restoration levels. Furthermore, interplanting to counteract the impact of flooding and animal damage on the native vegetation at Mirror Lake would allow for development of canopy and naturally reproducing plant populations. Experimental measures to deter animal damage - such as the experiments with bamboo to control vole damage implemented at the Delta - might prove beneficial for any new installed plantings as well as plants previously installed on the Mirror Lake unit.

Columbia River Bank (140 Acres)
High priority treatments at this unit are interplanting in understocked areas and continuing annual weed control treatments until the planted and naturally-recruited seedlings are established.

Table 15. Recommended 2011 maintenance treatments

Task	**Treatment Date**	**Sundial Island N**	**SW Quad**	**S Bank N Slough**	**N Bank Sandy Channel**	**CRB**	**Mirror Lake**
Interplanting	2/1/2012	**X**	**X**			**X**	**X**
RCG and blackberry spot spray	5/1/2012		**X**			**X**	**X**
Mow	8/1/2012	**X**	**X**			**X**	**X**
Blackberry spot spray	9/1/2012	**X**	**X**	**X**	**X**	**X**	**X**

4.6 Conclusions

2011 monitoring indicates that intensive site preparation, planting, and stewardship treatments are resulting in re-establishment of significant areas of functional Columbia River floodplain forest within the areas surveyed. Additional treatments that enhance native cover and control the most aggressive weeds continue to be necessary to meet target conditions on all units, but intensity and frequency of treatments on older units continue to decline.

The Delta is entirely within the floodplain of the Columbia River and encompasses numerous stream banks, riparian areas, off-channel ponds, sloughs, and other habitats critical to sustaining healthy aquatic life. Combined with upcoming efforts to restore natural channels and access to off-channel habitats, the opportunity to manage healthy native vegetation over the remainder of this expansive, complex area provides an unparalleled opportunity to chart a course for management of similar areas in the estuary.

All of Sundial Island and a portion of the nearby mainland at the Delta, totaling over 700 contiguous acres, have now been managed to reduce noxious weeds and restore diverse native plant cover. The scale and inter-connectedness of the Delta restoration projects sets this work apart from many others. The marked reduction of annual maintenance costs for the oldest, most established restoration units at the Delta may be largely due to decline in sources of weed seed in immediate proximity and across the larger delta landscape. This trend suggests that comprehensively restored, largely self-sustaining riparian and floodplain systems can be achieved. Smaller, isolated projects that are not accompanied by similar management of surrounding areas might never achieve this level of sustainability.

5.0 Vegetation and Habitat AEM at Scappoose Bottomlands

5.1 Introduction

The purpose of these action effectiveness assessments is to build upon previously conducted baseline studies (ORAF 2004) in order to understand how cattle exclusion and riparian re-vegetation restoration actions affect the function of Lower Scappoose Creek and the Hogan Ranch wetlands. Assessing changes following riparian restoration can be difficult to measure until the vegetation becomes established. At this time, SBWC staff monitor habitat conditions and document changes in the site with photo points. In the future, this information will be helpful in combination with other datasets (e.g., on-the-ground planting monitoring) to determine the effects of restoration activities over time.

The long-term goal of restoration activities in Scappoose Bay Watershed is to enhance the critical habitat connections between Scappoose Bay and the salmon refugia habitat in the upper watershed. To date, restoration work has focused on a three-mile section of Lower Scappoose Creek (between the confluence of North and South Scappoose Creeks) and 100 acres of wetland complex on the Hogan Ranch property. Restoration activities were implemented to enhance both the riparian corridor along Scappoose Creek and the wetlands on Hogan Ranch through control of invasive plant species, planting with native trees and shrubs, and fencing along waterways to exclude livestock. Water quality is one of the monitoring elements because warm water (water temperatures greater than 20 degrees Celsius), low dissolved oxygen (DO) (less than 8 milligrams per liter [mg/L]), and high pH (higher than 9) can create stressful conditions for salmon. This water quality monitoring was conducted to characterize basic water quality conditions important to salmonids and identify changes in these conditions as an indicator of changing salmonid habitat quality due to livestock exclusion. Monitoring water quality early in the restoration process allows parameter levels to be established and changes to be identified as the restoration sites change over time.

In 2008 through 2010, SBWC implemented the following work elements for their AEM:

1. Photo Point Collection. SBWC collected photo points twice during late spring and summer and compiled previously collected photo point data.
2. Water Quality Sampling. SBWC monitored water quality monthly for temperature, dissolved oxygen, turbidity, conductivity, and pH and installed temperature and depth loggers at the 2 sites. SBWC also collected monthly *E. coli* bacteria samples at Hogan Ranch.
3. Vegetation Planting and Community Sampling. SBWC assessed the success of vegetation plantings along Lower Scappoose Creek and the Hogan Ranch wetlands and vegetation communities at Hogan Ranch.

5.2 Site and Restoration Description

Scappoose Bay Bottomlands

The Scappoose Bay Watershed has a variety of habitats, including the bay area, tidal wetlands and sloughs in the Scappoose Bottomlands, and instream habitats in Scappoose Creek and its tributaries, North and South Scappoose Creeks. Scappoose Creek connects the Scappoose Bottomlands with salmon refugia habitat in the Scappoose tributaries. Four salmonid species (including Endangered Species Act listed steelhead and coho salmon) spawn and rear within the Scappoose Bay Watershed. The Bottomlands, in particular, provide habitat for resident fish species, wildlife, and plants (including threatened and endangered species) and for salmon and bird species migrating through the Columbia and Willamette River Basins and Pacific flyway. The ash gallery forests, oak woodlands, and tidal wetland plant communities throughout the watershed host numerous migratory birds such as waterfowl and neo-tropical migrants such as heron, eagle, osprey, and other birds of prey.

The lands surrounding the Scappoose Bay Bottomlands are primarily used as pasturelands for livestock. As such, riparian areas were cleared and little to no canopy cover exists along Lower Scappoose Creek and with few native species in the Hogan Ranch wetlands. Temperature and sediment are considered limiting factors for salmonids in this area. In the summertime, livestock graze right up to the stream edges in some areas. In particular, heavy cattle grazing around the wetlands on the Hogan Ranch property has resulted in an under story dominated by non-native invasive species like reed canarygrass and blackberry. Little regeneration of native ash and willow has occurred, and beaver take down mature trees. Cattle heavily graze on unprotected wetland plants in late summer, reducing the diversity of native wetland vegetation.

Hogan Ranch

Hogan Ranch lies north of the city of Scappoose, between Scappoose Creek (to the east) and Multnomah Channel (to the west; Figure 18). This area has low alluvial rolling plains with numerous ponds, creeks and sloughs (DEA 2000). Restoration of these wetland Ponds has been conducted in partnership with the Estuary Partnership, Oregon Watershed Enhancement Board (OWEB), Natural Resources Conservation Service (NRCS), the Wetlands Conservancy, Ducks Unlimited, Bureau of Land Management (BLM), Hogan Ranch landowners, and the Scappoose Bay Watershed Council. In 2004 the NRCS acquired a conservation easement for the property through the Wetlands Reserve Program on Hogan Ranch. The Estuary Partnership provided funding for the establishment of monitoring sites within the easement and pre-restoration site monitoring in 2004. In 2005 fencing was installed around the easement, partially excluding livestock. In 2007 additional fencing was installed and livestock were fully excluded from the restoration area. In 2007 Ducks Unlimited replaced the failed water control structures on Ponds 1 and 2, removed a dike on the south end of Pond 2 and excavated the west side of Pond 2 to create additional wetlands (Pond 3 has maintained natural hydrology throughout the restoration process) (Figure 18). The excavated areas were seeded with native wetland plants. In 2007, 2008 and 2009 native trees and shrubs were planted around the Ponds. In 2007, 2008, 2009 and 2010 native plantings were maintained by mowing and weed suppression. The Estuary Partnership, Ducks Unlimited, NRCS, Wetlands Conservancy and BLM assisted in the project development stage of the restoration. The Estuary Partnership and OWEB provided funding for restoration of the plant communities, additional fencing and maintenance. The Estuary Partnership funded the restoration site monitoring.

For this action effectiveness monitoring effort, all 3 major ponds (referred to as Ponds #1, #2, and # 3) are being evaluated. This area consists of seasonal and perennial wetlands and ash forests. The water levels of Ponds 1 and 2 are controlled by two water control structures (Figure 18). However, both ponds are subject to sheet flows and tidal influence during high water events. Pond 3 lies on the eastern edge of the property and has natural tidal hydrology year round (Figure 18). According to the Cowardin estuarine wetland classification system, Pond 1 is classified as seasonally flooded forested and emergent wetland (Cowardin et al. 1979). Pond 2 is considered a partial seasonal and partial permanently flooded wetland (Cowardin et al. 1979). Pond 3 is classified as a sub-tidal, semi-permanently flooded emergent wetland (Cowardin et al. 1979). Pond 1and 2's water levels are controlled during the dry season by the water control structures located at the northwest corner of Pond 1 and northern end of Pond 2 (Figure 18). The immediately surrounding fields (meadows) of all three Ponds are irregularly flooded during high water events (Cowardin et al. 1979). Before the water control structures were replaced, Pond 1 tended to dry up by late summer and Pond 2 (which is deeper than Pond 1) tended to hold water throughout the year.

Scappoose Creek (Wilson/LaCombe Properties)

The Scappoose Creek riparian vegetation restoration project is located on two adjacent private properties (Wilson and LaCombe) which compose a total of 18.5 acres (Figure 19). Scappoose Creek runs along these properties' northern border for approximately 560 meters (Figure 19). The restoration area can be described as part of the low alluvial rolling plains forming Scappoose Creek's flood plains (DEA 2000). This section of Scappoose Creek has a very low gradient, a deep fine sediment base and is tidally influenced year round. The surrounding area is subject to sheet flows several times each year during winter high water events. According to the Cowardin wetland classification system this site is classified as a riverine landscape with persistent emergent vegetation and the adjacent fields are irregularly flooded (Cowardin et al. 1979).

Riparian vegetation restoration was conducted along the stream's south edge (8-10 meters wide) for a total of approximately 1 acre of riparian plantings (Figure 19). Prior to restoration this area was used for pasture and agriculture (hay crops). The pasture and hay planting areas are now backset from the stream's edge and restoration vegetation is fenced to protect it from grazing. Through a partnership between the landowners, Scappoose Bay Watershed Council (SBWC), OWEB, and the Estuary Partnership the restoration area was fenced (to exclude livestock) in 2006, and then planted with native riparian vegetation in 2007 and the spring of 2008. Before restoration there was only one tree providing canopy cover (within the restoration area) along this section of stream and non-native species such as reed canarygrass , oxeye daisy (*Leucanthemum vulgare*), curly dock (*Rumex crispus*), Canada thistle (*Cirsium arvense*), and Himalayan blackberry dominated the site (Figure 19) (SBWC Planting Survival Report 2010). As the restoration plantings mature it is expected that the riparian area will become fully shaded and non-native species will be suppressed. The nature of riparian restoration work makes it difficult to observe significant habitat and water quality changes over a short period of time (Dosskey et al. 2010). Monitoring water quality conditions and documenting changes on the site with photo points help determine the long-term impacts of these restoration efforts.

5.3 Methods

5.3.1 Water Quality Methods

Water quality monitoring was conducted following the methods and protocols laid out by the Oregon Department of Environmental Quality (ODEQ) and OWEB for measuring water temperature, conductivity, pH, DO, bacteria, depth and turbidity (OWEB 2001). See Table 16 for specifics on equipment used and accuracy ranges of each parameter measured. Monthly (approximately every 4 weeks) water chemistry monitoring was conducted and continuous water temperature and depth data (from data loggers) was obtained year round. This was done to characterize water quality conditions. Monthly water quality tests were conducted on samples of water taken from the same sample location of all three Ponds throughout the study period (Figure 18). Continuous data loggers were placed in Teal Creek and Crooked Creek (Figure 18). Water quality data was summarized and compared to standard parameter ranges for ideal salmonid habitat as defined by the ODEQ, OWEB, the University of Wisconsin Extension (UWE), and EPA (EPA 2001, OWEB 2001, ODEQ 2003, UWE 2006).

In Scappoose Creek, monthly (approximately every 4 weeks) water chemistry monitoring was conducted and continuous water temperature and depth data (from data loggers) was obtained year round to characterize water quality conditions while juvenile salmonids were present, during migration and thereafter. Monthly water quality tests were conducted on samples of water taken from Scappoose Creek at the corner of the LaCombe property (SSCA05) upstream of the restoration site, and downstream of the restoration site on the Wilson property (SSCA01)(Figure 19). A continuous data logger was placed in the stream near the Wilson property monthly water quality testing site (Figure 19). Water quality data was summarized and compared to standard parameter ranges for ideal salmonid habitat as defined by the ODEQ, OWEB, EPA, and UWE (EPA 2001, OWEB 2001, ODEQ 2003, UWE 2006).

Table 16. Water quality parameters measured, equipment used and accuracy standards (ODEQ A level data quality standards) (OWEB 2001).

Water Quality Parameter	**Equipment**	**Accuracy**
Water Temperature	HOBO Data Logger and YSI 30 Conductivity Meter	(+/-) 0.5 °C
Air Temperature	NIST Digital Thermometer	(+/-) 0.5 °C
Dissolved Oxygen	Hach Dissolved Oxygen Titration Kit	(+/-) 0.3mg/l (ppm)
pH	Orion pH meter	(+/-) 0.2 pH
Turbidity	Hach Turbidity Meter	(+/-) 5% of standard value (NTU)
Specific Conductance (Conductivity)	YSI 30 Conductivity Meter	(+/-) 7% of standard value (µS/cm)
Depth	HOBO Data Logger	(+/-) 0.5 cm water
Bacteria and E. Coli Counts	IDEXX Quanti-Tray 2000® MPN	(+/-) 0.5 log

Figure 18. Location of restoration wetland Ponds 1-3, as well as location of water control structures, water quality grab sample sites, and data logger sites along Teal and Crooked Creek.

Figure 19. Map of Scappoose Creek Riparian Restoration Area and Water Quality Testing Sites

5.3.2 Vegetation Survey

In 2004, three years prior to restoration, transects were permanently established through each Pond (Figure 20). Pond 1 and Pond 2 have two transects and Pond 3 has one transect. The number and location of transects were determined through field surveying of each Pond to identify the best location for each transect to represent the larger Pond area. These transects were situated across each Pond to capture the wetland plant communities on either side and through the middle of each Pond (Figure 20). The simple basin topography of each Pond leads to clear bands of dominant vegetation ringing the central Pond depression. The vegetation communities change abruptly along this hydrologic gradient. The vegetation varies from a mix of upland and facultative upland pasture grasses, to a band of facultative wetland grass with a sparse willow overstory, to an obligate wetland marsh edge community, to the submerged and floating vegetation in the wetted area of the Pond. This pattern is reflected on both sides of the Pond. The transects run across each Pond and intersect each of the upper rings of vegetation twice. Vegetation composition and wetland plant community width were monitored along the transects in 2004 and from 2008 through 2011. In 2005 vegetation composition data was collected but no community widths were reported.

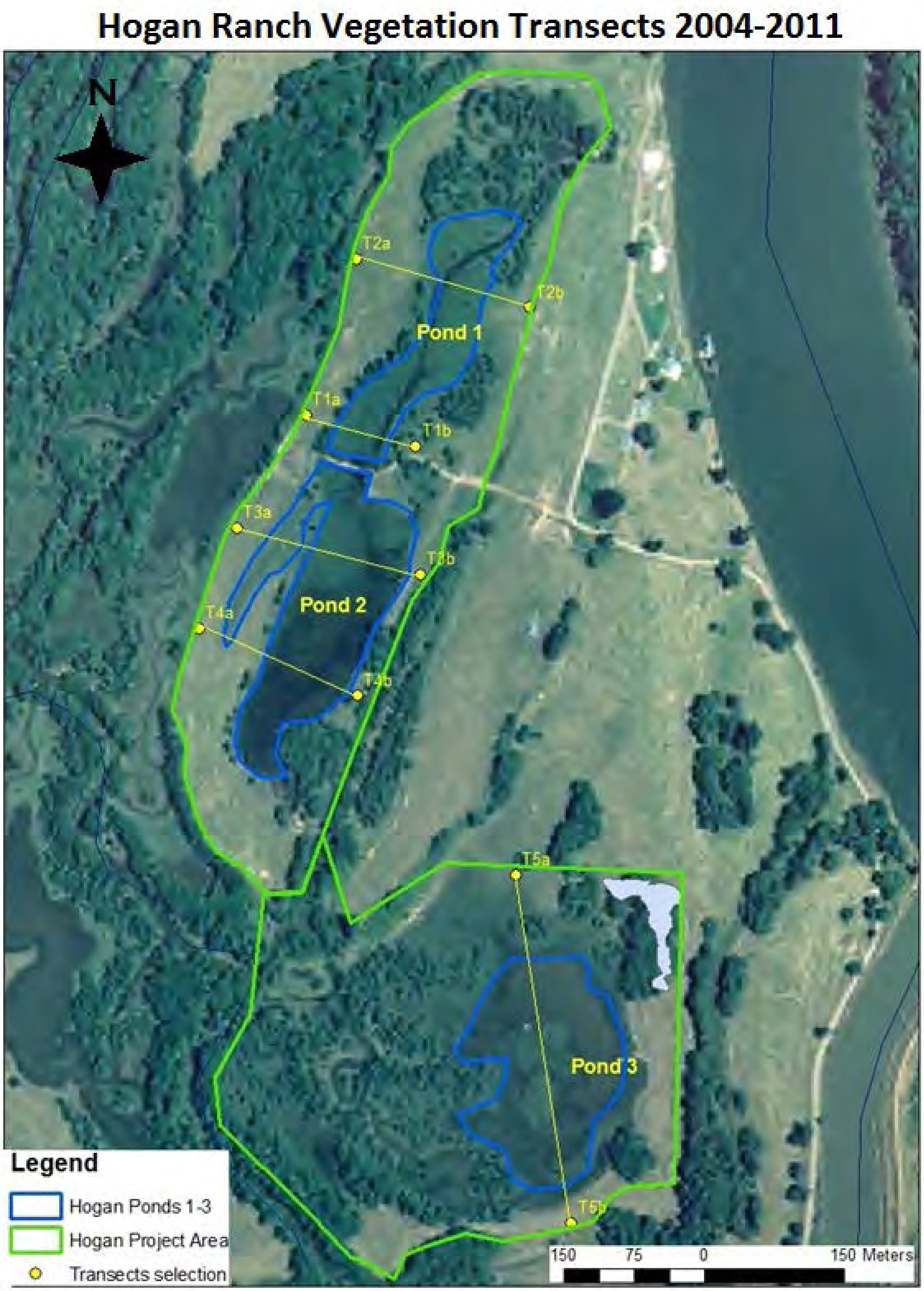


Figure 20. Location of vegetation community transects in the three Ponds on Hogan Ranch

Vegetation surveys were conducted during the first week of August from 2008-2011 because this is typically during the driest part of the year, allowing for the best access to the Pond wetland areas. A vegetation survey was conducted along each transect by first identifying the vegetation communities found along each transect and then collecting vegetation composition data for each community. Vegetation communities were identified as facultative upland (FACU): grasses and forbs, facultative wetland (FACW): grasses and forested, facultative wetland (FACW)/obligate wetland (OBL): marshy shore, or obligate wetland (OBL): floating and submerged (wetted area). These vegetation communities were identified visually based on changes in dominant vegetation wetland indicator status (WI) and soil moisture along each transect. A plant's WI status is commonly used to determine the likeliness of the plant to grow in different wetland conditions (saturated, anoxic soil), based on the species tolerance to flooding (Table 17, Tiner 1991, Welch et al. 2006).

Table 17. Wetland Indicator Categories (Tiner 1991)

Wetland indicator category	Estimated probability of occurrence in wetlands	Estimated probability of occurrence in nonwetlands
Obligate wetland (OBL)	>99%	<1%
Facultative wetland (FACW)	67–99%	1–33%
Facultative (FAC)	34–66%	34–66%
Facultative upland (FACU)	1–33%	67–99%
(Upland (UPL)	<1%	>99%)

The width of each community along each transect was recorded in 2004 and from 2008 through 2011 (no community widths were recorded in 2005). Within each identified community, 50cm x 100cm quadrant plots were randomly established within a 2 meter band extending on both sides of the transect. The random location of the plots was determined by tossing the plot frame along the transect with closed eyes. The number of plots in each community varied by the width of each community sampled along the transect. Wider communities were sampled more times than narrow communities, with plots being distributed in a random systematic fashion along the transect through each community. In 2010 and 2011 vegetation plots were randomly tossed every 5 meters along each transect and plot (meter) locations along the transect were recorded. This change in methodology for locating vegetation plots was done to increase the resolution and repeatability of vegetation data collected. The number of plots in each community also varied between years as community widths changed in response to changes in hydrology (Table 17 and Table 18) and plant community width. The 2010 change in plot location methodology increased the number of plots measured in each community (Table 17and Table 18).

Plant cover (species of all heights, up to 2 meters) of every plant species rooted in the quadrant was recorded for every plot, and when possible plants were identified to species. Taxonomic guides to regional flora were consulted; Hitchcock and Cronquist (1973), Pojar and MacKinnon (1994), and Guard (1995), to help with species identification and to determine native or non-native (introduced) status of each plant species. Native, non-native and invasive status determination, in addition to the wetland indicator status of each plant species was also identified using the online NRCS PLANTS database (http://plants.usda.gov). Water depth and canopy cover of plots were also recorded when applicable. When deep water and/or mud made it impossible to access the central areas of the Ponds, community composition was estimated visually from the edge of the Pond and the width of the inaccessible area was estimated by subtraction from the total transect length, determined with a rangefinder.

Table 18. Sampling effort associated with each vegetation community in three Ponds on Hogan Ranch.

		Number of Plots by Year					
Pond	Community	2011	2010	2009	2008	2005	2004
1	FACU grasses and forbs (I and C)	9	15	12	8	5	5
	FACW grasses/ forested fringe (H and D)	13	13	6	6	4	4
	Marshy shore (G and E)	6	7	9	4	5	7
	Wetted area (F)	37	26	8	6	1	0
2	FACU grasses and forbs (I and C)	2	7	10	7	5	6
	FACW grasses/ forested fringe (H and D)	18	16	0*	1	2	2
	Marshy shore (G and E)	7	6	8	5	2	3
	Wetted area (F)	44	31	9	7	1	5
3	FACU grasses and forbs (I and C)	0+	0+	4	1	3	0
	FACW grasses/ forested fringe (H and D)	5	9	0*	3	1	3
	Marshy shore (G and E)	7	9	4	2	1	4
	Wetted area (F)	15	0+	4	1	0	2

* In 2009 the FACW and Marshy shore plant communities were not distinguishable in Ponds 2 & 3.

+In 2010 and 2011 the FACU community was not distinguishable in Pond 3 and vegetation within the wetted area was not accessible.

5.3.3 Vegetation Cover

Plot vegetation cover was summed and averaged by plant community to determine the overall % cover represented by each plant in the vegetation communities for each Pond (Appendix B). When the estimated cover was less than 1%, it was recorded in the field as 0.5%, which allowed more ease of calculation than classifying it as “trace”. Final data tables represent species with total cover less than 1% as trace with a “T” (Trace species listed as T in Appendix B).

5.3.4 Diversity

Native and non-native (introduced) plant species richness and relative cover were calculated for each Pond. Plant community diversity was determined by calculating the species richness along each transect. Species richness is defined as the total number of species in a given area and weights all species equally (Ludwig and Renolds 1988, Chaneton and Facelli 1991). Percent relative cover was calculated for all plant species along each transect to determine species dominance. Percent relative cover was calculated by dividing the total percent cover of an individual plant species within each plant community by the total percent cover of all plant species found within that plant community. Plant species with the highest relative percent cover on a transect were considered dominant.

Data were analyzed by comparing plant species cover and diversity in each community at each Pond. This allowed us to look for changes in native richness and wetland status between monitoring years. Additionally, we compared the widths of the communities along the transects, both to explain observed changes in vegetation and to document hydrologic changes associated with restoration activities on Ponds 1 and 2. Since the transects intersect each of the outer rings of vegetation twice, plant communities were recorded separately in the field. Recurrent communities were combined for the purposes of data analysis when no significant differences emerged between sides of the Pond.

5.3.5 Survival Monitoring Methods

Survival monitoring was conducted in August of 2008-2011 after summer mowing. Sites are mowed once or twice a year to control the non-native reed canarygrass herbaceous layer between 2008-2011 on the Wilson/ LaCombe site and 2008-2010 on the Hogan Ranch site. In 2011 no funding was available for maintaining the plantings on Hogan Ranch, however extreme high water during April – July made mowing less important. Without mowing reed canarygrass can overgrow and suppress the plantings, causing poor planting vigor and mortality (Lavergne and Molofsky 2004, WRMWG 2009). At each site, we followed the current protocols recommended by the Estuary Partnership (Roegner et al. 2008) as closely as possible. The riparian planting site, Wilson/LaCombe, has plantings in a very narrow strip (4-5m) running along Scappoose Creek (Figure 21). The Wilson/LaCombe riparian plantings consisted of a dense mixture of riparian under and overstory plants (Appendix D). It was not possible to implement the monitoring protocol calling for a baseline and perpendicular transects at this site because of the size and shape of the planted area. We instead chose to place plots systematically from a random start in a path parallel to the creek. Property fence lines mark the starting and ending points of the planted area at this site. Plots were located every 50m along the length of the planted area (Figure 21), starting at the property line. The initial plot starting point was determined by choosing a number from a random number table. We assessed planting survival and vigor at a total of twelve plots (total area of 600 m^2 surveyed) on this site; the number of plots was chosen based on the guidelines in Roegner et al. (2008) for this.98 acres project site.

Figure 21. Planted area and approximate location of survival monitoring plots 2008-2011 Wilson/LaCombe property, Scappoose Creek.

At the second site, Hogan Ranch Pond 3, the planted area was wider, but irregularly shaped. We were able to use the condition and baseline transect sampling design for this area, but had to modify transect widths and locations along the baseline to conform to the planted area. On Hogan Ranch, plantings are composed of ash forest, willow, and shrub communities (Appendix D). We placed a baseline transect through each of the communities and constructed transects and plots systematically from a random start as much as was feasible. In total, we assessed planting survival and vigor at 62 plots (compared to 62 in 2009, 2010 and 54 in 2008) on this site (Figure 22); this met the recommendations in Roegner (2008) for this 16.67 acres planting area. The locations of the survival monitoring baseline transects were changed slightly from 2008 to 2009 which accounts for the additional 8 plots assessed in 2009-2011. This slight adjustment in location was done to establish a better representation of the larger planted area. In 2010 monitoring on Hogan Ranch were permanently marked with fence stakes for easier long-term identification and monitoring.

Total yearly surveyed planting survival was calculated as the total number of living plants surveyed divided by the total number of plants (dead and living) surveyed. These survival calculations are necessary because original planting numbers are not known for these sites. High, medium and low vigor was assessed qualitatively in the field. An estimate of plants per acre (plants/acre) was calculated by dividing the total number of plants surveyed by the total plot area (acres) surveyed on the site. Average planting density (APD) was calculated as the average of the density of plantings in each plot (plants/m^2).

An increase in APD year to year can result from adding new plantings to the survey area, while a decrease in APD can result from plants missed in the survey due to mortality. APD can also vary from year to year due to the random placement of survey plots. In addition to monitoring survival and vigor of plantings at each site dominant herbaceous vegetation and overstory canopy cover was visually estimated at each plot.

Plantings are clustered in some places at Hogan Ranch and these planting clusters may or may not be captured from year to year depending on the plot placement which can cause the number of plants found (APD) to vary from year to year. On the Wilson/LaCombe site plants were place with more consistent spacing and no additional plants were added after the initial survey in 2008. These planting characteristics on Wilson/LaCombe allow us to account for the missing plants in the survival calculations by calculating an adjusted survival. The adjusted survival takes into account the difference between the yearly APD to estimate how many plants were dead and missing from the site between survey years. The difference in yearly APD is multiplied by the area surveyed to get an estimated number of missing plants. This number is then added to the survival calculation as dead plantings and the adjusted survival is calculated using this new total number of plantings and number of dead plantings. Adjusted survival was calculated for the 2009-2011 surveys on Wilson/LaCombe to get a more encompassing yearly survival estimate. Adjusted survival cannot be calculated for Hogan Ranch because of the variability of the planting layout and because supplemental plantings were added in between years on this site.

Hogan Ranch Property Wetland Survival Monitoring Plots

Figure 22. Approximate location of plots for monitoring vegetation survival on Hogan Ranch Pond 3 for 2009 and 2011.

5.4 Water Quality Results

5.4.1 Hogan Ranch Ponds

5.4.1.1 Monthly Water Quality Data

Monthly water quality data was collection from August 2004 through August 2011. The exact months that data was collected at the sites can be seen in Table 19. A table of the average, minimum and maximum values for each parameter by site and year can be found in Appendix E.

Table 19. Years and Months of Water Quality Data Collection at Hogan Ranch Ponds 1-3, Teal Creek and Crooked Creek

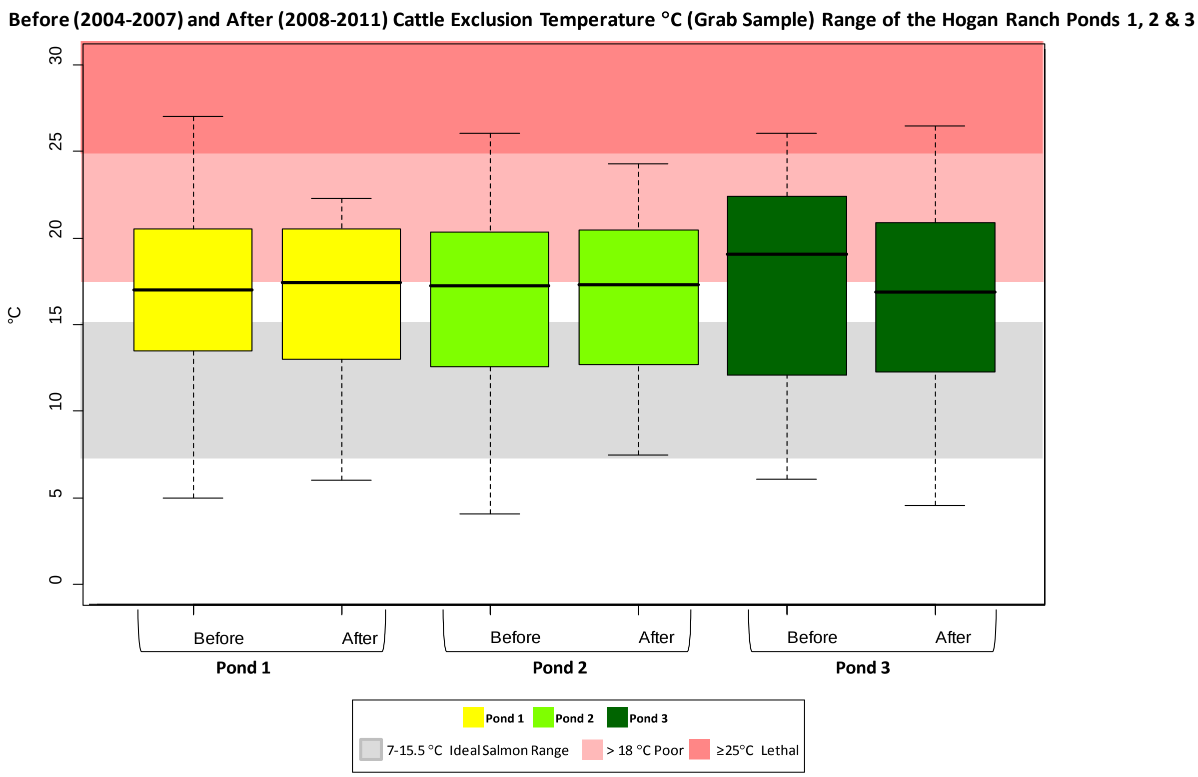
Year\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004								■		■	■	
2005		■	■	■	■	■						
2007						■	■	■	■			
2008				■		■	■ **T**	■ **T**	■ **T**	**T**	■ **T**	**T**
2009	■ **T**	■ **T/C**	**T/C**	**T/C**	■ **T/C**	■ **T/C**	■ **T/C**	■ **T/C**	■ **T/C**	■ **T/C**	**T/C**	**T/C**
2010	■ **T/C**	**T/C**	■ **T/C**	■ **T/C**	■ **T/C**	■ **T/C**	■ **T/C**	■ **T/C**			■	■
2011		■	■	■	■	■	■	■				

■	**Grab Sample Water Quality Collected**

Data Loggers Collecting Temperature Data:
TTeal Creek
CCrooked Creek

Monthly Sampling Temperature

Monthly grab sample water temperatures were similar among the Ponds with seasonal trends of high temperature in the summer months (Figure 23). No difference in the pond temperatures was found before (study years 2004-2007) and after (study years 2008-2011) the cattle exclusion occurred. As the restoration site matures and the tree/shrub plantings begin to provide significant shade, water temperatures may decrease. Over the study period the warmest temperatures (>18°C) were observed from May through September. During July through September 2007, July and August 2008, May through September 2009 and June through August 2010 the water temperature was close to or greater than 18°C, which is not optimal for salmonids (Figure 23, ODEQ 2003). No major differences in water temperature were observed between sites and/or across years (Figure 23, Appendix E). For detailed temperature ranges please see Appendix E and the 2010 water quality report.



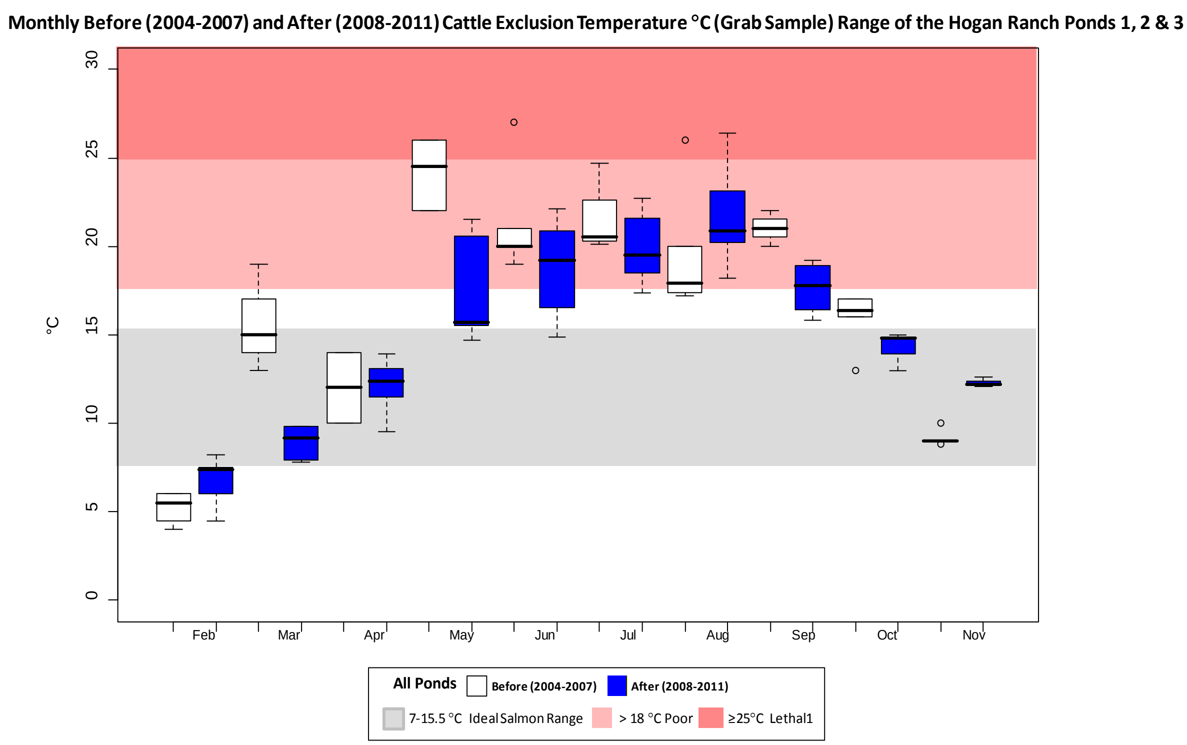


Figure 23. Hogan Ranch Ponds Total and Monthly Water Grab Sample Temperature Ranges Before (years 2004-2007) and After (years 2008-2011) Cattle Exclusion. Gaps in graph indicate no data was collected for those months, for exact months sampled each year see Table 19. Water temperatures between 7-15.5°C are considered ideal for adult salmonids (OWEB 2001) and water temperatures >18°C are considered poor for salmonids (ODEQ 2003).

Monthly Sampling Dissolved Oxygen

Diel fluctuations during the 24 hour daily cycle in dissolved oxygen (DO) were observed in all of the Ponds and are typical in these environments (Egna and Boyd 1997). Diel fluctuations in DO are caused by algae and submerged plants which have a dramatic influence on DO levels in a pond during a 24 hour day-night cycle. During the day the photosynthesis process can dramatically increase DO levels in the ponds to saturation point and beyond. This is typically coupled by a dramatic drop in DO levels with the reversal of the photosynthesis process (respiration) at night which corresponds to very low DO levels in the morning. The strong relationship between the DO concentration and the time of day at which the samples were taken is clearly apparent in figures 3-5 with DO concentrations low in the morning and progressively increasing throughout the day.

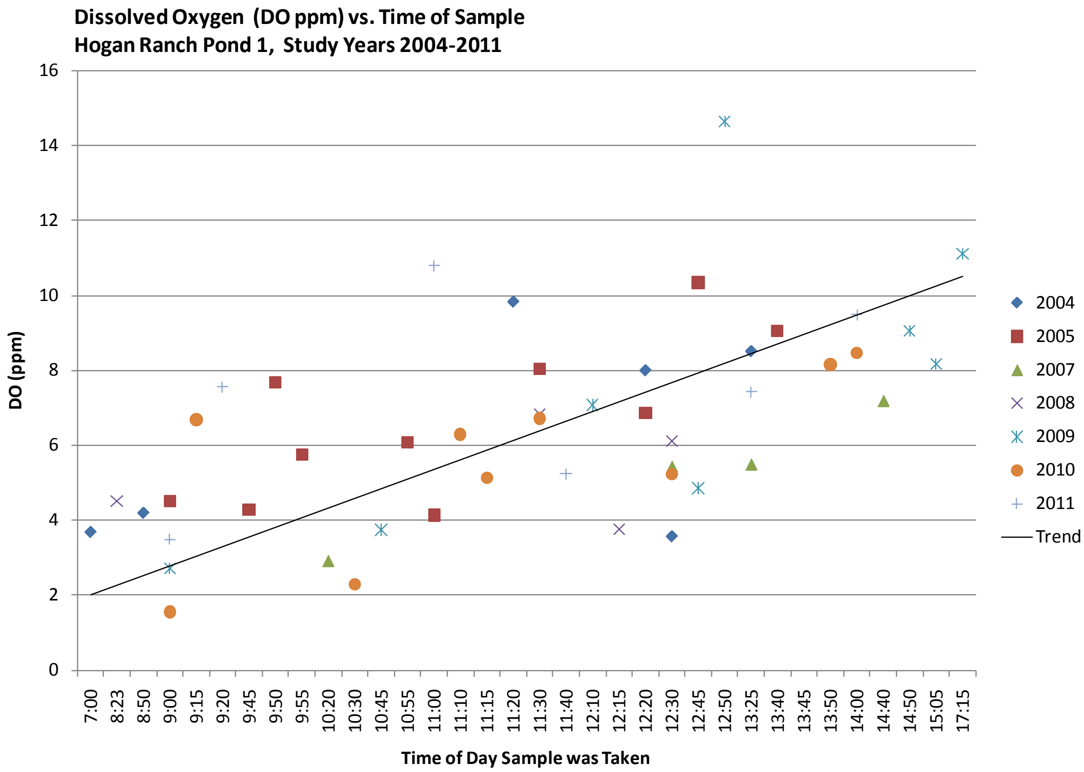


Figure 24. Pond 1 Dissolved Oxygen Concentration vs. Time of Day Sample was Taken for Study Years 2004-2011.

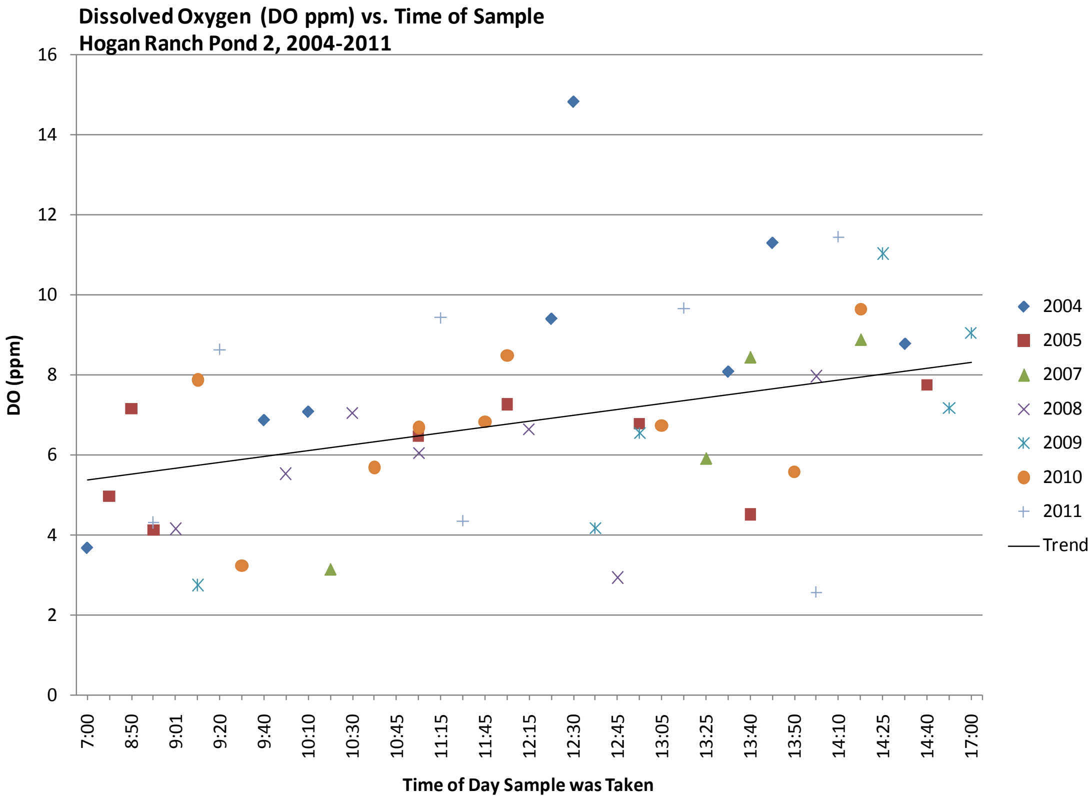


Figure 25. Pond 2 Dissolved Oxygen Concentration vs. Time of Day Sample was Taken for Study Years 2004-2011.

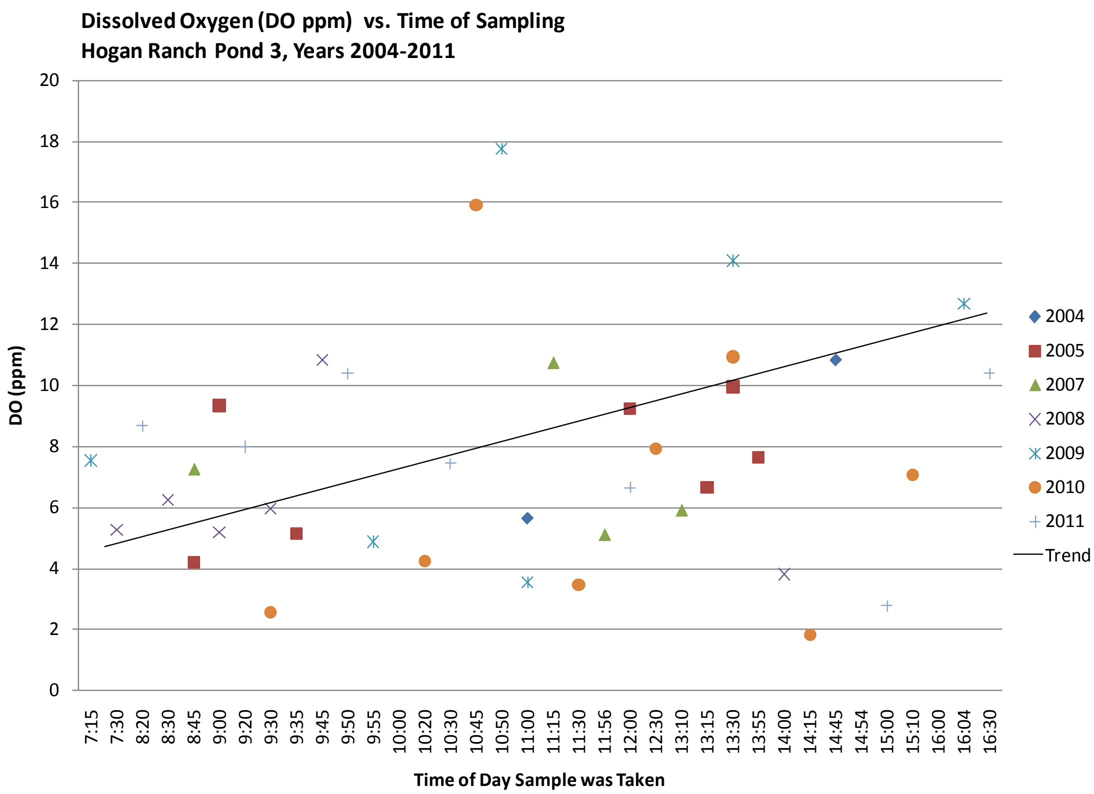


Figure 26. Pond 3 Dissolved Oxygen Concentration vs. Time of Day Sample was Taken for Study Years 2004-2011.

This relationship can make it difficult to determine if there were any changes in the DO from year to year or even season to season because of the variability in sample times over the duration of the study period. However, even with these confounding factors, the DO ranges of the Ponds were similar before and after the restoration activity (Figure 27). The concentration of DO in the water varied seasonally at all Ponds, with higher DO concentrations in the cooler winter months and lower DO concentrations in the warmer summer months (Figure 28 and Figure 29). Pond 3 had a higher DO range than both Pond 1 and Pond 2 which had similar DO concentrations throughout the study period (Appendix E). Pond 3's tidal hydrology may account for the larger DO range as compared to the other ponds which have a less dramatic tidal influence. No other major changes in DO concentrations were observed between sites and/or across years (Figure 24, Appendix E).

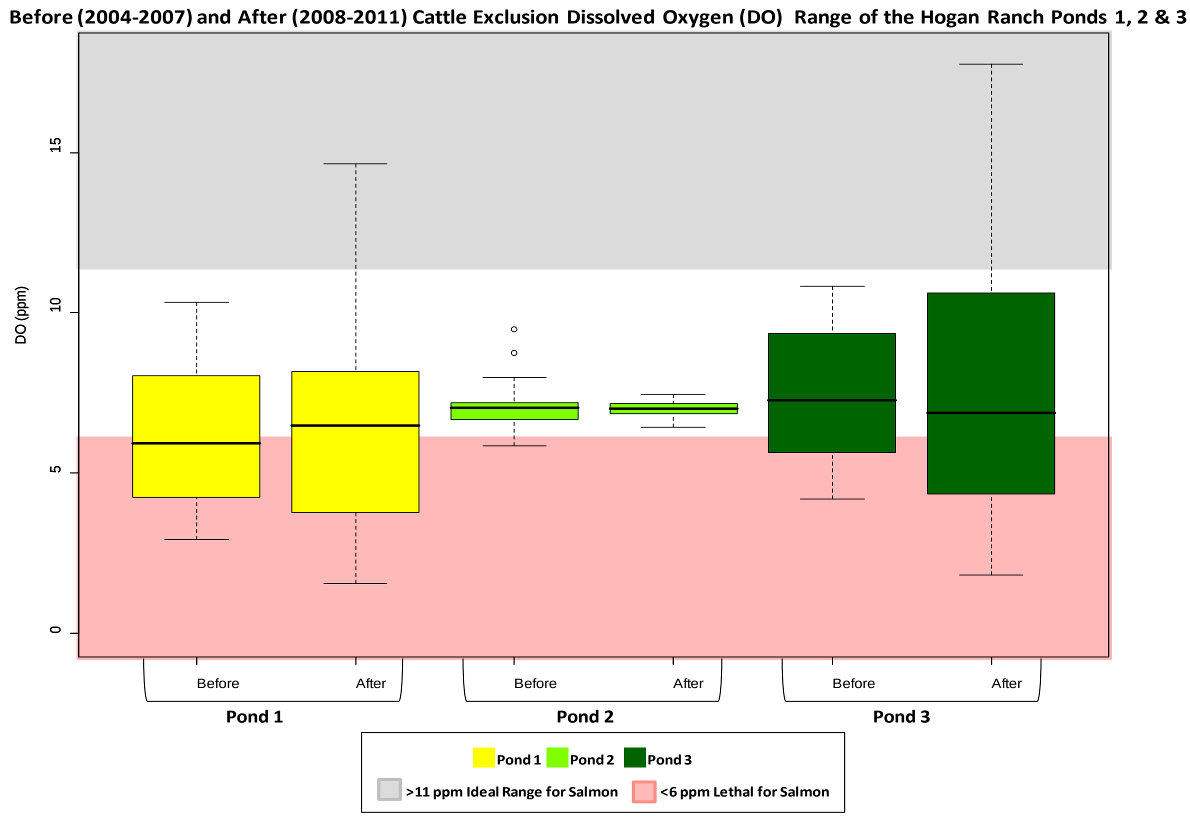


Figure 27. Hogan Ranch Ponds Total Dissolved Oxygen (ppm) Concentration Ranges Before (years 2004-2007) and After (years 2008-2011) Cattle Exclusion. Water dissolved oxygen concentrations ≥11ppm are considered ideal for salmonids (ODEQ 2003) and dissolved oxygen concentrations <6 ppm are considered lethal for salmonids (OWEB 2001).

Monthly Dissolved Oxygen (DO) Range of the Hogan Ranch Pond 1 Before (2004-2007) and After (2008-2011) Cattle Exclusion

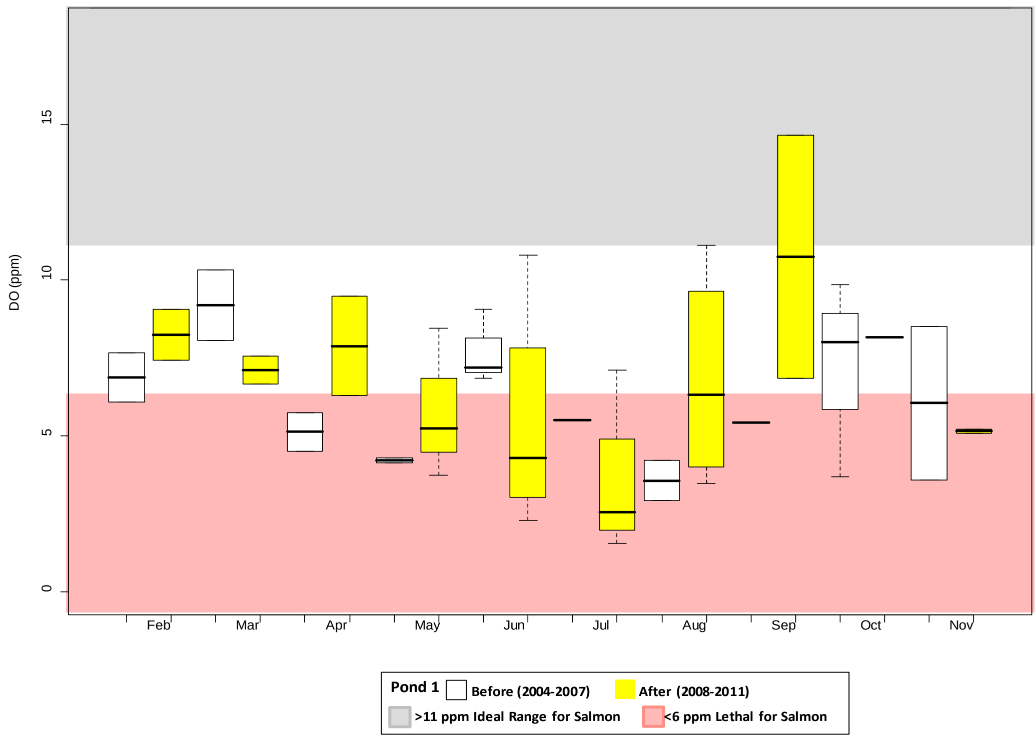


Figure 28. Pond 1 Monthly Dissolved Oxygen (DO) Before (2004-2007) and After (2008-2011) Cattle Exclusion.

Monthly Dissolved Oxygen (DO) Range of the Hogan Ranch Pond 2 Before (2004-2007) and After (2008-2011) Cattle Exclusion

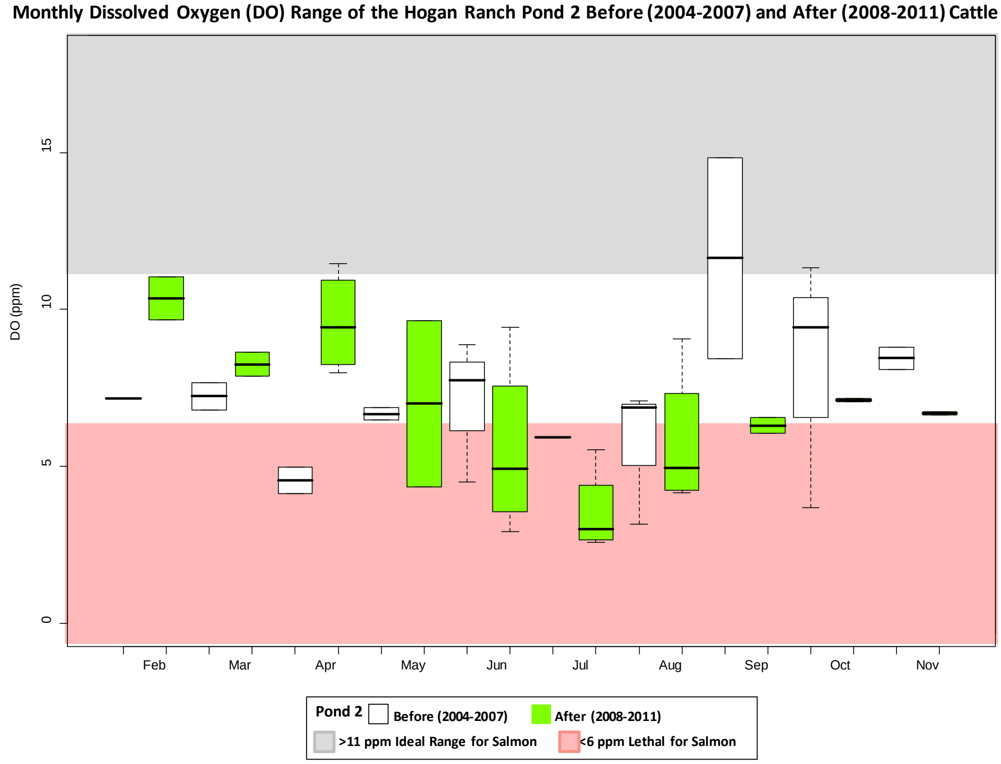


Figure 29. Pond 2 Monthly Dissolved Oxygen (DO) Before (2004-2007) and After (2008-2011) Cattle Exclusion.

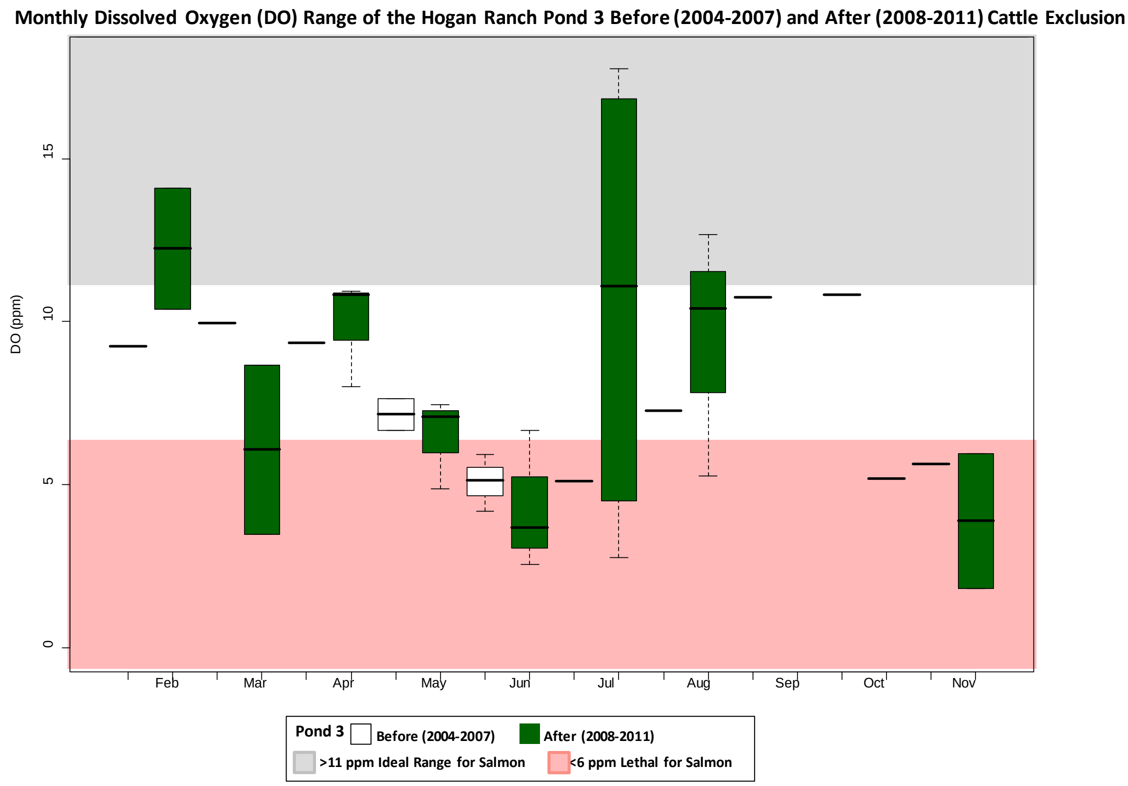


Figure 30. Pond 3 Monthly Dissolved Oxygen (DO) Before (2004-2007) and After (2008-2011) Cattle Exclusion.

Monthly Sampling pH

Overall, pH levels were similar among the Ponds with no difference found before (study years 2004-2007) and after (study years 2008-2011) the cattle exclusion occurred (Figure 31). Pond water pH levels stayed within the salmon tolerance range between 8.5 and 6.5 pH for the majority of the study period (Figure 31). Pond 3 had the largest pH fluctuations of all the ponds, with clear seasonal trends of higher pH levels in the summer months of Jun-Aug. No other major changes in pH levels were observed between sites and/or across years (Figure 31, Appendix E).

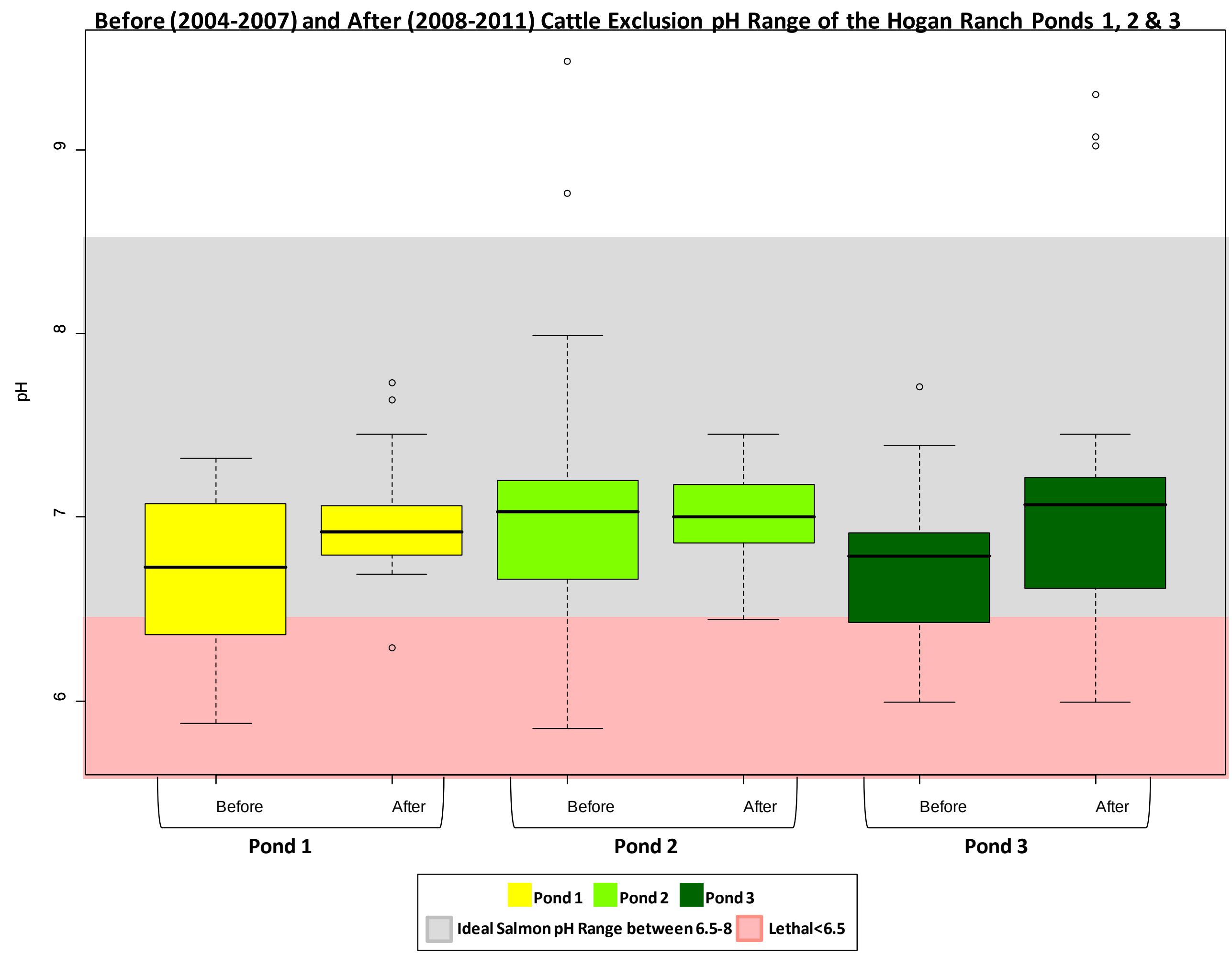


Figure 31. Hogan Ranch Ponds pH Ranges Before (years 2004-2007) and After (years 2008-2011) Cattle Exclusion. Water pH levels between 8.5-6.5 are considered ideal for salmonids and water pH <6.5 or >8.5 are considered poor for salmonids (OWEB 2001, ODEQ 2003).

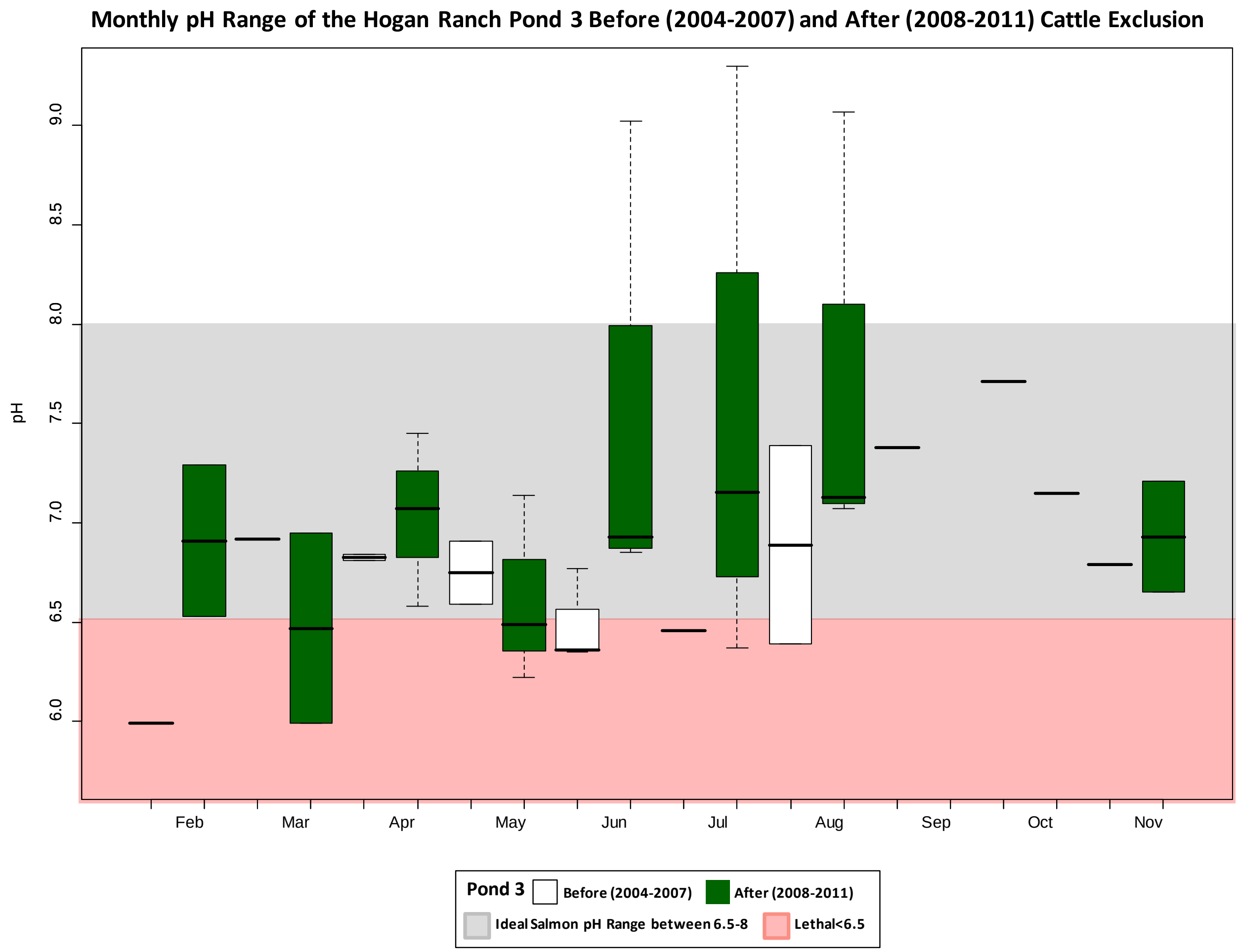


Figure 32. Pond 3 Monthly pH Range Before (2004-2007) and After (2008-2011) Cattle Exclusion.

Monthly Sampling Turbidity

Overall turbidity ranges were similar among the Ponds with a slight decrease in turbidity in all Ponds found after cattle exclusion (study years 2008-2011) when compared to the turbidity range prior to cattle exclusion (study years 2004-2007) (Figure 33). However, average turbidity levels (before and after cattle exclusion) were typically greater than 10 NTUs in all of the Ponds which is considered unhealthy for salmonids (UWE 2006).

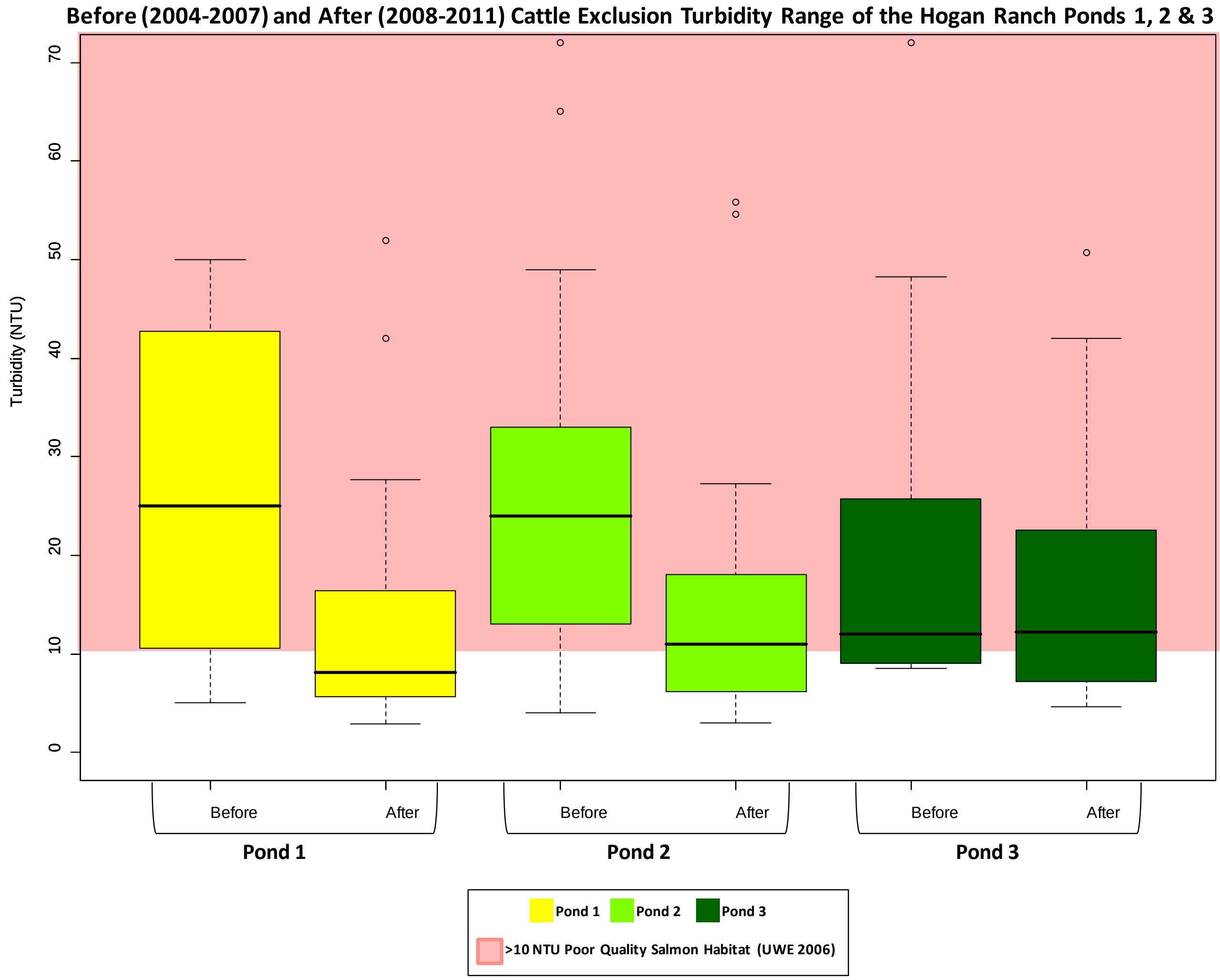


Figure 33. Hogan Ranch Ponds pH Ranges Before (years 2004-2007) and After (years 2008-2011) Cattle Exclusion. Water turbidity >10 NTUs is considered poor for salmonids (UWE 2006).

Seasonal trends in Pond water turbidity (NTU) levels were similar between Pond 1 and 2 with high(>10) NTU levels during the late summer and early fall corresponding with high summer algal levels and seasonal low water (Figure 34 and Figure 35). Pond 3 typically has very low water (<3-4 inches)during late summer and early fall which makes it difficult to collect water samples during this time and explains the lack of data for this Pond during these months (Figure 36). In general, Pond 3 has more variable seasonal turbidity levels than both Ponds 1 & 2 which can possibly be explained by its unique tidal hydrology compared to the other Ponds (Figure 34, Figure 35, and Figure 36). A detailed summary of the yearly Pond turbidity levels can be found in Appendix E.

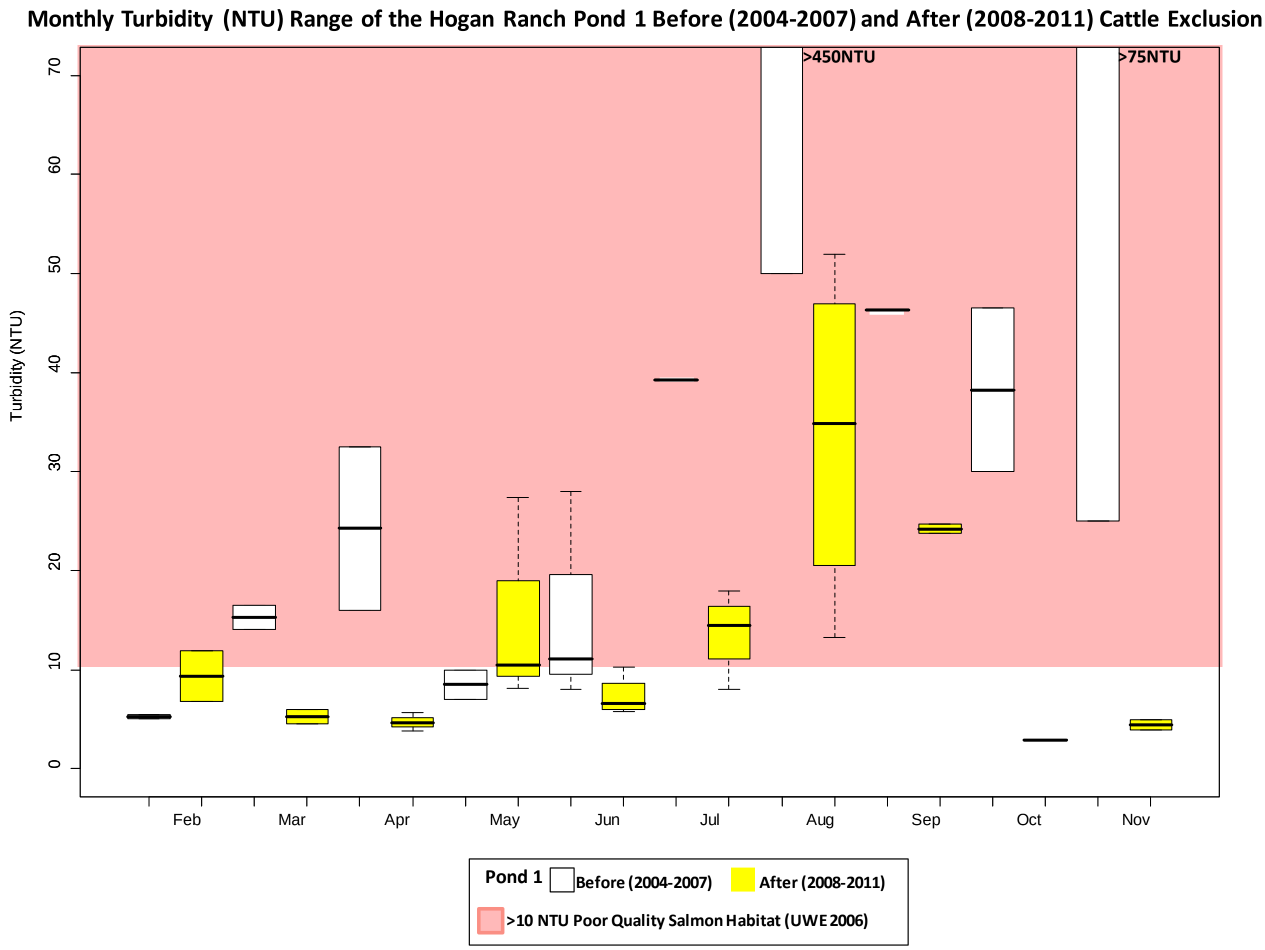


Figure 34. Pond 1 Monthly Turbidity Range Before (2004-2007) and After (2008-2011) Cattle Exclusion.

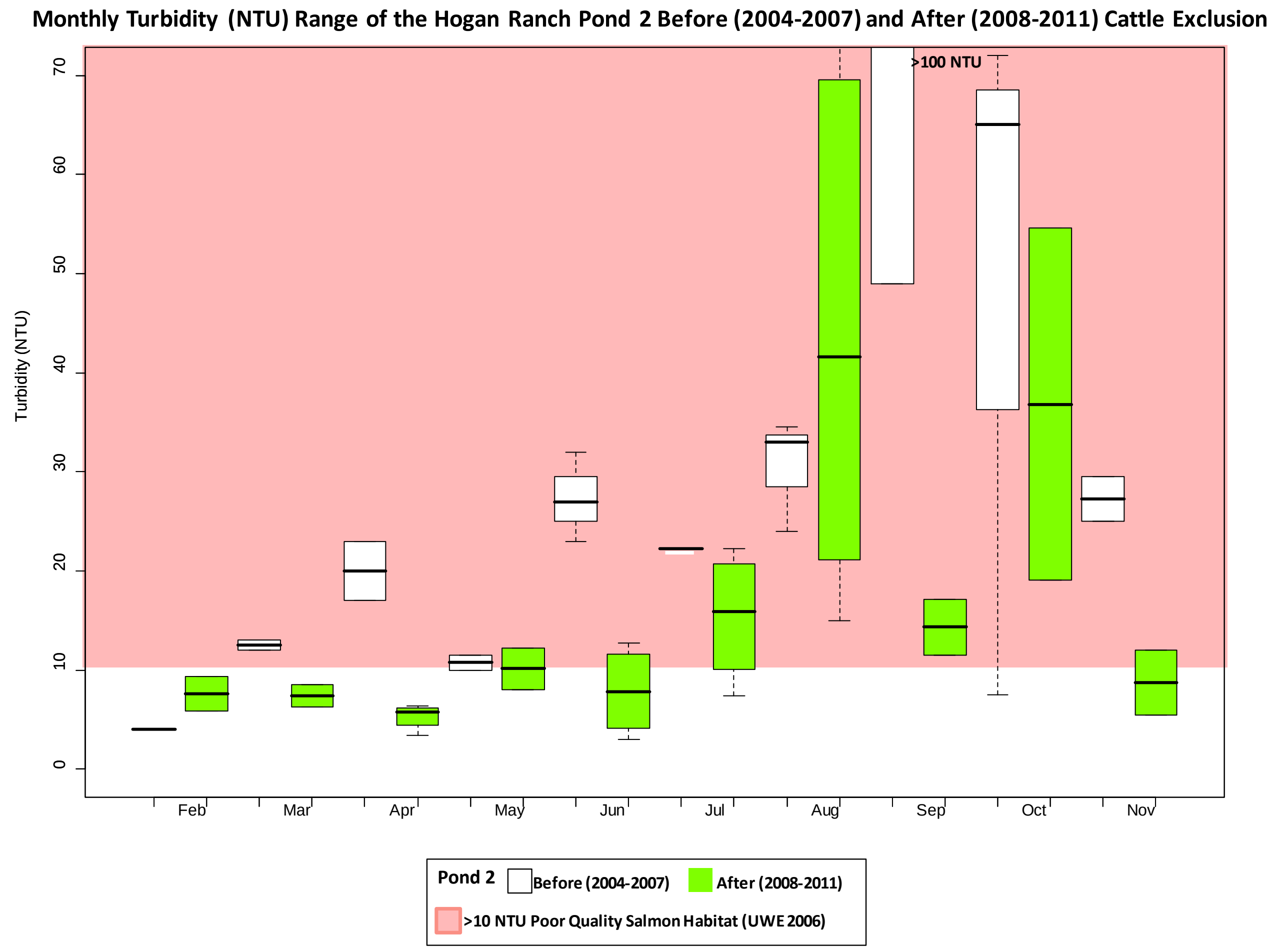


Figure 35. Pond 2 Monthly Turbidity Range Before (2004-2007) and After (2008-2011) Cattle Exclusion.

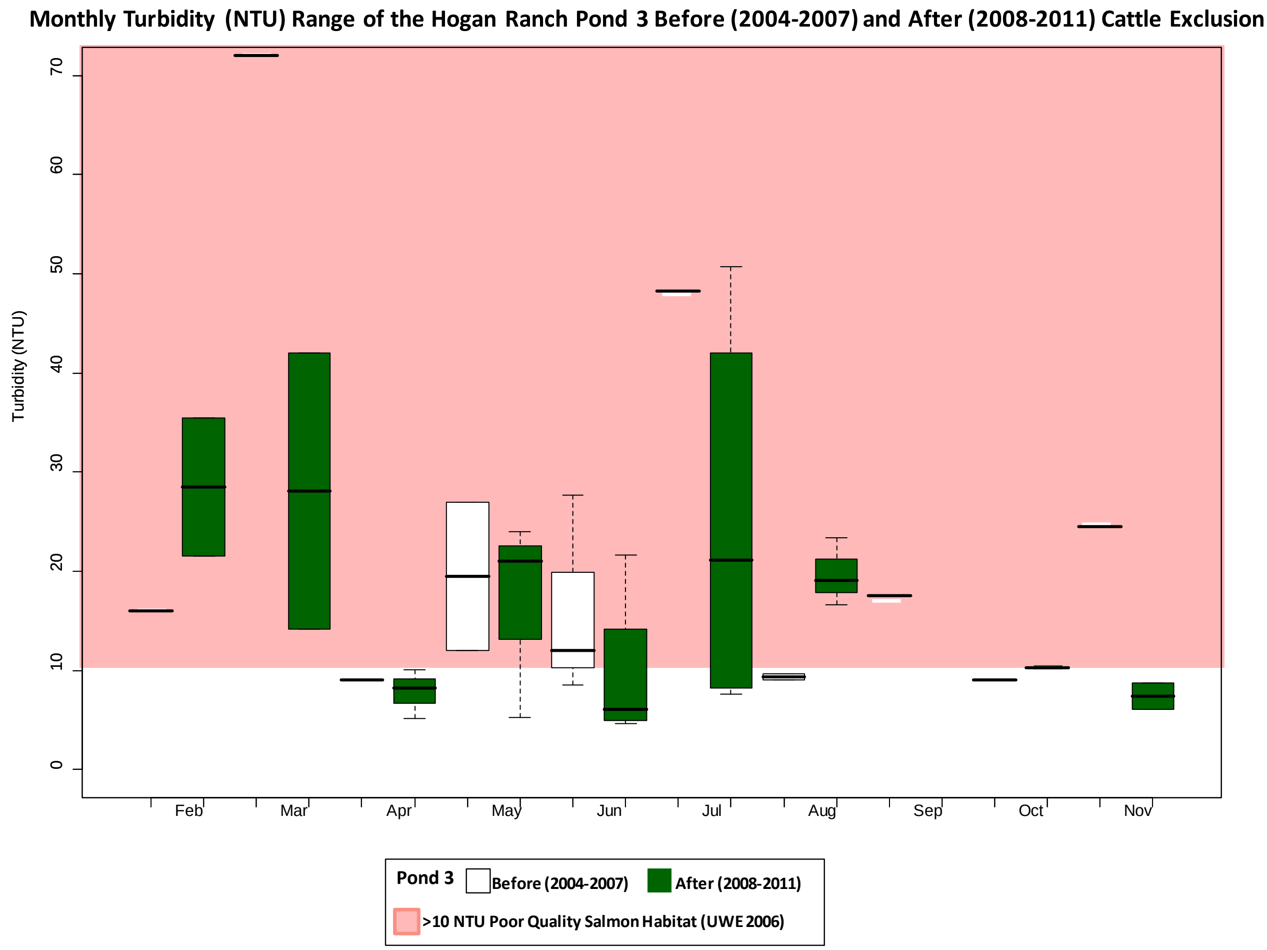


Figure 36. Pond 3 Monthly Turbidity Range Before (2004-2007) and After (2008-2011) Cattle Exclusion.

Monthly Sampling Conductivity

Overall conductivity ranges were similar among the Ponds with a slight decrease in average conductivity levels found in all Ponds after cattle exclusion (study years 2008-2011) when compared to prior to cattle exclusion (study years 2004-2007) levels (Figure 37). A decrease in conductivity levels can indicate a decrease in turbidity and a decrease in bacteria levels, both of which occurred in the Ponds after cattle exclusion in 2007 (EPA 2001). In general wetland conductivity can range from 50-1500 µS/cm throughout the year, with conductivity levels > 500 µS/cm considered limiting for fish use (EPA 2001). Pond average conductivity levels (before and after cattle exclusion) fell below this 500µS/cm threshold. Seasonal trends in conductivity paralleled the seasonal trends in turbidity with the highest levels occurring during the late summer and early fall in Ponds 1 and 2 and yearlong variability in the conductivity levels found in Pond 3 (Figure 34, Figure 35, and Figure 36). A detailed summary of the yearly Pond conductivity levels can be found in Appendix E.

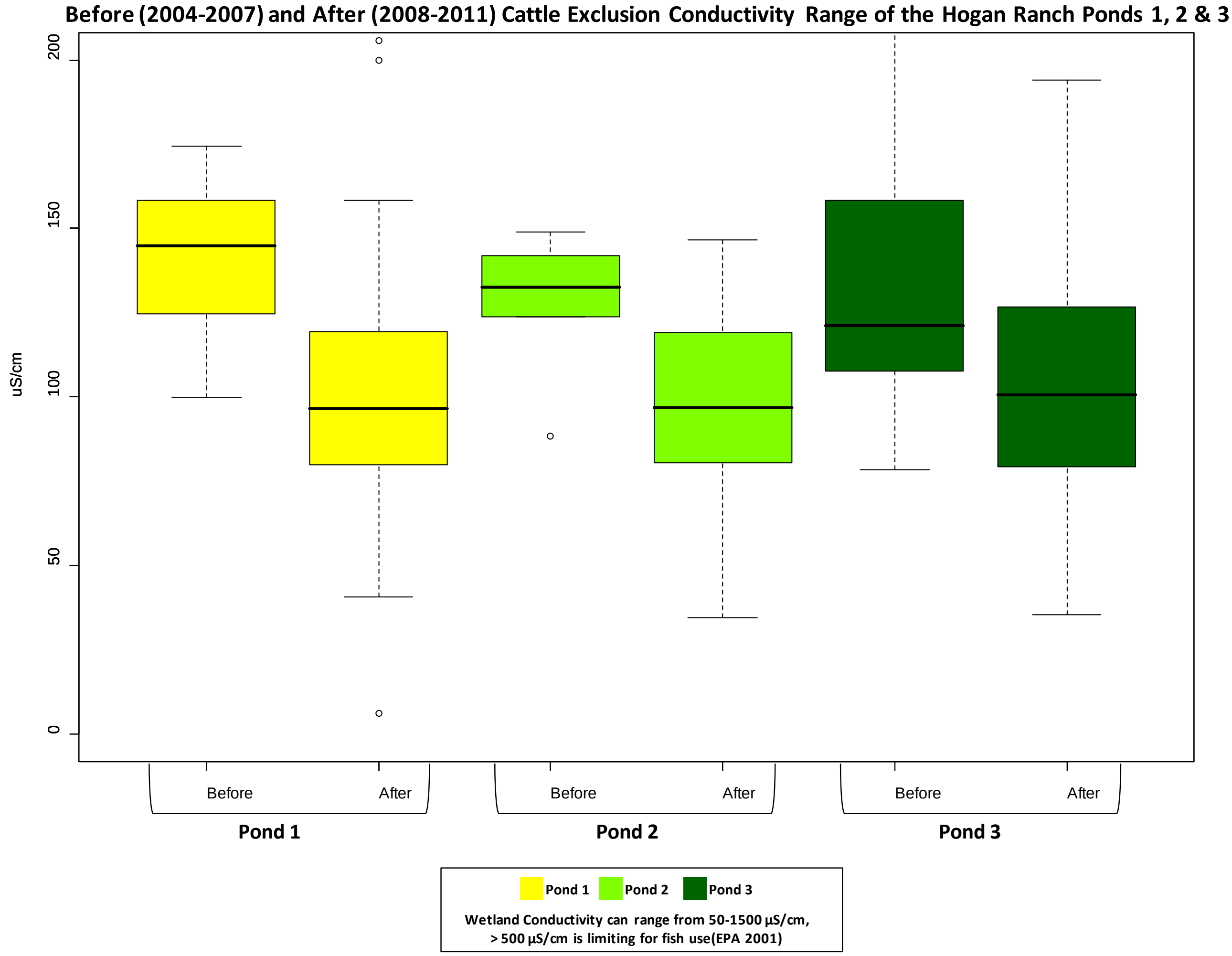


Figure 37. Hogan Ranch Ponds Conductivity Ranges Before (years 2004-2007) and After (years 2008-2011) Cattle Exclusion.Wetland conductivity can range from 50-1500 µS/cm throughout the year, with conductivity levels > 500 µS/cmconsidered limiting for fish use (EPA 2001).

Monthly Sampling E. Coli Bacteria

E. coli (*Escherichia coli*) bacteria are used as indicator organisms for fecal contamination. High E. coli levels in water ways and ponds are associated with poor water quality (possible harmful bacteria presence) for human exposure (OWEB 2001). The ODEQ recommends no single water sample should exceed an E. coli MPN of 406 MPN/100mL and the EPA recommends that water should not exceed 235 MPN/100 mL (EPA 2001, ODEQ 2003). During the 2004-2005 before cattle exclusion occurred and in 2009 (when ponds 1 &2 were exposed to cattle for several weeks due to a failure in the electric fence) E. coli level were significantly higher (> 235 MPN/100ml) than the levels found in the ponds after full cattle exclusion occurred during 2010-2011 (Figure 38 and Figure 39). Overall, a significant decrease in the average E. coli bacteria levels was found in both Ponds 1 &3 after cattle exclusion in 2007 and in Pond 2 after 2009 (Figure 38 and Figure 39). A trend of decreasing E. coli levels can be seen for all the ponds over the duration of the restoration activity between 2004-2011 (Figure 39). Seasonal highs in E. coli levels both before and after cattle exclusion correspond to periods of high water temperatures during the summer and early fall (Figure 23). During the 2011 study period none of the Ponds had E. coli bacteria levels over 40 MPN/100mL for the year, well below the ODEQ and EPA thresholds (Appendix E). It should also be noted that in May of 2011 bacteria samples could not be taken at the study sites because of extreme high water. Reference samples were taken from the closest assessable areas which were all active cattle pastures. All of these samples were returned with extremely high E. coli levels >800 MPN/100 ml. This may indicated that at times of extreme high water bacteria from adjacent grazing sites may contaminate the restoration wetlands.

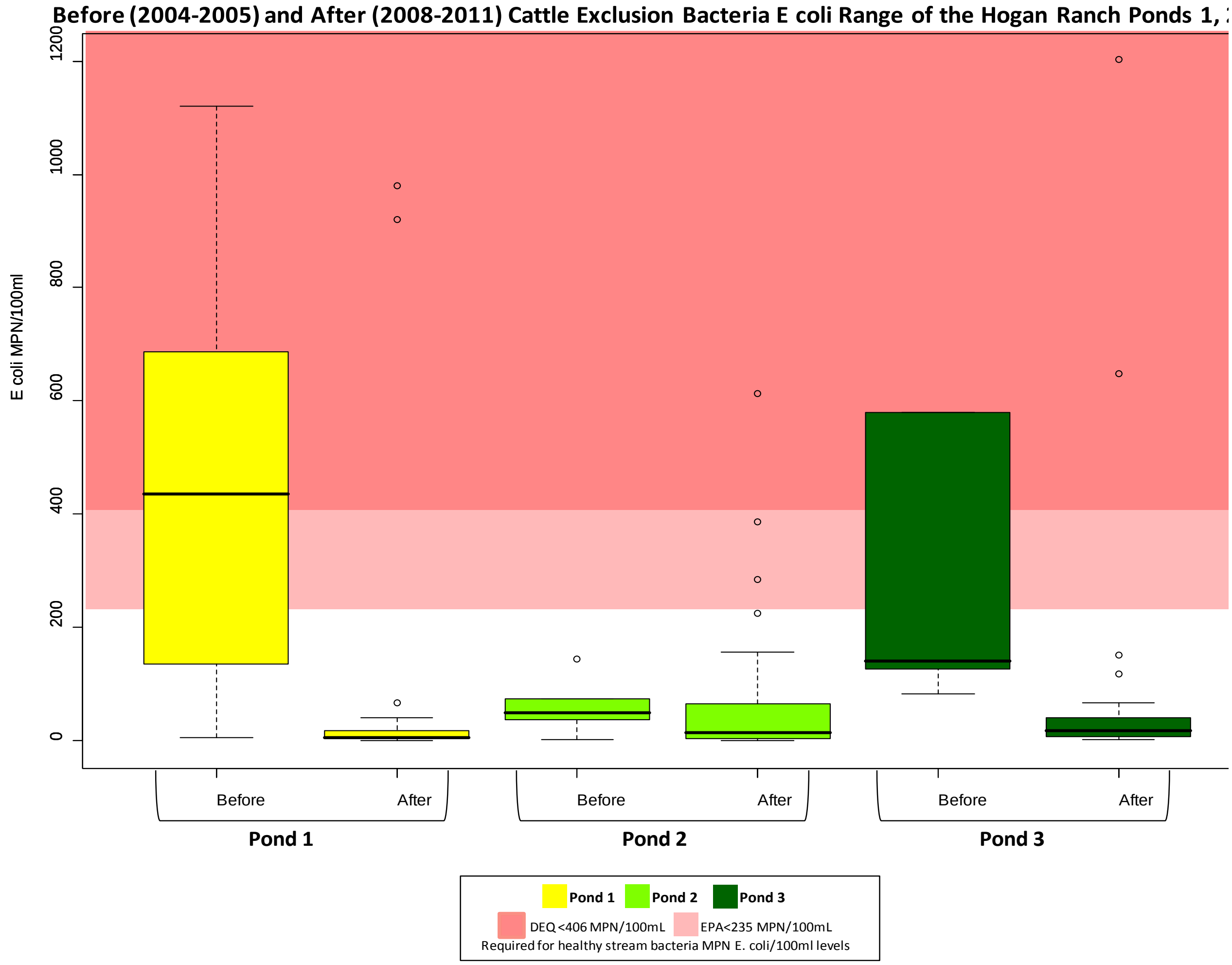


Figure 38. Hogan Ranch Pond E. coli levels (MPN/100mL) Before (2004-2005) and After Cattle Exclusion (2008-2011).

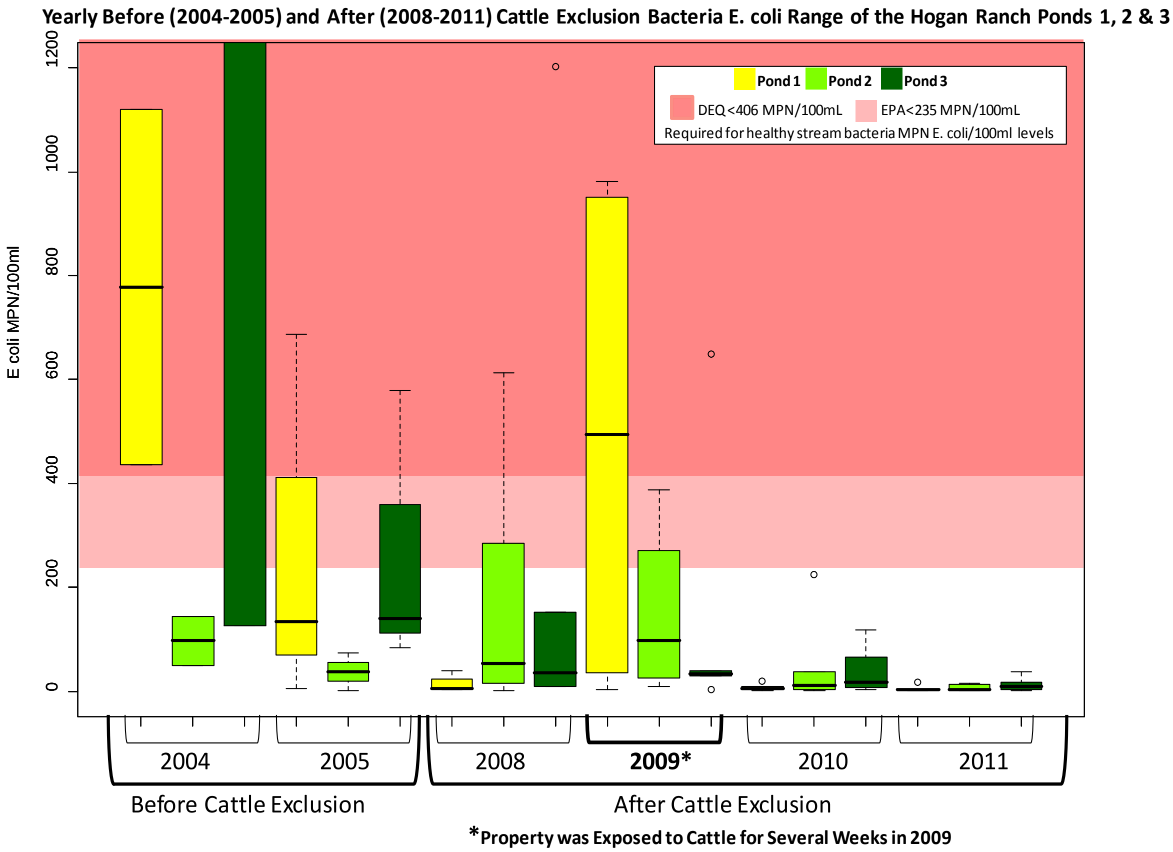


Figure 39. Yearly Before (2004-2005) and After(2008-2011) Cattle Exclusion Bacteria E. coli levels of the Hogan Ranch Ponds 1-3. *In 2009 the ponds were exposed to cattle for several weeks which resulted in high bacteria levels during that time.

5.4.1.2 Seasonal Data Logger Water Quality Trends

Continuous temperature data was collected at Teal Creek (which flows into Pond 3) from July 2008 through August 2010 and Crooked Creek (which flows into Pond 1) from Feb 2009 through August 2010 (Table 19). In addition, continuous depth data was also collected from Feb 2009 through August 2010. Continuous temperature and depth data were not collected during the remainder of the 2010 and for all the 2011 study seasons due to technical difficulties with the logger equipment. Seasonal depth and temperature trends were similar for both Crooked and Teal Creek with high water levels in the winter and spring and low water levels in the summer (Figure 40). This is similar to the depth and temperature trends of the Hogan Ranch Ponds as seen in Figure 41 and Figure 23 (based on monthly sampling). Teal Creek's seasonally high temperatures started in the April and lasted throughout the summer months with average temperatures >25°C (lethal limit for salmonids) in July and August (Figure 40). Crooked Creek's seasonally high temperatures started later in May and also lasted through the summer with average temperatures >18°C (poor for salmonids) but not exceeding 25°C. During the study period daily tidal depth fluctuations were ≤1 meter a day in Crooked Creek and ≤0.6 meters a day in Teal Creek. For further details (figures and data summary) please refer to the 2010 water quality report and Appendix E.

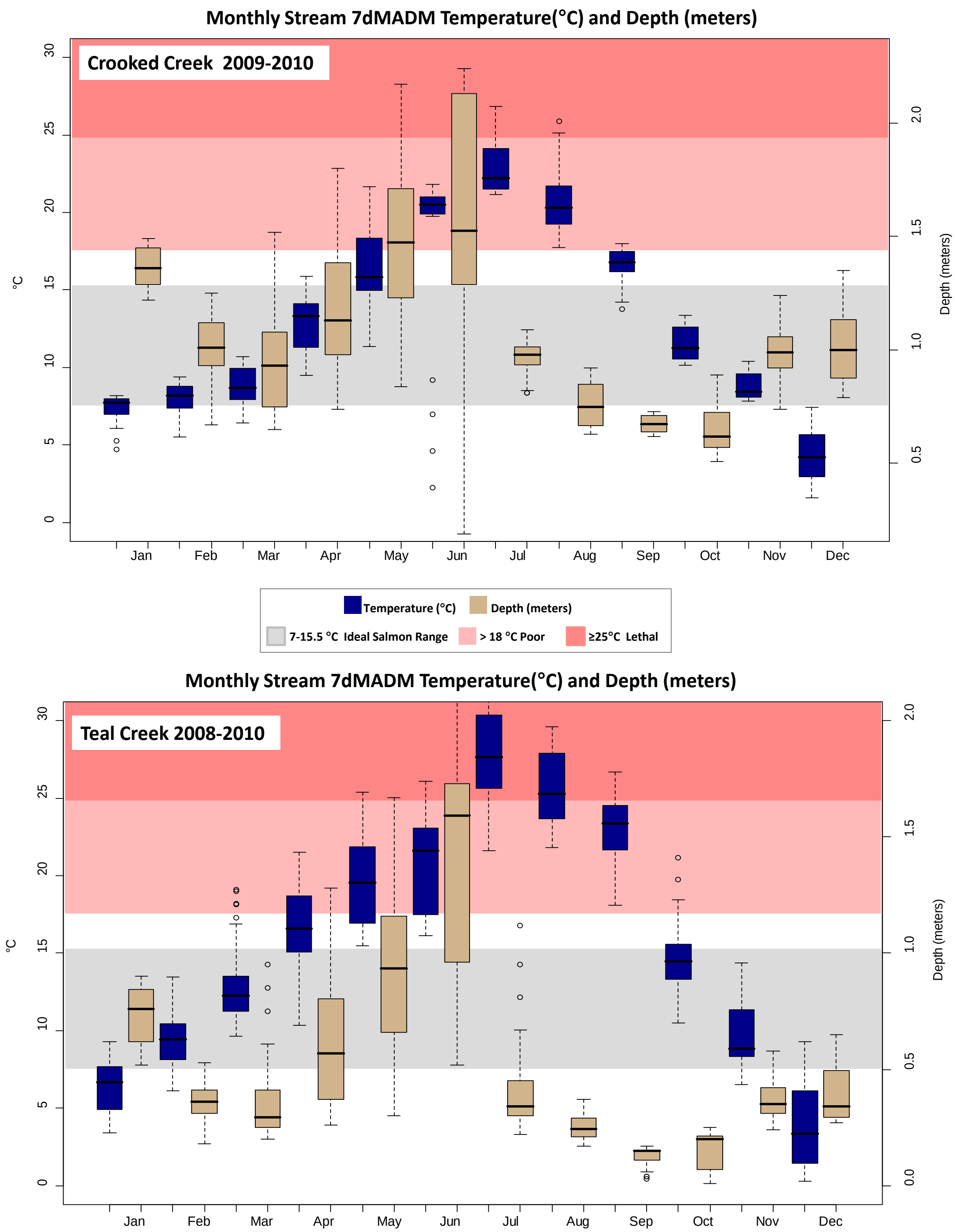


Figure 40. Monthly Stream 7dMADM Temperature and Depth for Crooked (2009-2010) and Teal Creek (2008-2010).

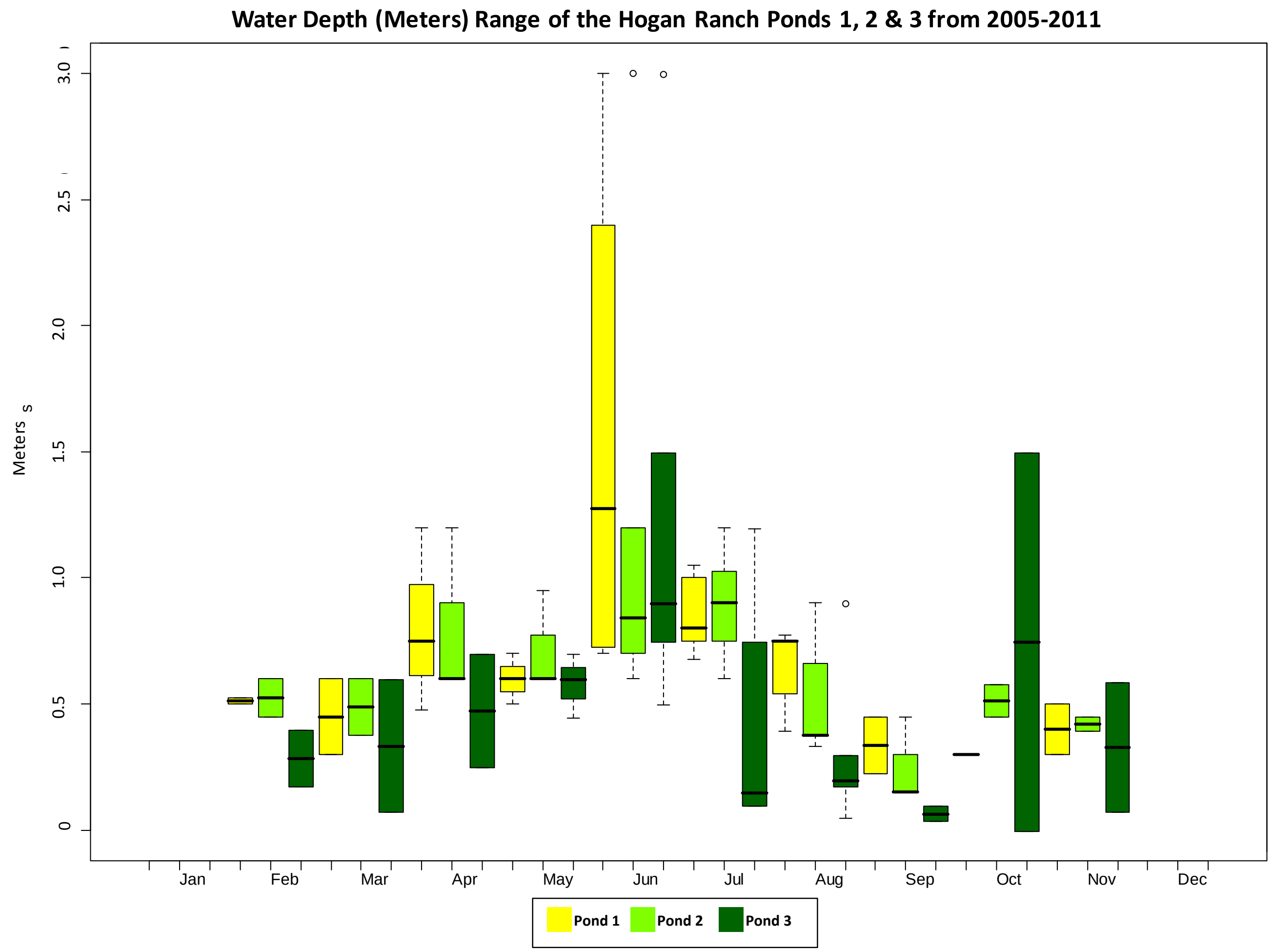


Figure 41. Water Depth (Meters) Range of the Hogan Ranch Ponds 1-3 from 2004-2011.

5.4.2 Scappoose Creek

5.4.2.1 Monthly Water Quality Data

Monthly water quality data was collected from April 2007 through August 2011. Data was summarized so differences in yearly parameter ranges could be identified between the sites (up and down stream of the restoration). During 2007 and 2008 data was primarily collected during the late summer and fall with little data overlap with the other study years 2009-2011. Because of this variability in the months data was collected in 2007 and 2008, the data ranges from these years cannot be compared with 2009-2011 data ranges (Table 20).

Table 20. Years and Months of Water Quality Data Acquired for Scappoose Creek Wilson/LaCombe Restoration Properties. Depth data was also acquired with the temperature data loggers starting in 2009.

Year\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007				■		■	■	■	■			
2008							■		■ X	■ X	■ X	X
2009	■ X	■ X	■ X	■ X	■ X	■ X	■ X	■ X	■ X	■ X	■ X	X
2010	■ X	■ X	■ X	X	■ X	■ X	■	■			■	■
2011		■	■		■	■	■	■				
■	Grab Sample Water Quality Collected											
X	Data Loggers Collecting Temperature Data											

Yearly and monthly water quality parameter ranges can be seen in Figures 2-6. Yearly and monthly site to site comparisons of the data ranges for each water quality parameter show that these datasets are very similar. This is due to the close proximity of the water quality sites along the stream (Figure 19). Even though the LaCombe water quality site is located upstream of the restoration activity and the Wilson water quality site is located downstream it is too early in the re-vegetation process for a significant difference in water quality parameters such as temperature to be noticed. Year to year comparisons may appear to show differences in the data range between years (not sites) but this is a product of the different month ranges sampled between years as seen in Table 20. A table of the average, minimum and maximum values for each parameter by site and year can be found in Appendix F.

Monthly Sampling Temperature

Figure 42 shows the cumulative data for each year and the monthly grab sample water temperature for 2007-2011. Yearly temperature ranges for 2007 and 2008 are higher than those shown for 2009-2011 because data was only collected in the summer and fall of 2007 and 2008 (the warmest months of the year) (Table 20). Year round data was collected in 2009-2011 showing that the average year-round monthly water temperature for these sites was below the 18°C temperature threshold for salmonids. Water temperature varied seasonally at both sites, with warmer temperatures in the summer and cooler temperatures in the winter. During the months of Jun-Sept water temperatures increased beyond the 18°C threshold which is not optimal for salmonids (Figure 42, Table 20). No major changes in water temperatures were observed between sites throughout the study period (Figure 42, Appendix F).

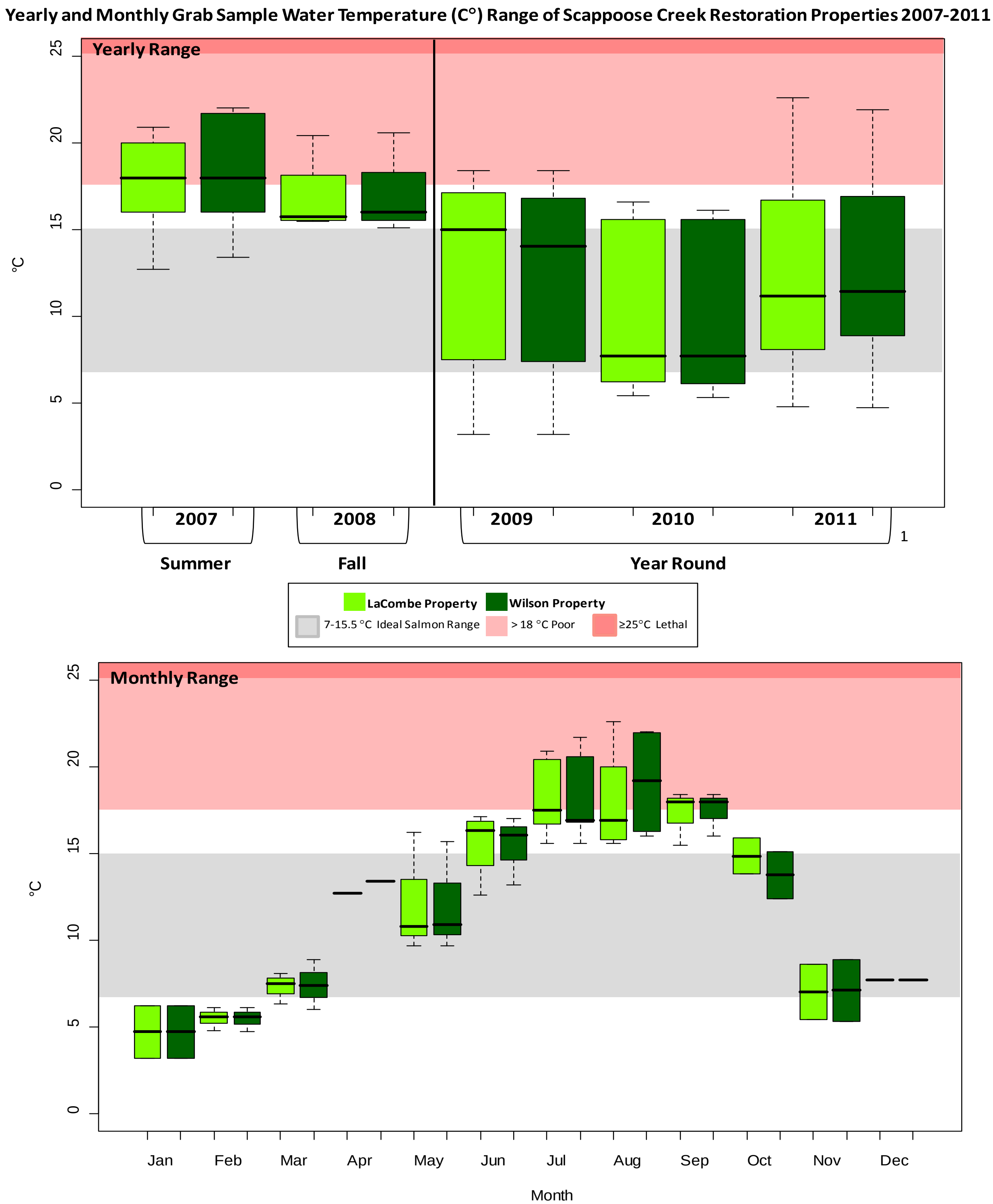


Figure 42. Scappoose Creek monthly grab sample water temperature for study years 2007-2011. For exact months sampled during each study year see table 3. Stream water temperatures between 7-15.5°C are considered ideal for adult salmonids (OWEB 2001) and water temperatures >18°C are considered poor for salmonids (ODEQ 2003).

Monthly Sampling Dissolved Oxygen

Figure 43 shows the cumulative data for each year and the monthly grab sample DO ranges for 2007-2011. Yearly DO ranges for 2007 and 2008 are lower than those shown for 2009-2011 because data was only collected in the summer and fall for 2008 and 2007 which are the warmest months of the year and consequently have the lowest DO concentrations (Table 20). Year round data was collected in 2009-2011 showing that the average year-round monthly DO range for these sites is near the 11 ppm ideal DO concentration for salmonids. The concentration of DO in the water varied seasonally at both sites, with higher DO concentrations in the cooler winter months and lower DO concentrations in the warmer spring and summer months (Figure 43). During the months of May-Oct DO ranges tended to be sub-optimal with levels below the 11ppm threshold for ideal salmonid conditions but not below the lethal threshold of 6 ppm (Figure 43, Table 20). The Wilson site generally showed lower DO concentrations than the LaCombe site but overall no major changes in DO concentrations were observed between sites over the study period (Figure 43, Appendix F).

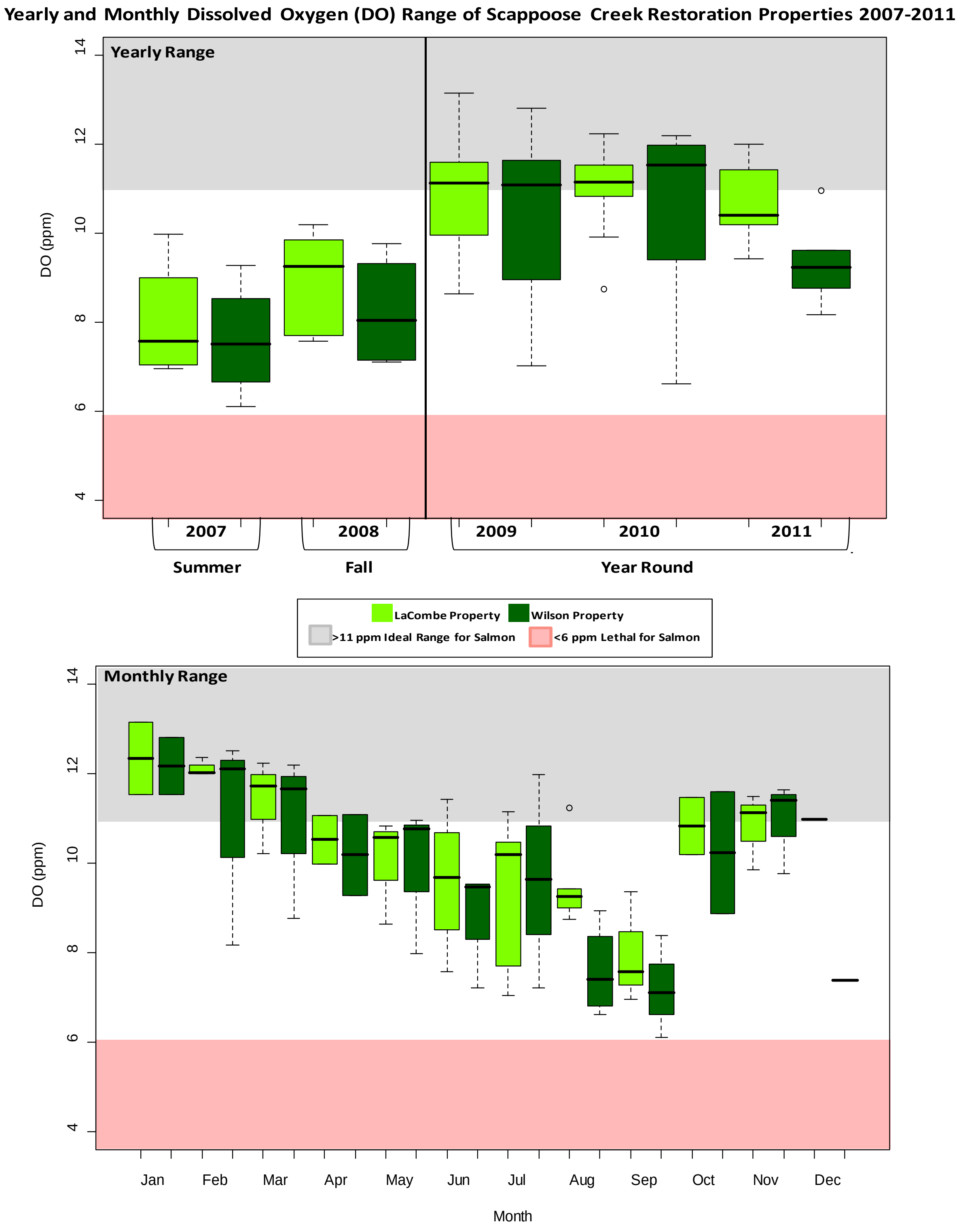


Figure 43. Scappoose Creek monthly dissolved oxygen (ppm) data for study years 2007-2011. For exact months sampled during each study year see Table 20. Stream water dissolved oxygen concentrations ≥11ppm are considered ideal for salmonids (ODEQ 2003) and dissolved oxygen concentrations <6 ppm are considered lethal for salmonids (OWEB 2001).

Monthly Sampling pH

Figure 44 shows the cumulative data for each year and the monthly grab sample pH ranges for 2007-2011. Yearly pH ranges were similar between sites but variable between years. This yearly variability is possibly a product of the differences in months sampled each year (Table 20). Overall the yearly average pH range for both sites was within the ideal pH range of 8-6.5 for salmonid habitat. Both sites showed slight seasonal variations in pH with higher pH levels in the spring and lower pH levels in the winter months (Figure 44). No major changes in pH levels were observed between sites over the study period (Figure 44, Appendix F).

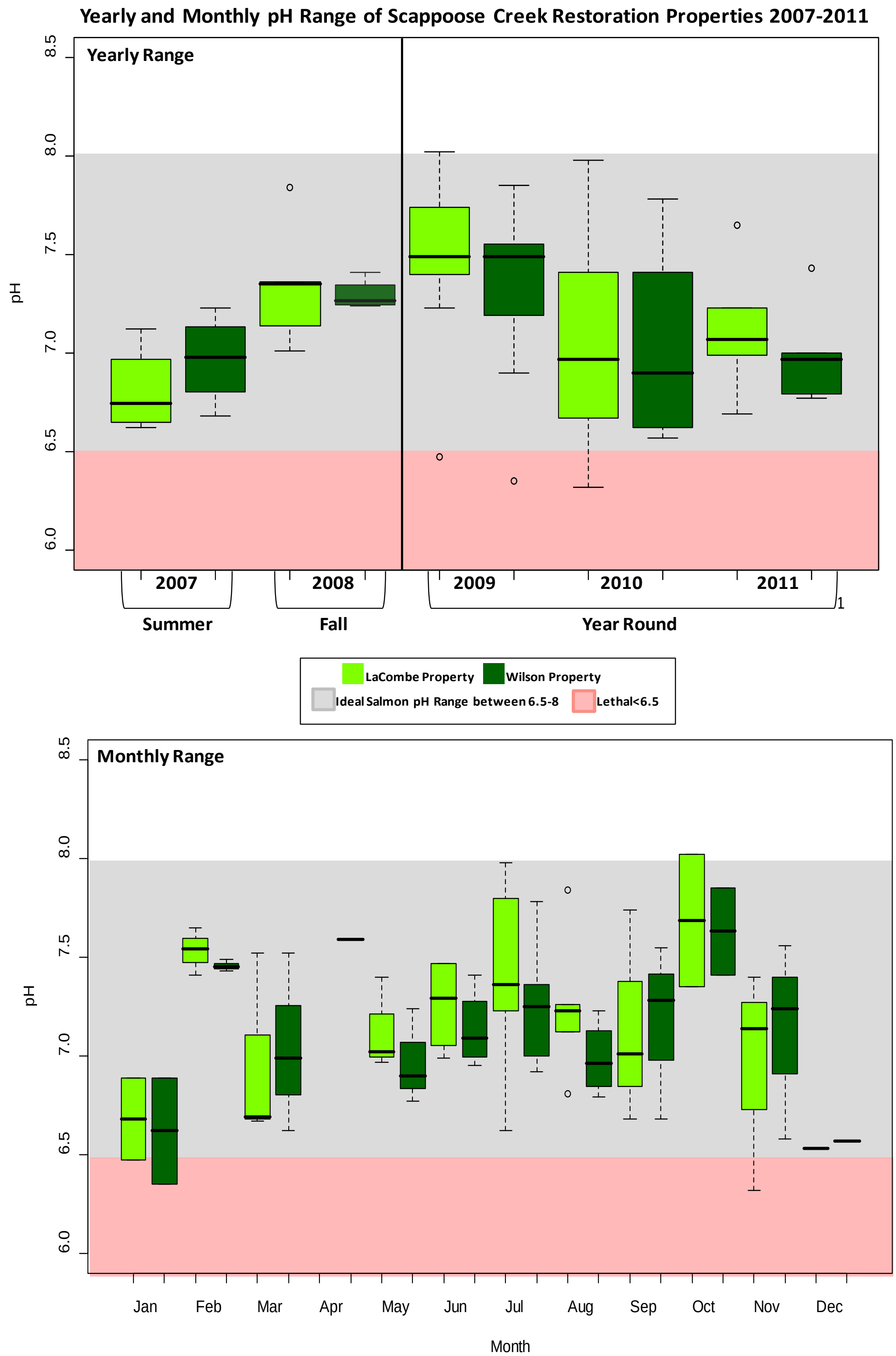


Figure 44. Scappoose Creek pH data for study years 2007-2011. For exact months sampled during each study year see Table 20. Gaps in graph indicate no data was collected for those months. Stream water pH between 8.5-6.5 are considered ideal for salmonids and water pH <6.5 or >8.5 are considered poor for salmonids (OWEB 2001, ODEQ 2003).

Monthly Sampling Turbidity

Figure 45 shows the cumulative data for each year and the monthly grab sample turbidity ranges for 2007-2011. NTUlevels were similar between sites with some seasonal variation (Figure 45). Yearly average turbidity levels for both sites were under the 10 NTU threshold with levels greater than 10 NTU considered unhealthy for salmonids (UWE 2006). In 2008 one high turbidity sample of 17.4 NTU recorded during the month of Nov is responsible for the larger range difference found between these sites for this year (Figure 45, Appendix F). Both sites showed seasonally high turbidity levels in the winter months with occurrences of greater than 10 NTUs in Nov-Jan. Overall, no major changes in turbidity levels were observed between sites over the study period (Figure 45, Appendix F).

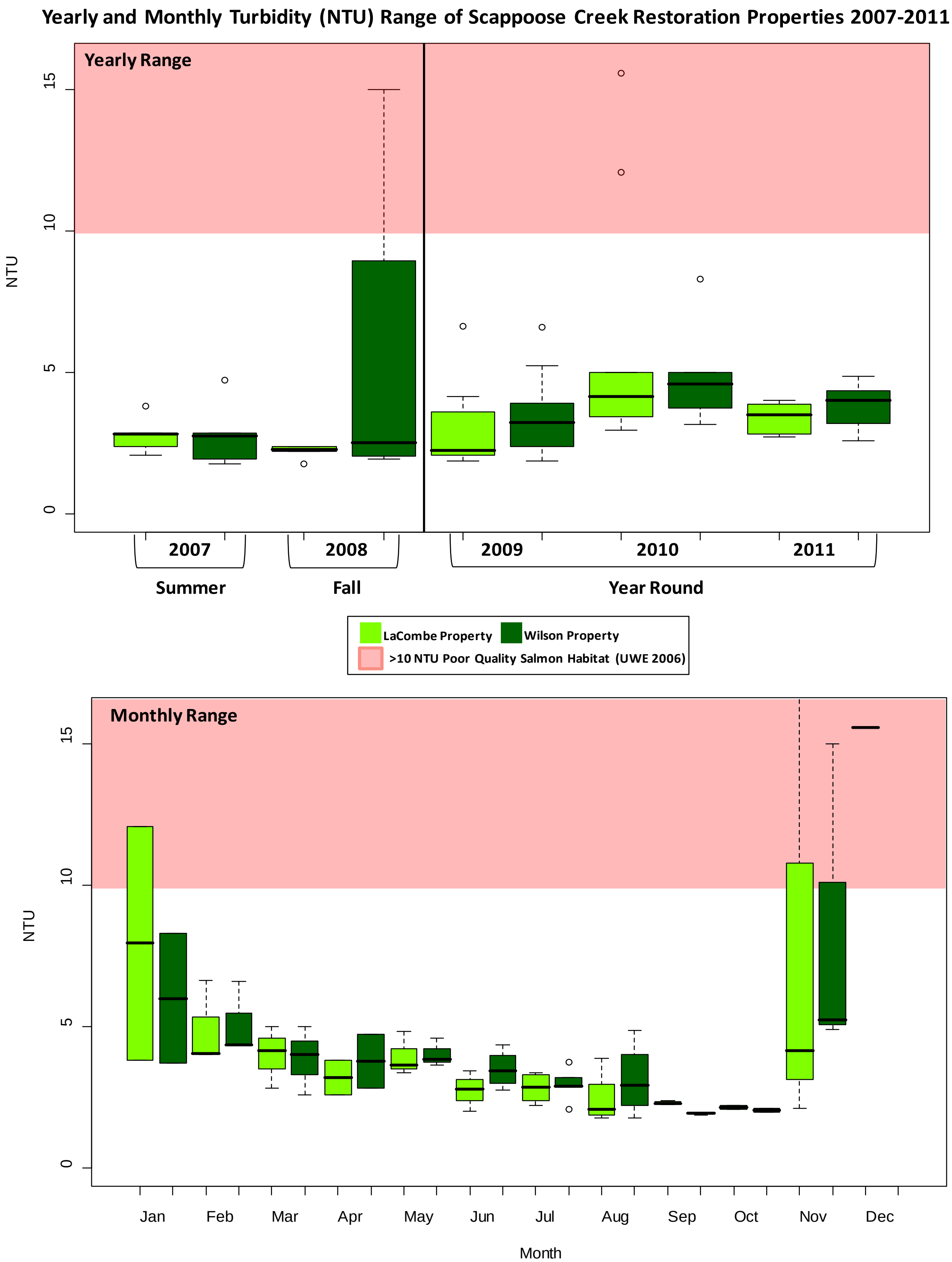


Figure 45. Scappoose Creek monthly turbidity data for study years 2007-2011. For exact months sampled during each study year see Table 20. Stream water turbidity >10 NTUs is considered poor for salmonids (UWE 2006).

Monthly Sampling Conductivity

Figure 46 shows the cumulative data for each year and the monthly grab sample conductivity (µS/cm) ranges for 2007-2011. Stream water conductivity (µS/cm) levels were similar between sites with seasonal variation (Figure 46). Between 2007-2008 (summer and fall sampling) the conductivity range was higher than in 2009-2011 (year round sampling). This variability is a product of the differences in months sampled each year (Table 20). Seasonal trends in conductivity levels are apparent at the sites with higher conductivity levels in the late summer and fall and lower levels in the spring months. Over the study period, both sites' conductivity levels were less than 150 µS/cm which is considered typical for streams in the Willamette Basin and the North Coast (OWEB 2001). No major changes in conductivity levels were observed between sites over the study period (Figure 46, Appendix F).

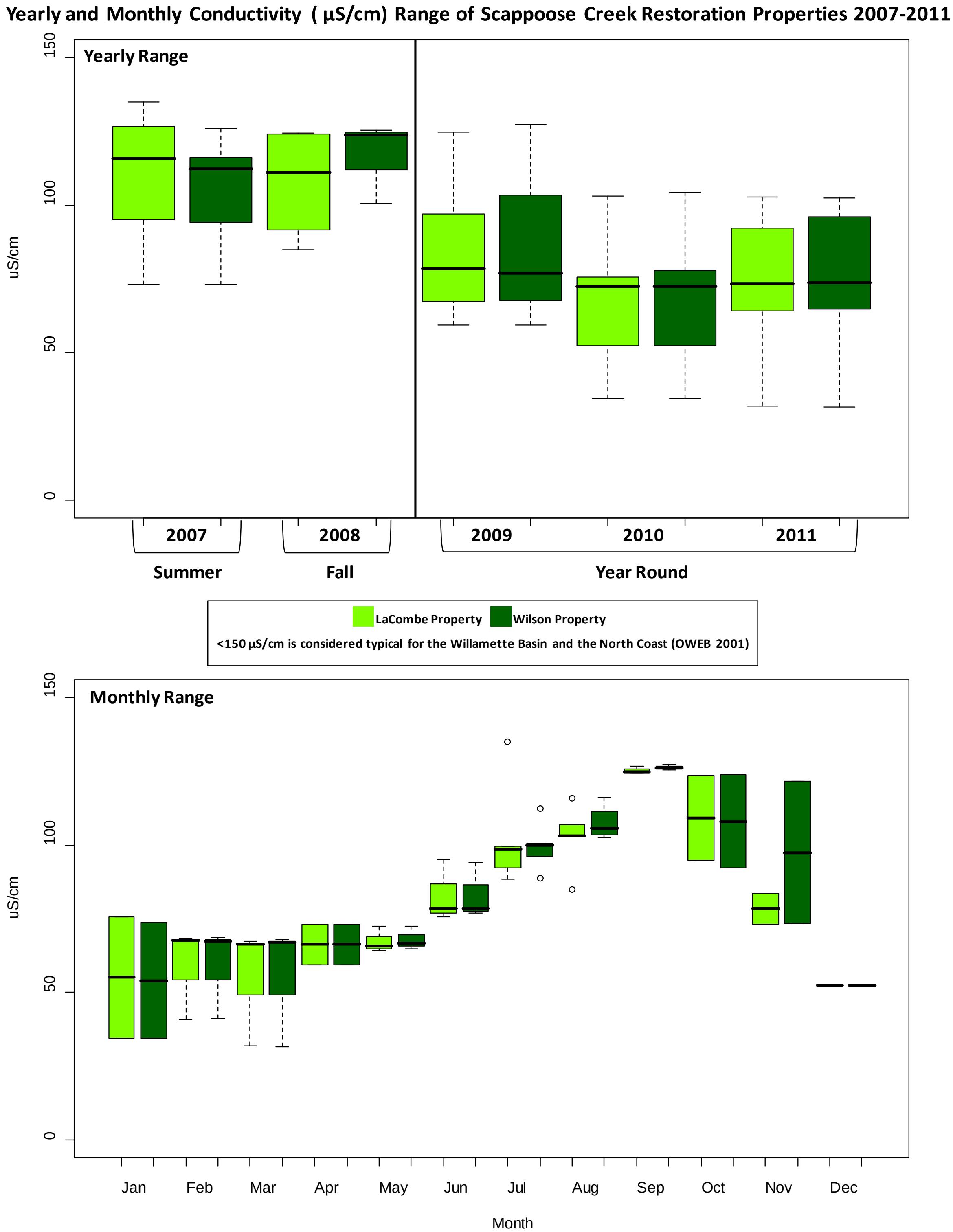


Figure 46. Scappoose Creek monthly conductivity (µS/cm) data for study years 2007-2011. For exact months sampled during each study year see Table 20. Stream water conductivity <150 µS/cm is considered typical for streams in the Willamette Basin and the North Coast (OWEB 2001).

5.4.2.2 Seasonal Data Logger Water Quality Trends

Continuous temperature data was collected at the LaCombe property from Sept 2008 through June 2010 (Table 20). In addition, continuous depth data was also collected from Feb 2009 through June 2010. Continuous temperature and depth data were not collected during the remainder of the 2010 and for all the 2011 study seasons due to technical difficulties with the logger equipment. Below is a general overview of these data, for further details (figures and data summary) please refer to the 2010 water quality report and Appendix F.

To protect salmonids and other cold water fish species, ODEQ has established a maximum total maximum daily load (TMDL) of 18°C (over a 7 day period) for this stream throughout the year. Stream temperatures >18°C are considered poor for salmon (DEQ 2003). Between Sept 2008-June 2010 the 7 day average of the daily maximum temperature (7dMADM) at this site ranged from 20.9 °C (Aug 2009) to 0.24 °C (Dec 2008), with 55 days over the 18°C 7dMADM (Figure 47). The highest average temperatures and greatest number of days over 18°C occurred during the months of July-Sept (Figure 47). Ideal temperature conditions for adult salmon between 15.5-7°C were found from Oct through May (Figure 47). During this study period there were a total of 5,504 hours where the temperature was over 15.6°C, the OWEB specified temperature threshold for healthy adult salmon habitat, which occurred mainly between Jun-Sept (Figure 47). There were also a total of 7,573 hours over 13.9°C, the OWEB specified temperature threshold for healthy juvenile salmon habitat, which occurred mainly occurred between May-Oct (Figure 47). Water depth varied seasonally with high levels (average >2 meters) observed March 2009 through June 2009 and November 2009 through April 2010 (Figure 47). Low water levels (average < 2 meters) were observed between July 2009 through October 2009 and May 2010 through June 2010 (Figure 47). Figure 47 shows the monthly temperature and depth range for the entire study period.

Overall, the months of greatest concern regarding water temperature in this section of stream are July, August, and September with seasonal summer temperatures outside of the DEQ and OWEB thresholds for healthy salmon habitat. In addition these months are also associated with the lowest water levels of the year (Figure 47).

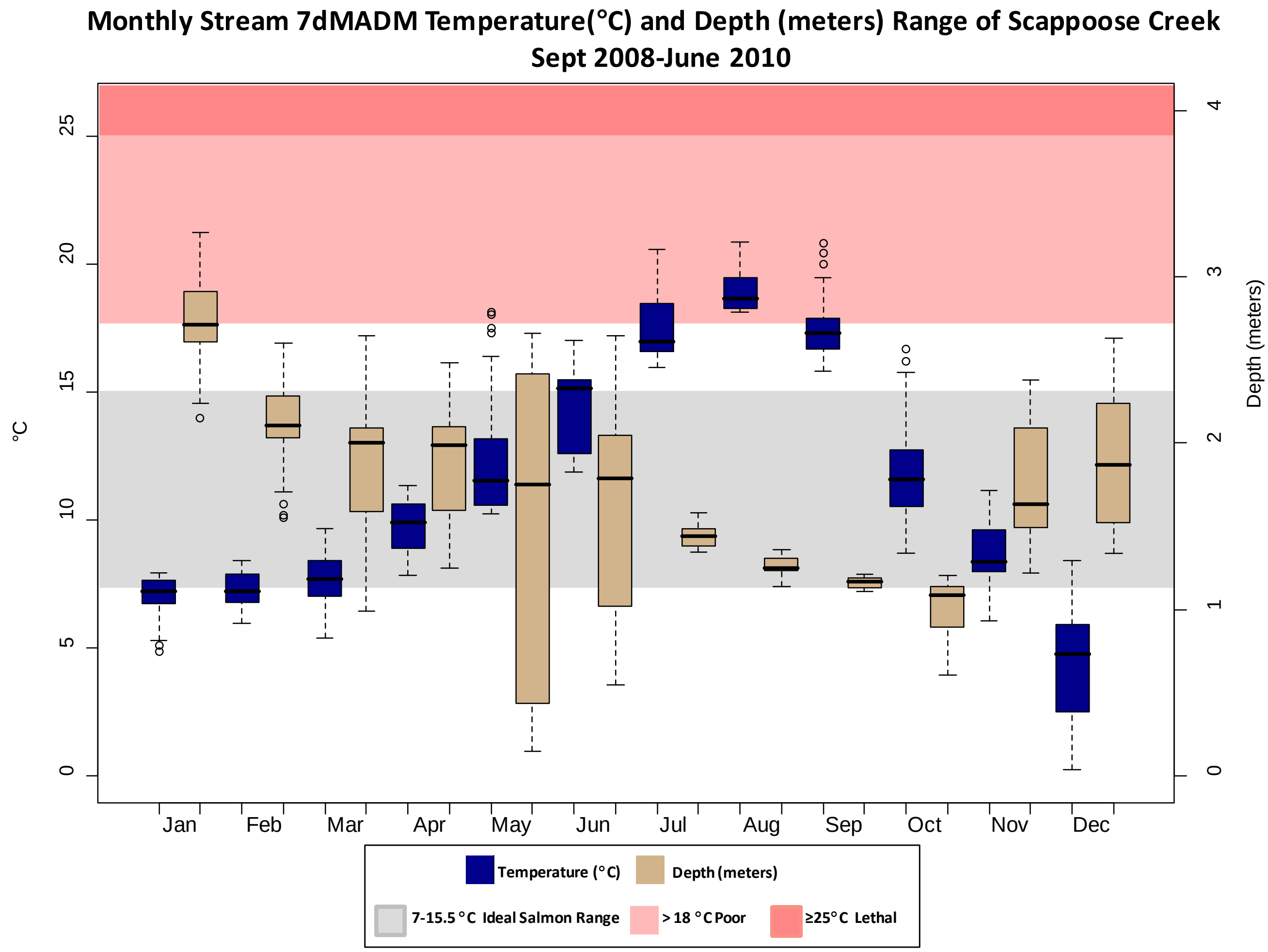


Figure 47. Monthly Stream 7 Day Maximum Moving Average Temperature and Depth Ranges of Scappoose Creek Between Sept 2008-June 2010. Depth data was collected between Feb 20th 2009-June 30th 2010.

According to the ODEQ, temperatures need to remain cool from Jan 15th-May 15th in this region to accommodate for salmonid use and spawning. During this time period in both 2009 and 2010 average stream temperatures remained below the 13.9°C juvenile salmonid habitat threshold (Figure 48). This time period in 2010 did have slightly higher temperatures and greater water depth fluctuations than in 2009 (Figure 48). Figure 48 shows the 7 day maximum moving average temperature and depth range for this time period in 2009 and 2010.

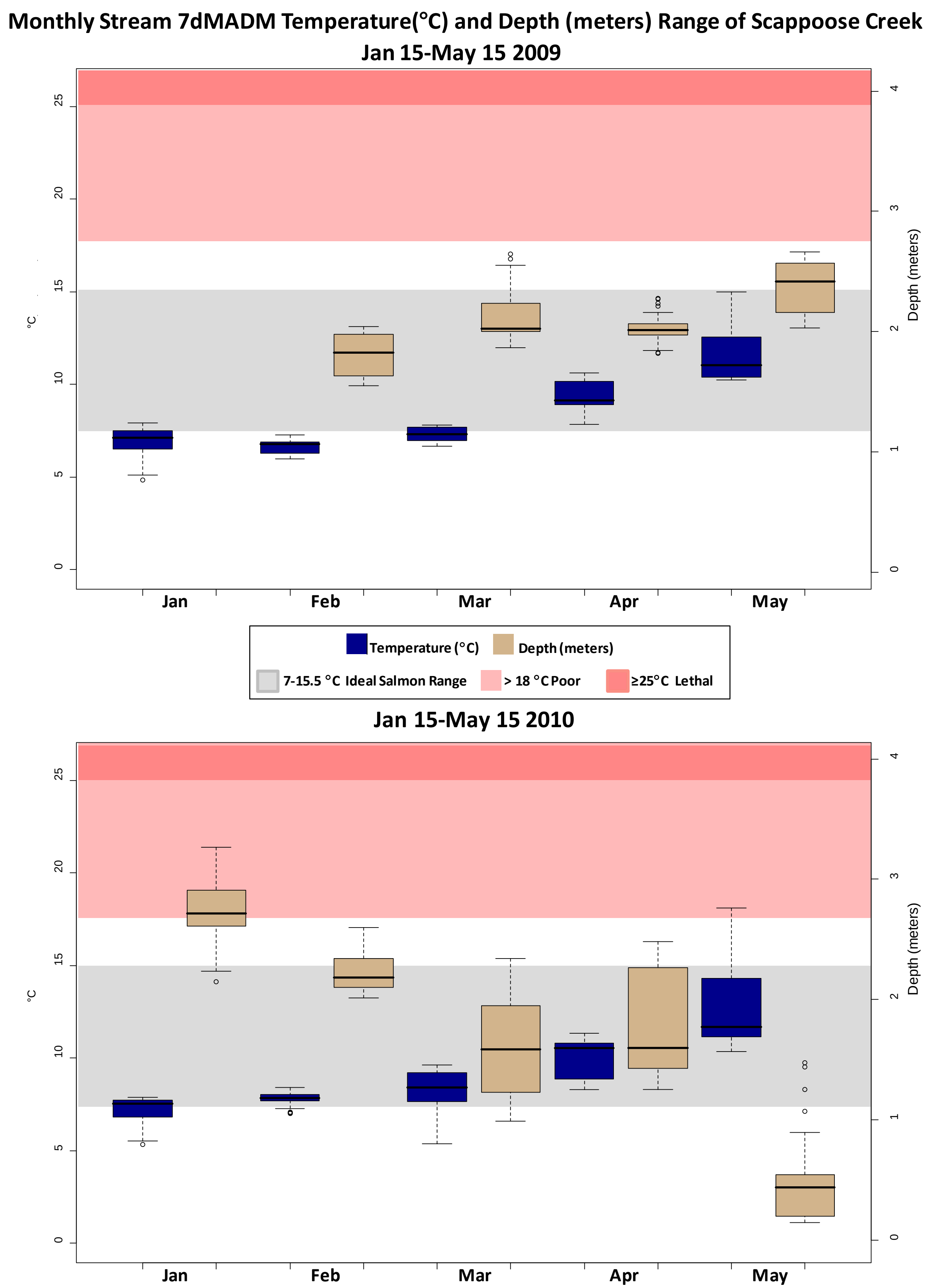


Figure 48. Yearly Stream 7 Day Maximum Moving Average Temperature and Depth Ranges of Scappoose Creek from Jan 15th –May 15th 2009 & 2010. Depth data for 2009 is from Feb 20th-May 15th.

5.5 Water Quality Discussion

Hogan Ranch Ponds

Over the 2004-2011 study period of the Hogan Ranch Ponds the largest parameter change observed was a significant decrease in E. coli levels in all ponds from >235 MNP/100 ml before cattle exclusion to <40 MPN/100 ml in 2011 (Figure 38 and Figure 39). This drop in E. coli levels can be attributed to the cattle exclusion which occurred on all of the sites in 2007. During the study period there was only one accidental cattle exposure on Ponds 1 and 2 in 2009 which did result in an increase in E. coli levels during that season. Other changes to the Ponds water chemistry before and after cattle exclusion include a slight measurable decrease in turbidity and conductivity, both can be attributed to the removal of the cattle from the Ponds. Seasonally high water temperatures during late spring and summer in the Ponds and creeks suggest these areas do not provide ideal habitat for salmonids during these times. However, these wetlands and streams are rich in wildlife and are highly valued as waterfowl habitat throughout the year. As the restoration plantings on this site mature and the areas continue to recover from heavy cattle grazing, a decrease in stream and Pond temperatures and other water chemistry changes may be observed (Dosskey et al. 2010). Long-term observation is needed to determine the overall impacts of the riparian restoration on the water quality of these ponds and creeks (Dosskey et al. 2010).

Scappoose Creek

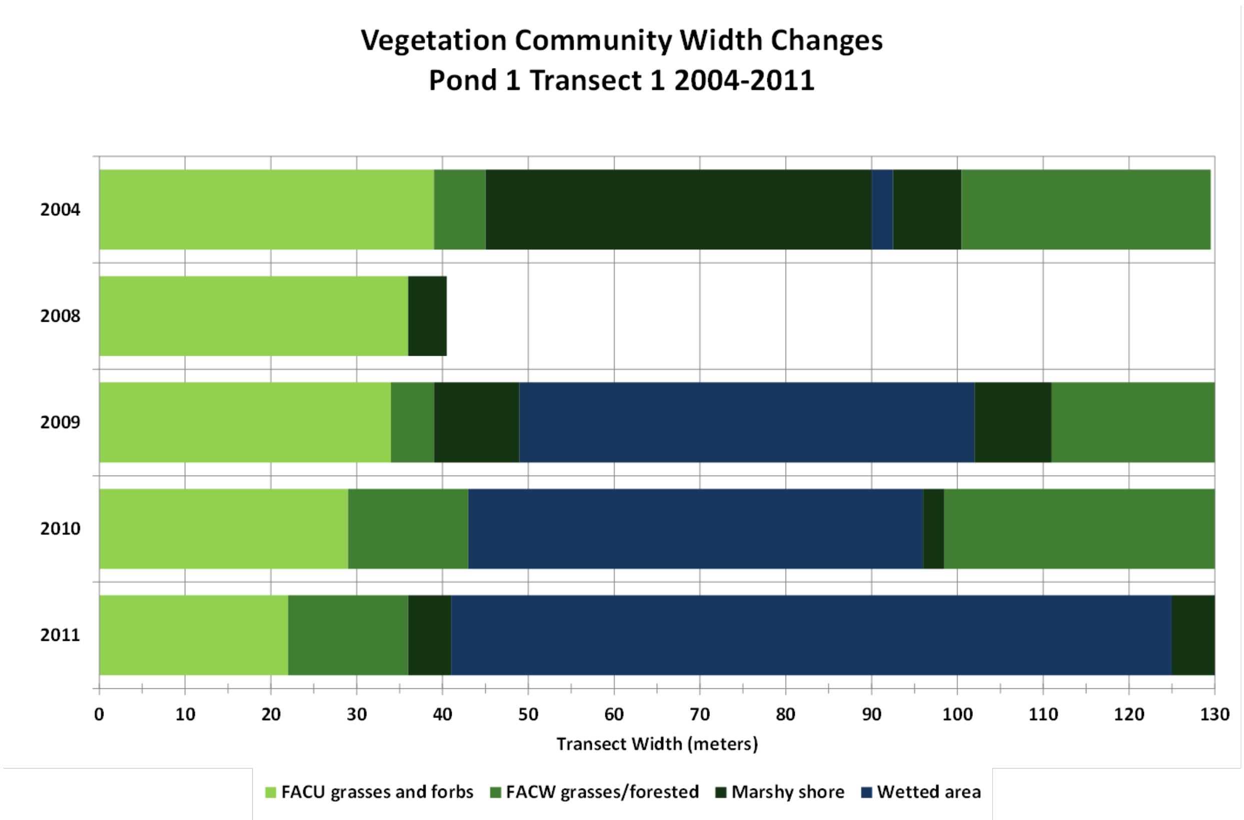
Over the four year study period no large changes in the streams seasonal or inter-annual water chemistry were observed between sites. During this time the only water quality parameter that consistently did not meet the prescribed salmon habitat water quality standards was temperature. During the summer low flow months (Late July-September) both sites experienced high water temperatures (>18°C) that would be considered “poor” with respect to conditions for salmon health (OWEB 2001, ODEQ 2003). However, after July, juvenile salmonids are expected to have already migrated through this stream and not be threatened by exposure (ODEQ 2003). Long-term observation is needed to determine the overall impacts of the riparian restoration on the stream’s water quality.

5.6 Vegetation Community Results

Pond 1

Plant community widths

In 2011 Pond 1’s marshy shore and wetted area plant communities increased in width and the FACU and FACW plant communities widths decreased (Table 21, Figure 49). The wetted area and marshy shore plant communities were significantly wider than previous years due to the abnormally high water this season (2011) (Figure 50). Overall, since 2004 the plant community widths of Pond 1 have shifted with a decrease in the FACU and increase in FACW and wetted area plant community widths (Table 21, Figure 49). This is mainly in response to increased water retention in the pond from water control structures. These water control structures have increased the area, depth and time period of open water in the pond promoting obligate and aquatic plant community growth (Figure 50). The resultant increase in soil moisture and the release from grazing pressure (from cattle exclusion) around the edge of the pond has also encouraging more FACW plant species such as reed canarygrass to increase and other common FACU grazing pasture species to decrease.



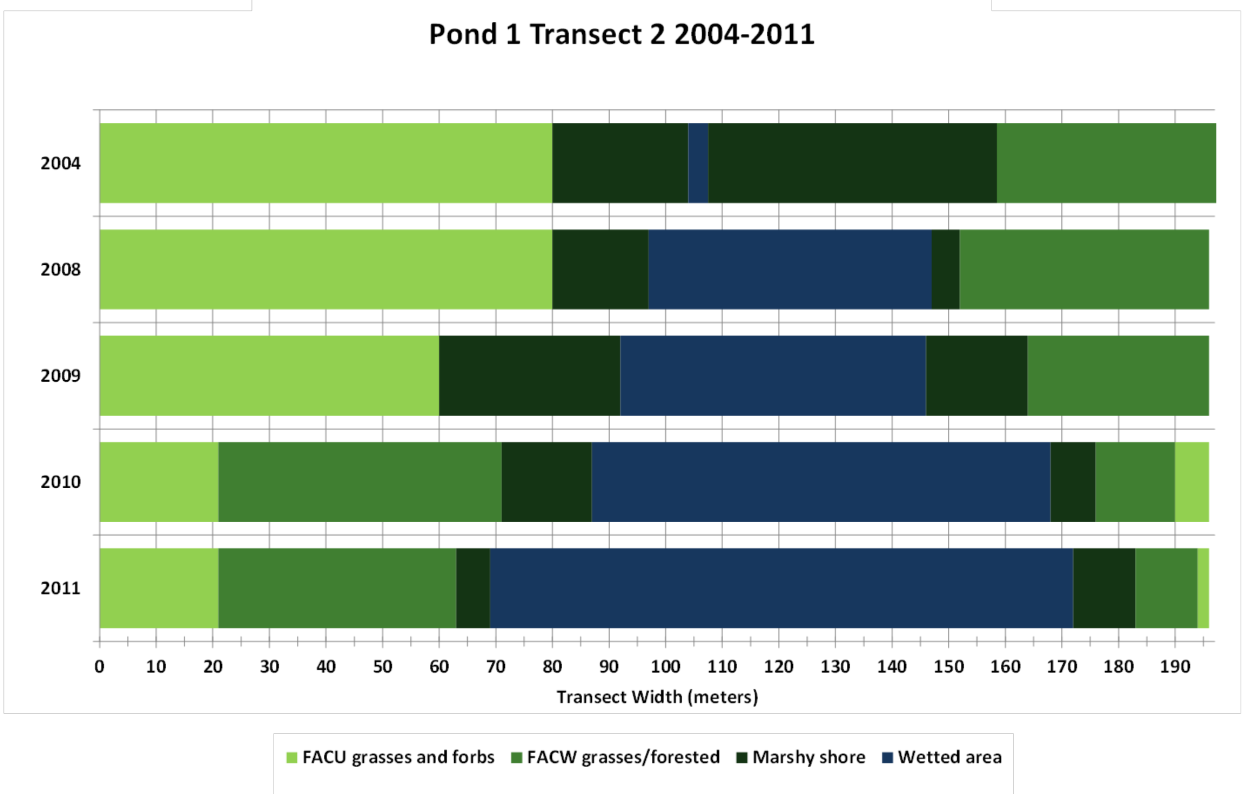


Figure 49. Pond 1 plant community widths along transects 1 & 2 for 2004 and 2008-2011. In 2008 only partial community width data was recorded for transect 1.

Table 21. Pond 1 plant community widths in meters along transect 1 & 2 for 2004 and 2008-2011. In 2008 only partial community width data was recorded for transect 1.

Pond 1, Transect #1	**Community Length (m) by Study Year**				
	2011	**2010**	**2009**	**2008**	**2004**
FACU grasses and forbs	22	29	34	36	39
FACW grasses/forested	14	14	5		6
Marshy shore	5	0	10	4.5	45
Wetted area	84	53	53		2.5
Marshy shore	6	2.5	9		8
FACW grasses/forested		31.5	19		29
Total:	**130**	**130**	**130**		**130**
Pond 1, Transect #2					
FACU grasses and forbs	21	21	60	80	80
FACW grasses/forested	42	50			
Marshy shore	6	16	32	17	24
Wetted area	103	81	54	50	3.5
Marshy shore	11	8	18	5	51
FACW grasses/forested	11	14	32	44	39
FACU grasses and forbs	2	6			
Total:	**196**	**196**	**196**	**196**	**198**

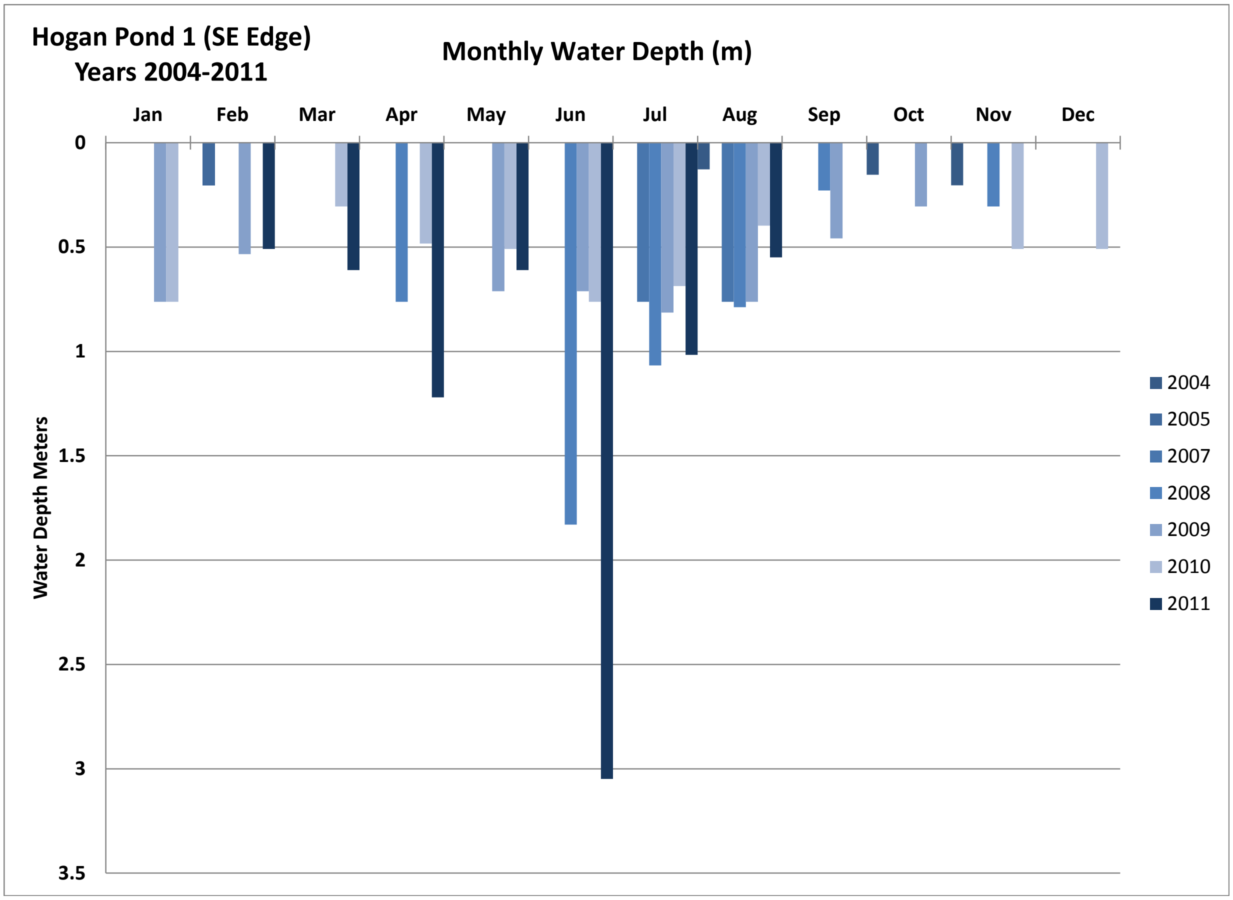


Figure 50. Hogan Ranch Pond 1 Water Depth (meters). Depth Recorded Monthly at Water Quality Testing Location (SE Edge of Pond 1, See Water Quality Report for Exact Location).

Plant community composition

In 2011 reed canarygrass (introduced*)* continued to be the dominant vegetation cover in the FACU (44 %), FACW (83%), marshy shore (32%) and wetted area (17%) plant communities of Pond 1 (Appendix B, Figure 52). Between 2010 and 2011 there was a decrease in reed canarygrass cover in the FACU (-2%), marshy shore (-16%) and wetted area (-2%) plant communities and an increase in reed canarygrass cover in the FACW (+8%).

Overall, the plant communities showed a significant shift in composition due to prolonged summer flooding (April through late July 2011). Extreme prolonged flooding in wetlands can result in plant die off, reduced germination and delayed plant growth (Casanova and Brock 2000). The reduction in reed canarygrass cover observed in the marshy shore and wetted area plant communities and the increase in reed canarygrass in the FACW plant community is a result of increased water depth and period of inundation (as compared to recent levels) in these plant community zones (Jenkins et al. 2008). In the wetted area and marshy shore depths were likely higher than reed canarygrass' tolerance range while in the FACW plant community the depth was more optimal for reed canarygrass than other less flood tolerant species. Other species such as colonial bentgrass (*Agrostis capillaris,* introduced) in the FACU plant community and water purslane (*Ludwigia palustris*, native) in the wetted area plant community showed significant declines compared to previous years. In places where declines in plant species abundance (cover) were observed an increase in dead organic matter ground cover was observed (Figure 51).

Figure 51. Taken in the Marshy Shore Plant Community of Pond 1 August 4, 2011.

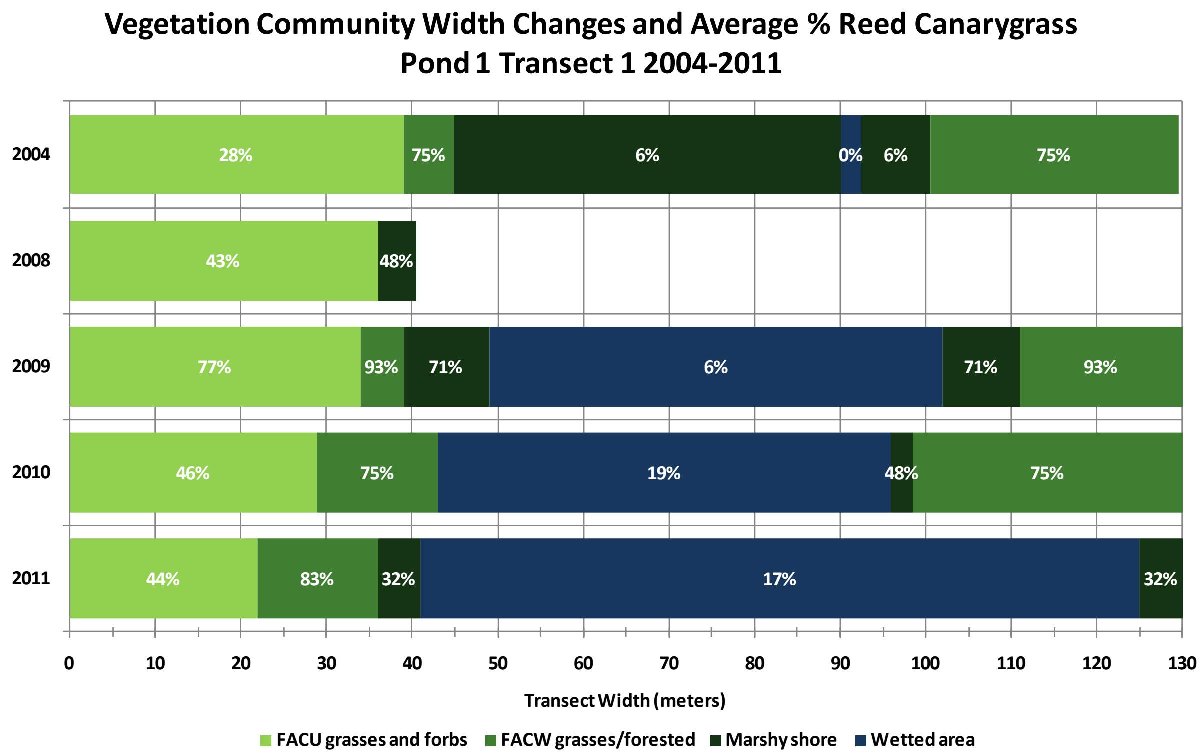


Figure 52. Pond 1 plant community widths along transect 1 and average % reed canarygrass cover for Pond 1 vegetation communities (average cover of both transects 1 and 2) for 2004 and 2008-2011. In 2008 only partial community width data was recorded for transect 1.

Total species richness for Pond 1 increased from 2004 to 2010 and then decrease in 2011. In 2011, species richness was significantly lower for both native and non-native plant species in all Pond 1 plant communities compared to 2010 (Figure 53, Table 22). This reduction in species richness, of up to 75% for each plant community (overall a 50% loss in native and non-native species richness), can be attributed to the prolonged flooding (inundation) of the entire pond area which occurred through late July of this year (typically flooding in these areas subsides in May) (Figure 50, Table 22).

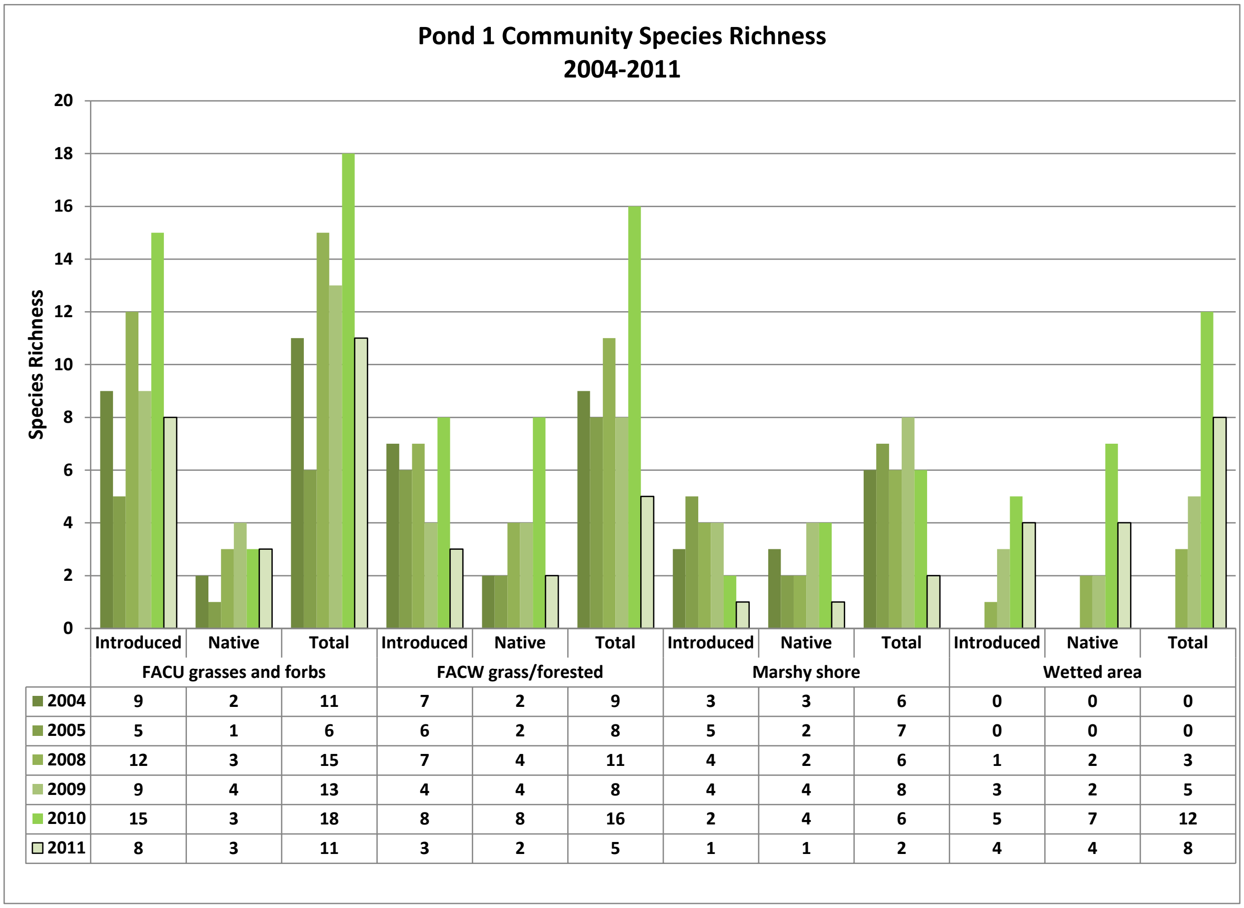


Figure 53. Pond 1 native and non-native (introduced) plant species richness by plant community from 2004-2011. The wetted area of Pond 1 did not exist in 2004 and 2005.

Table 22. Pond 1 total species richness 2004-2011

Pond 1 Total Species Richness						
Year	2004	2005	2008	2009	2010	2011
Introduced	9	7	15	12	19	10
Native	5	4	7	12	14	8
Unknown	7	10	4	3	3	3
Total	21	21	26	27	36	21

Overall, Pond 1 has shown a shift from a co-dominant plant community with the top 6 plant species ranging from 8% to 26% cover in 2004, to a plant community dominated by reed canarygrass at 52% in 2011 (Figure 54, Figure 55). Total reed canarygrass cover decreased by 9% between 2010 and 2011, this loss of reed canarygrass cover was observed mainly in the wetted areas and marshy shore plant communities. Plant community composition and species richness may recover to historic levels in the fall of this year or next summer depending on future hydrology and climate characteristics. If summer flooding continues to occur at the 2011 levels reed canarygrass abundance may continue to decline in the wetted area and marshy shore plant communities.

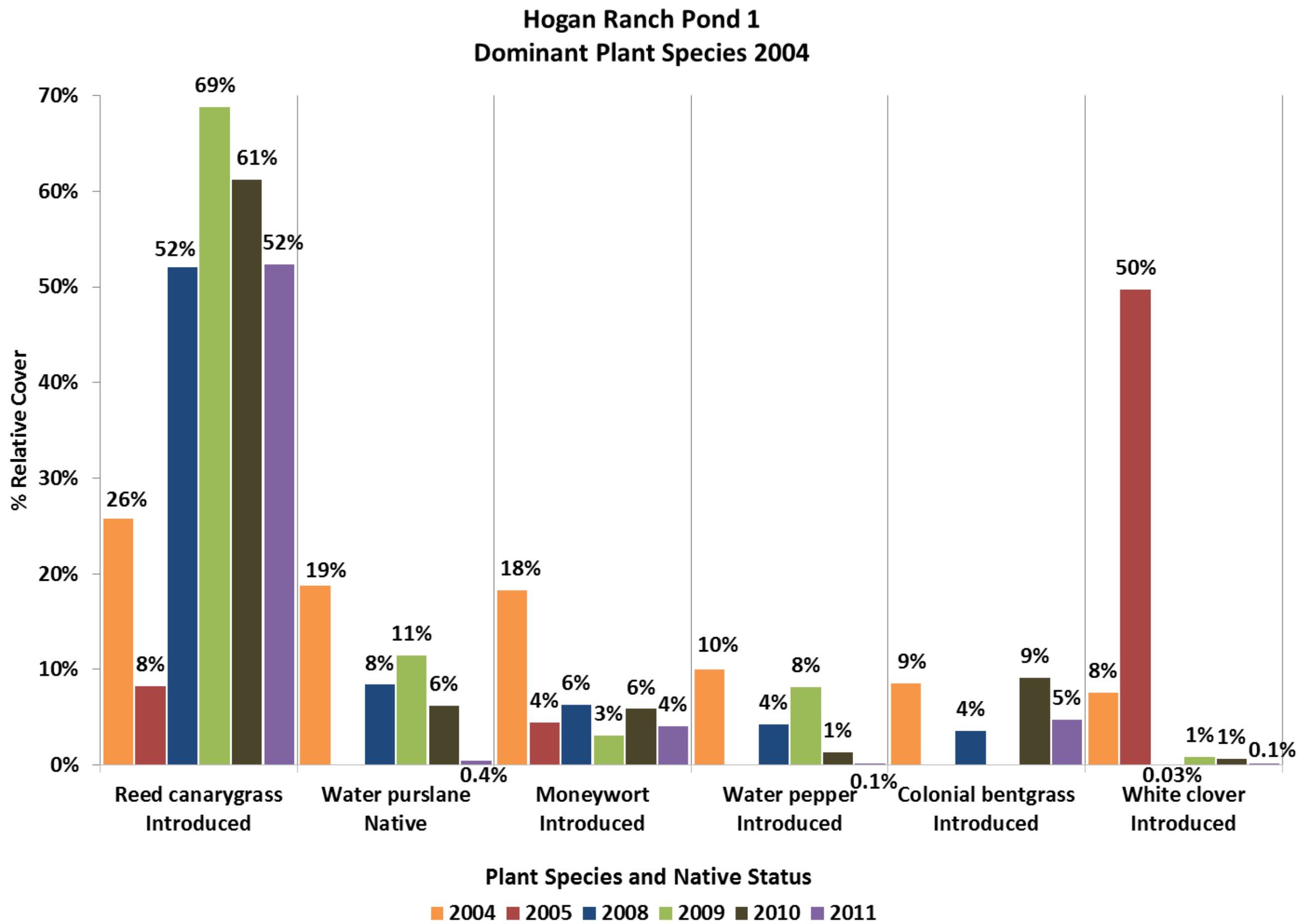


Figure 54. The top 6 dominant plant species of Pond 1 in 2004. 2005 and 2008-2011 cover percentages shown for comparison.

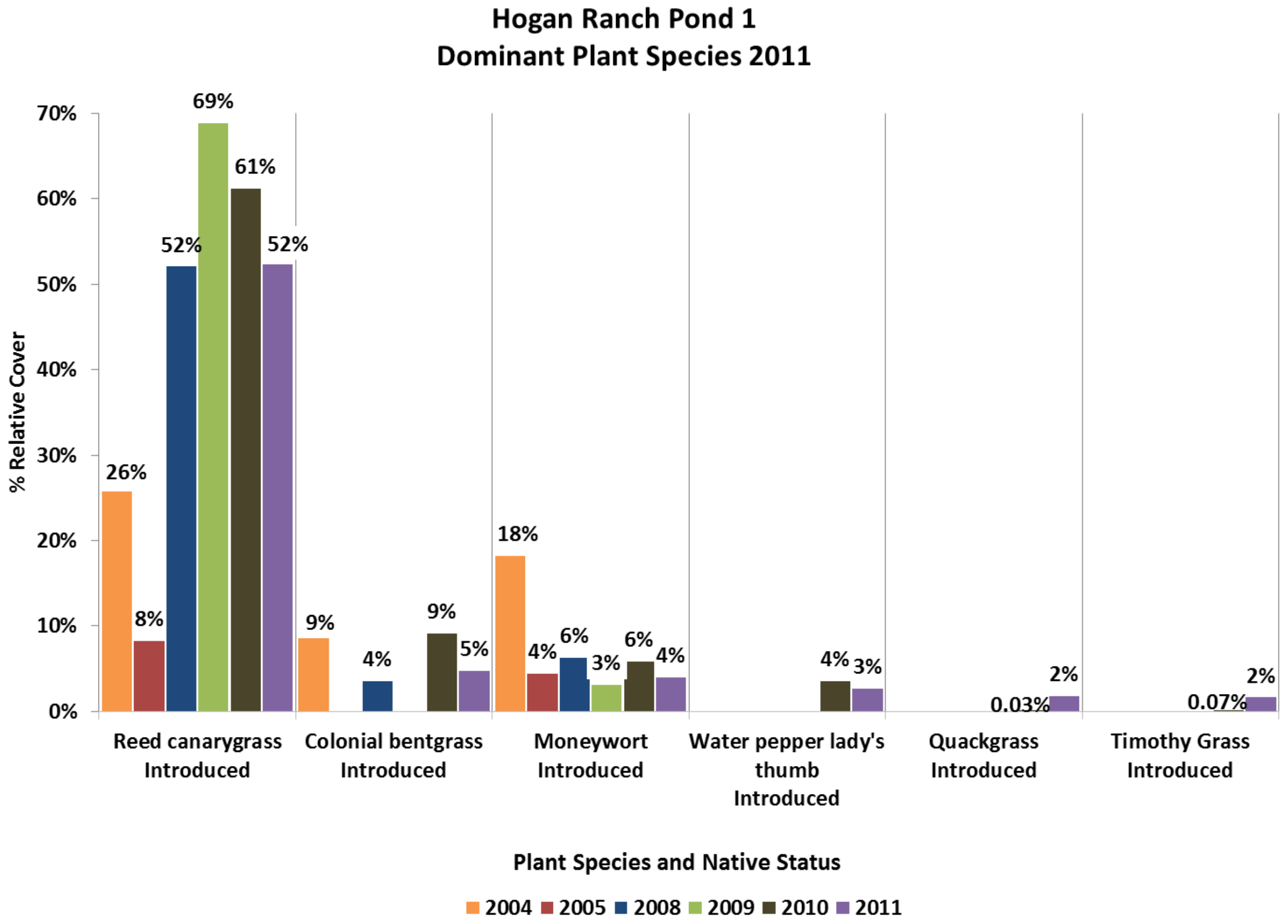
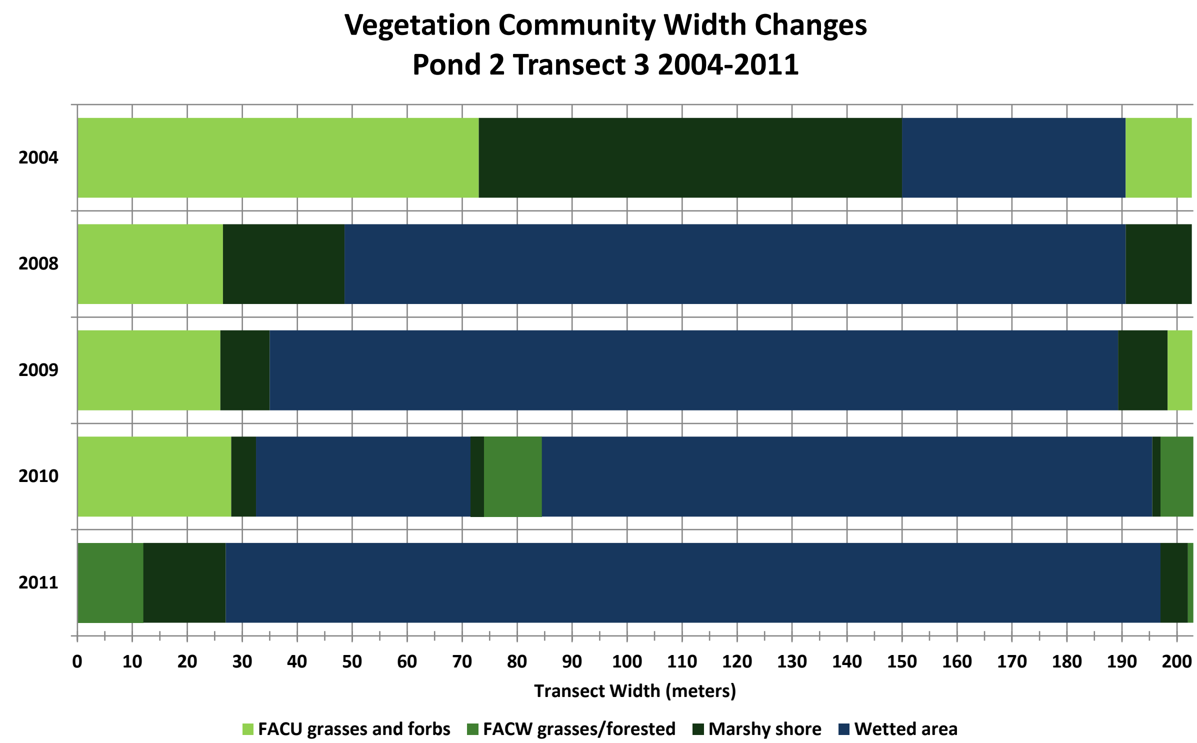


Figure 55. The top 6 dominant plant species of Pond 1 in 2011. 2004-2005 and 2008-2010 cover percentages shown for comparison. Note that all dominant species in 2011 are introduced (non-native) plant species.

Pond 2

Plant community widths

In 2011 Pond 2's FACW, marshy shore and wetted area plant communities increased in width and the FACU plant community width decreased (Figure 56, Table 23). Due to the abnormally high water this season (2011) the wetted area and marshy shore plant communities were significantly wider than previous years (Figure 57). Since 2004 plant community widths have shifted with a significant decrease in the FACU and increase in FACW and wetted area plant community widths (Figure 56, Table 23). This is mainly in response to increased water retention in the pond from water control structures and the grading/excavation along the west side of the pond in 2007 which has increased the open water area of the pond promoting obligate and aquatic plant community growth within the pond (Figure 57). The resultant increase in soil moisture and the release from grazing pressure (from cattle exclusion) has also resulted in more FACW and Marshy plant species such as reed canarygrass and creeping spike rush (*Eleocharis palustris*, native) to increase and other common FACU grazing pasture species to decrease.



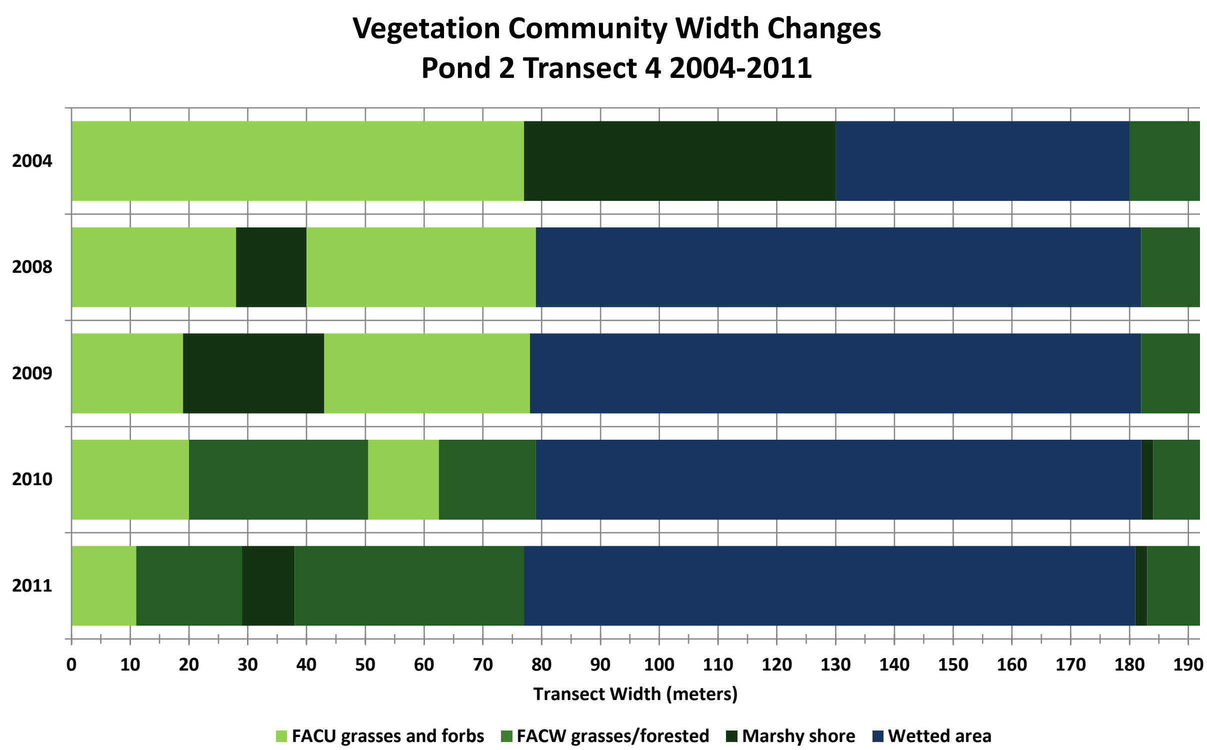


Figure 56. Pond 2 plant community widths along transects 3 & 4 for 2004 and 2008-2011.

Table 23. Pond 2 plant community widths in meters along transects 3 & 4 for 2004 and 2008-2011.

Pond 2, Transect #3	**Community Length (m) by Study Year**				
	2011	**2010**	**2009**	**2008**	**2004**
FACU grasses and forbs	12	28	26	26.5	73
Marshy shore	15	4.5	9	22.1	77
Wetted area	170	39			
Marshy shore		2.5			
FACW grasses/forested		10.5			
Wetted area		111	154.3	142.1	40.7
Marshy shore	5	1.5	9	12	
FACW grasses/forested	1	6			
FACU grasses and forbs			4.5		12
Total:	**203**	**203**	**203**	**203**	**203**
Pond 2, Transect #4					
FACU grasses and forbs	11	20	19	28	77
FACW grasses/forested	18	30.5			
Marshy shore	9		24	12	53
FACU grasses and forbs		12	35	39	
FACW grasses/forested	39	16.5			
Wetted area	104	103	104	103	50
Marshy shore	2	2			
FACW grasses/forested	9	8	10	10	12
Total:	**192**	**192**	**192**	**192**	**192**

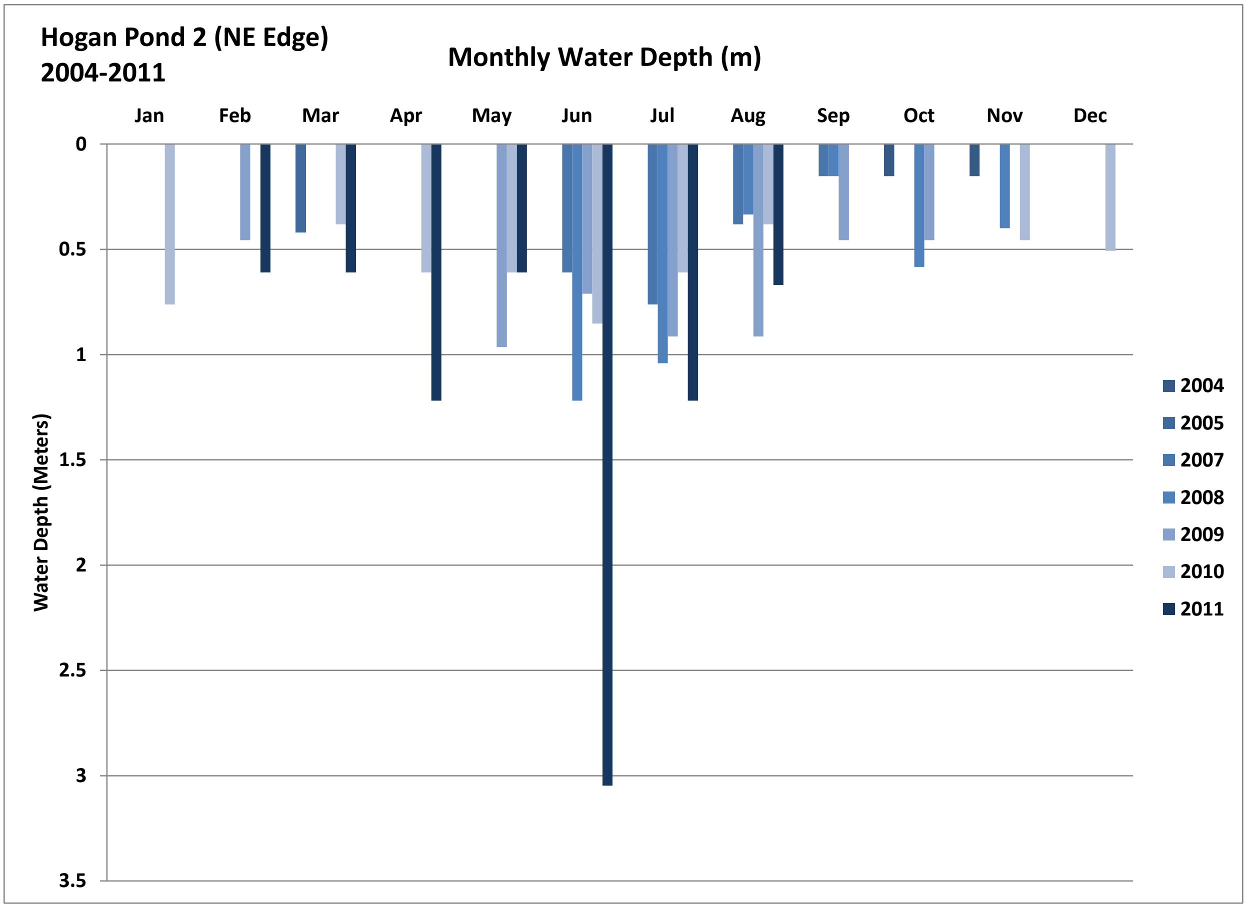


Figure 57. Hogan Ranch Pond 2 Water Depth (meters). Depth Recorded Monthly at Water Quality Testing Location (NE Edge of Pond 2, See Water Quality Report for Exact Location).

Plant community composition

In 2011 reed canarygrass continued to be the dominant vegetation cover in the FACU (67 %, only transect 3), FACW (67%) and marshy shore (30%) plant communities of Pond 2 (Appendix B, Figure 59). Between 2010 and 2011 there was an increase in reed canarygrass cover in the FACU (+39%), FACW (+7%) and wetted area (+1%) plant communities. The wetted area of Pond 2 shifted from being co-dominated by 28% western water milfoil, 13% Canadian waterweed (*Elodea Canadensis*, native) and 12% Eurasian water milfoil (*Myriophyllum spicatum L.*, introduced) to only 1% Canadian waterweed,12% Eurasian water milfoil, 10% coontail (*Ceratophyllum demersum*, native) and 9% water smart weed (*Polygonum amphibium*, native) (Appendix B). No western water milfoil was found in 2011. In the marshy shore plant community the amount of reed canarygrass was the same as 2010 (30%) but there was significant drop in water purslane (*Ludwigia palustris* , native) cover from 24% to 3% and no creeping spike rush (*Eleocharis palustris*, native) was in the 2011 survey (26% cover in 2010) (Appendix B). Major changes in the FACW plant community between 2010 and 2011 include a 7% increase in reed canarygrass cover and the absence of water purslane in the 2011 survey. The abundance of reed canarygrass has increased in the FACU plant community from 24% in 2010 to 65% in 2011, this was also coupled by a decrease in colonial bentgrass (*Agrostis capillaris*, introduced), a typical upland field grass. These changes in the species composition of the FACU plant community indicate it is transitioning into a more FACW plant community, which may be a result of the extreme high water in this pond during the summer of 2011 (Figure 58).

Figure 58. West side of Pond 2 Looking East Along Transect 3, Notice the Lack of Vegetation in the Marshy Plant Community.

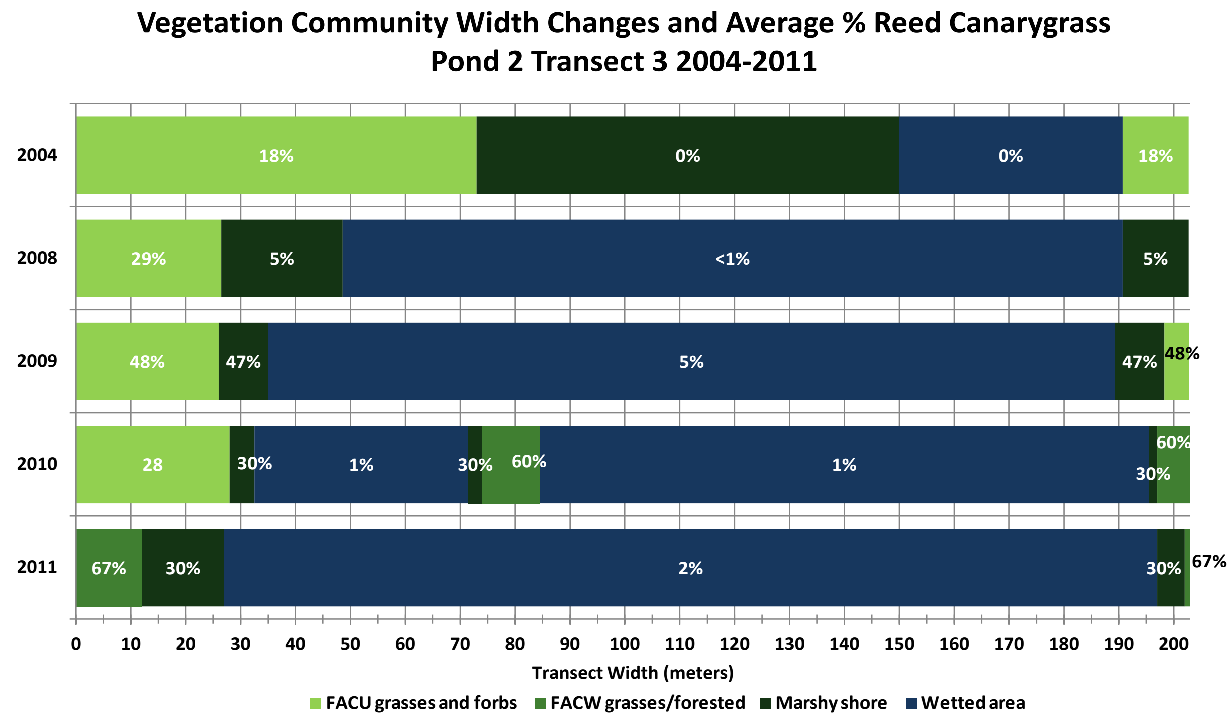
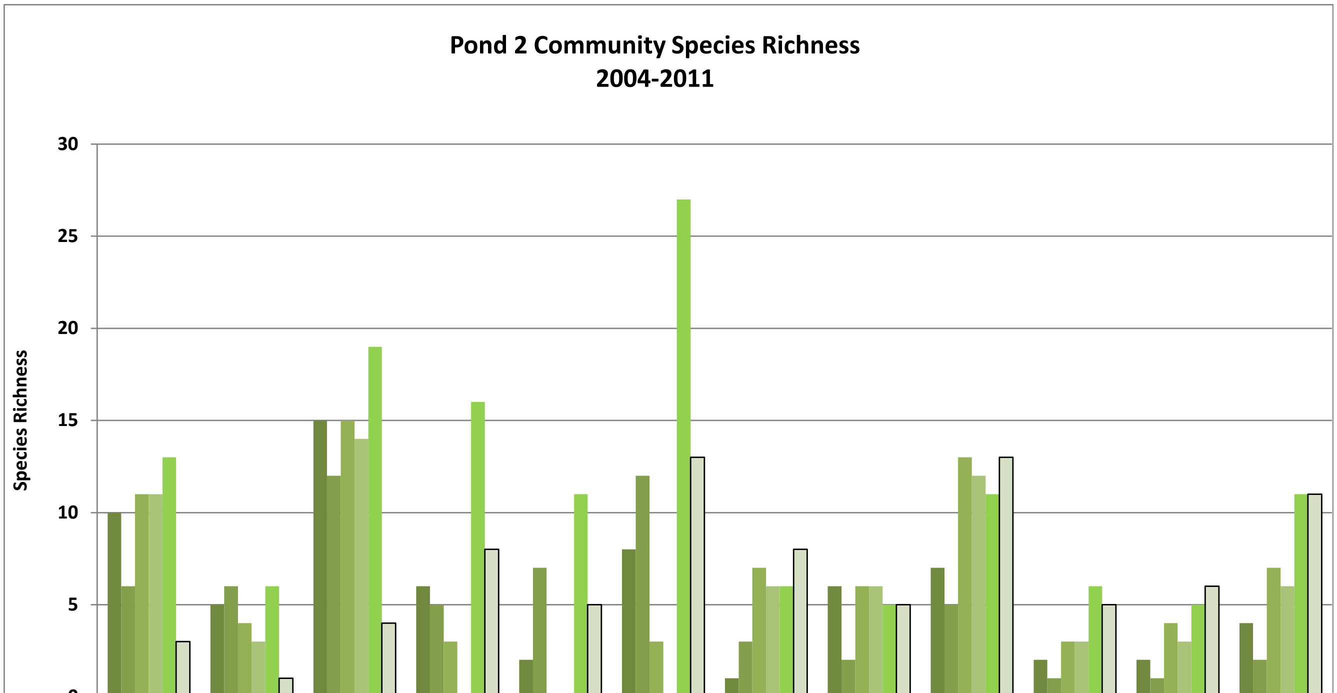


Figure 59. Pond 2 plant community widths along transect 3 and average % reed canarygrass cover for Pond 2 vegetation communities (average cover of both transects 3 and 4) for 2004 and 2008-2011.

In 2011 species richness was much lower (up to 75% loss) than in 2010 in both the FACU and FACW plant communities of Pond 2. The marshy shore and wetted area plant communities had similar (or higher) species richness levels compared to 2010 (Figure 60). Overall only 24 (11 native, 11 introduced, 2 unknown) individual plant species were identified on Pond 2 in 2011 compared to 41 (15 native, 22 introduced, 4 unknown) species found in 2010 (Table 24). This loss in species richness is likely attributed to the abnormally high water on the site during the summer of 2011 (Figure 57). Plant community composition and species richness may recover to historic levels in the fall of this year or next summer depending on future hydrology and climate characteristics.



	FACU grasses and forbs			FACW grass/forested			Marshy shore			Wetted area		
	Introduced	Native	Total	Introduced	Native	Total	Introduced	Native	Total	Introduced	Native	Total
2004	10	5	15	6	2	8	1	6	7	2	2	4
2005	6	6	12	5	7	12	3	2	5	1	1	2
2008	11	4	15	3	0	3	7	6	13	3	4	7
2009	11	3	14				6	6	12	3	3	6
2010	13	6	19	16	11	27	6	5	11	6	5	11
2011	3	1	4	8	5	13	8	5	13	5	6	11

Figure 60. Pond 2 native and non-native (introduced) plant species richness by plant community from 2004-2011. In 2009 the FACW plant community species data of Pond 1 was merged with FACU and marshy shore plant communities due to difficulty in distinguishing these communities.

Table 24. Pond 2 total species richness 2004-2011

Pond 2 Species Richness						
Year	2004	2005	2008	2009	2010	2011
Introduced	12	9	13	14	22	11
Native	12	10	9	7	15	11
Unknown	5	11	4	1	4	2
Total	29	21	26	22	41	24

Overall, Pond 2 has shown a shift from a plant community dominated by water purslane (32%) , white clover (*trifolium repens*, introduced) (15%), water pepper (12%) and reed canarygrass(11%) cover in 2004, to a plant community dominated by reed canarygrass (49%) and moneywort (*Lysimachia nummularia,* introduced)(12%) in 2011 (Figure 60 and Figure 61). In total reed canarygrass cover increased by 19% between 2010 and 2011, this increase of reed canarygrass cover was observed mainly in the FACW and FACU plant communities. If summer flooding continues to occur at the 2011 levels reed canarygrass abundance may decline in the wetted area and marshy shore plant communities and continue to increase along the ponds edges in the FACU and FACW plant communities.

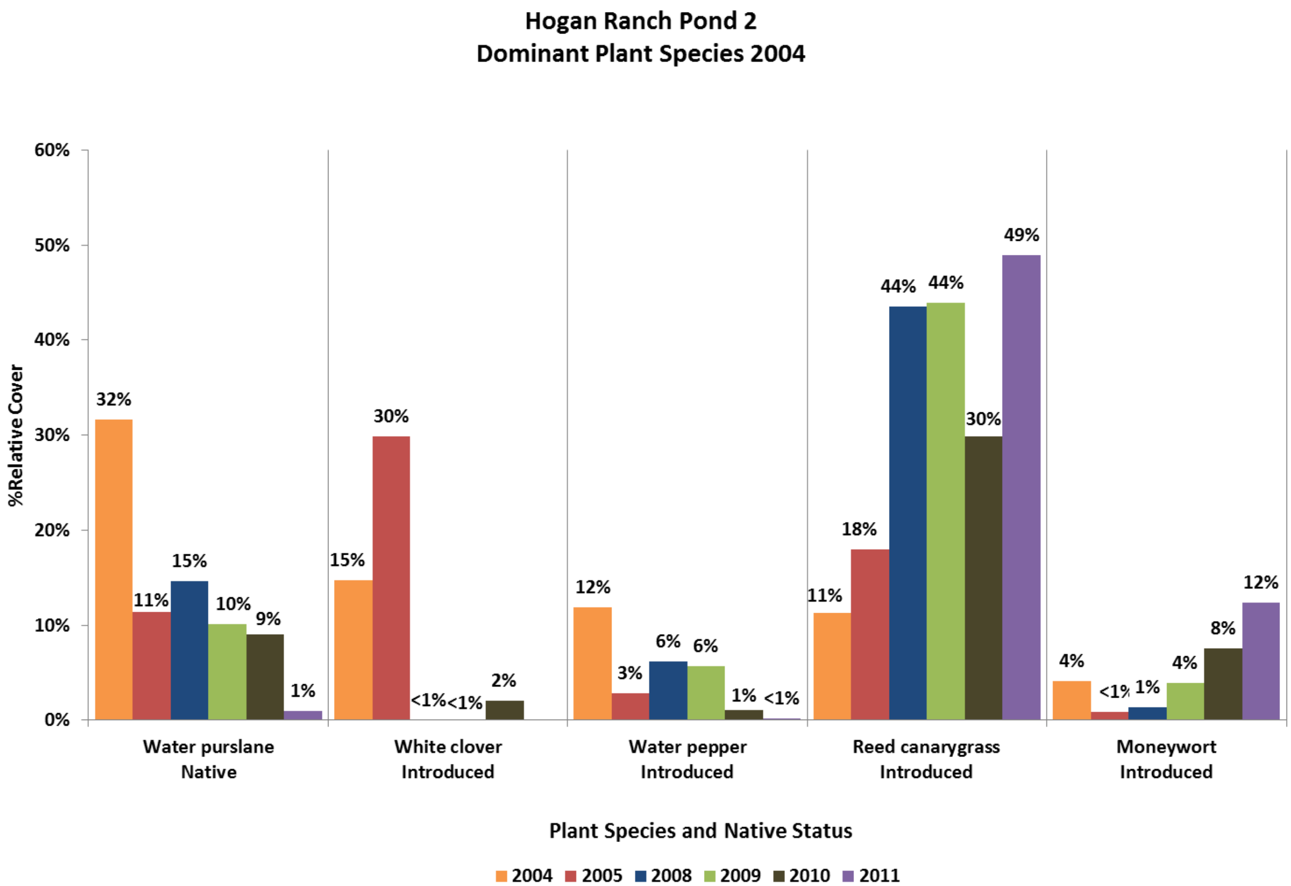


Figure 61. The top 6 dominant plant species of Pond 2 in 2004. 2005 and 2008-2011 cover percentages shown for comparison.

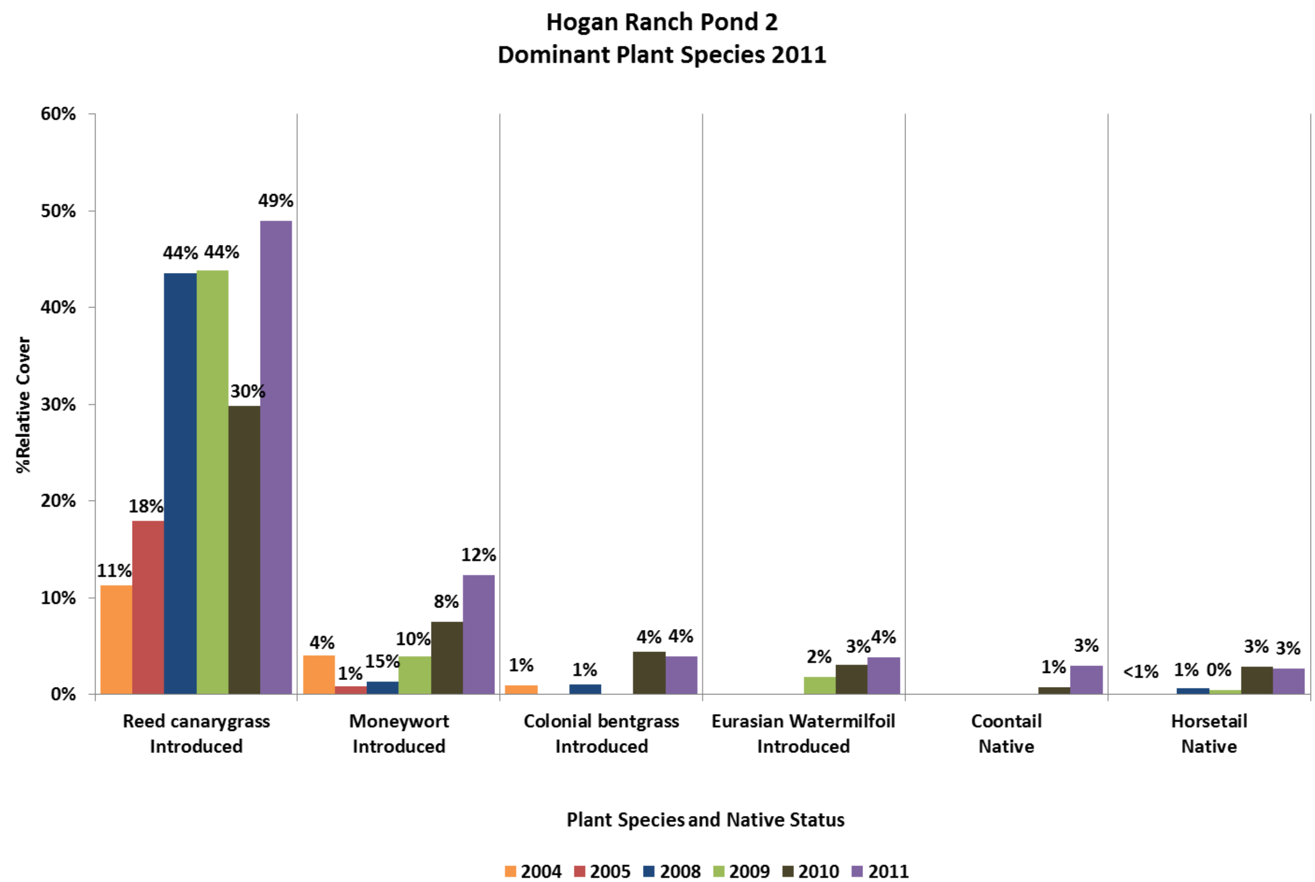


Figure 62. The top 6 dominant plant species of Pond 2 in 2011. 2004-2005 and 2008-20010 cover percentages shown for comparison.

Pond 3

Plant community widths

In 2011 Pond 3's marshy shore and wetted area plant communities increased in width and the FACU and FACW plant community widths decreased (Figure 63 and Table 25). Due to the abnormally high water this season (2011) the wetted area and marshy shore plant communities were significantly wider than previous years (Figure 63). Between 2004-2008 plant community widths shifted with a significant decrease in the FACU and increase in FACW and wetted area plant community widths (Figure 63, Table 25). From 2008-2010only small changes in plant community widths were observed. The overall plant community shifts recorded in 2011 (increase in wetted area and marshy shore) were a product of the extreme high seasonal water levels (Figure 63, Table 25).

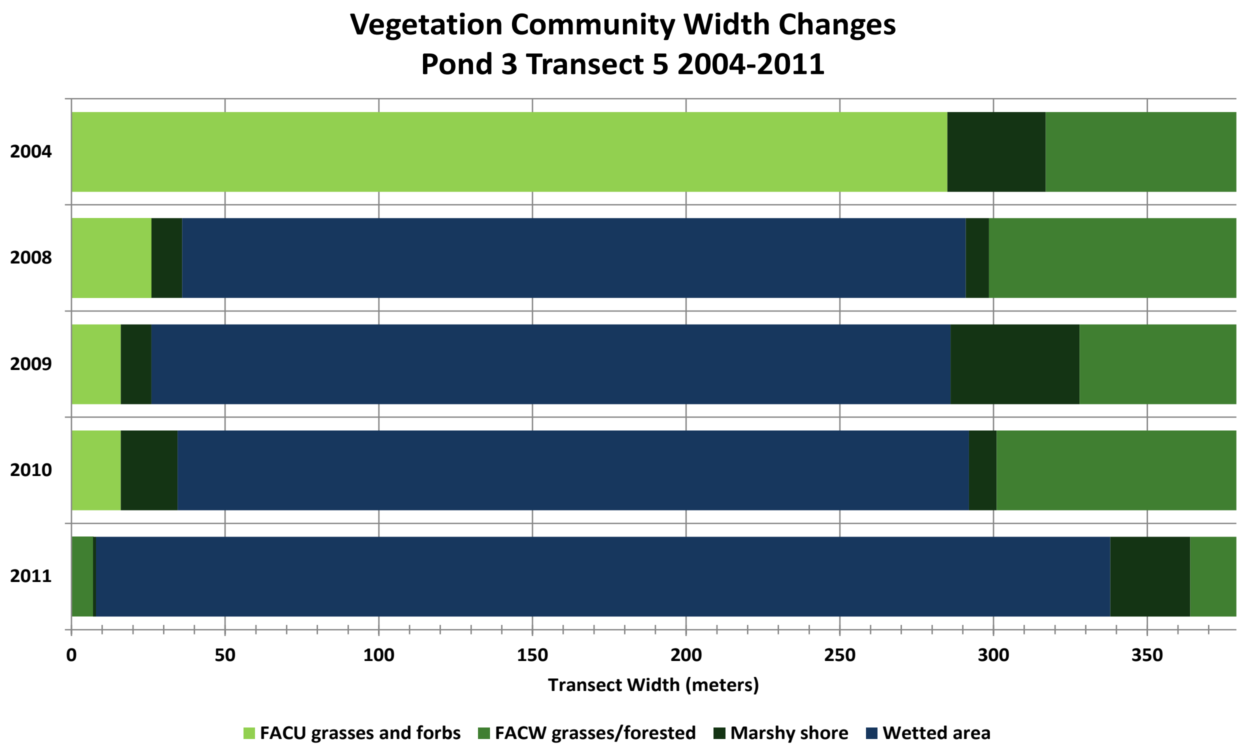


Figure 63. Pond 3 plant community widths in meters along transect 5 for 2004 and 2008-2011.

Table 25. Pond 3 plant community widths in meters along transect 5 for 2004 and 2008-2011.

Pond 3, Transect #5	**Community Length (m) by Study Year**				
	2011	**2010**	**2009**	**2008**	**2004**
FACU grasses and forbs	0	16	16	26	0
FACW grasses/forested	7				
Marshy shore	1	18.5	10	10	0
Wetted area	330	257.5	260	255	0
Marshy shore	26	9	42	7.5	32
FACW grasses/forested	15	78	51	80.5	62
Total:	**379**	**379**	**379**	**379**	**379**

.

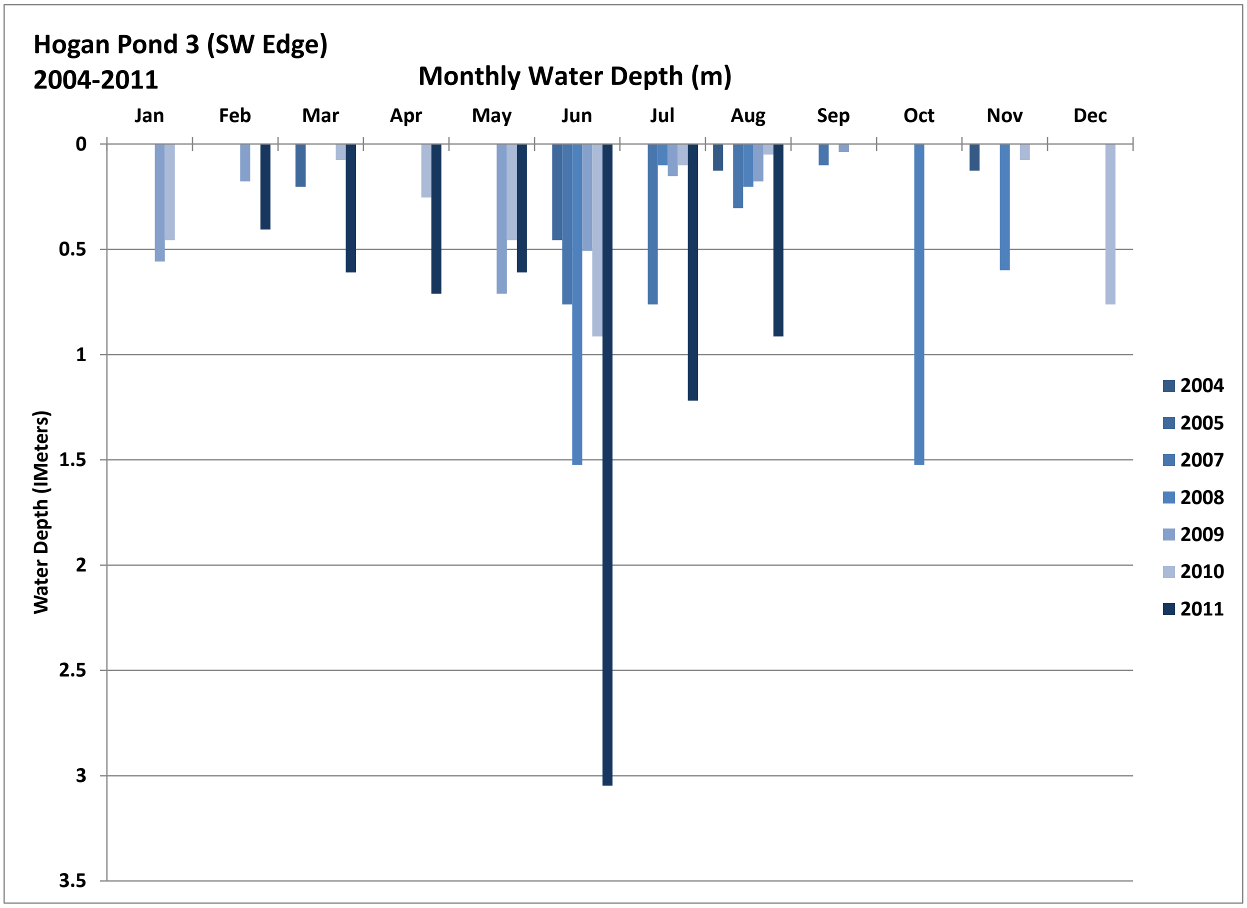


Figure 64. Hogan Ranch Pond 3 Water Depth (meters). Depth Recorded Monthly at Water Quality Testing Location (SW Edge of Pond 3, See Water Quality Report for Exact Location).

Plant community composition

In 2011 reed canarygrass continued to be the dominant vegetation cover in the FACW (52%) and marshy shore (9%) plant communities and wapato (*Sagittaria latifolia*, native) (1.5%) was dominant in the wetted area of Pond 3 (Appendix B, Figure 65). The percent cover of wapato in the wetted area of Pond 3 was significantly lower in 2011 with only 1.5% cover compared to 80% cover in 2010. The wapato found in Pond 3 in August of 2011 were just beginning to grow. Typically in August wapato in this pond is fully mature and in bloom. This pond also typically has only a few centimeters of water during the time of our yearly plant survey however this year (2011) there was almost a meter of water at the Pond's edge (Figure 64). This extremely high water also reduced the reed canarygrass abundance in both the FACW (-45%) and marshy shore (-44%) plant communities. As the water continues to draw down in this wetland the wapato and other plant species are likely to recover their full abundance in the early fall. However if future water levels continue to be high late into the summer and early fall, it is possible the plant community will shift and become more similar to Ponds 1 and 2.

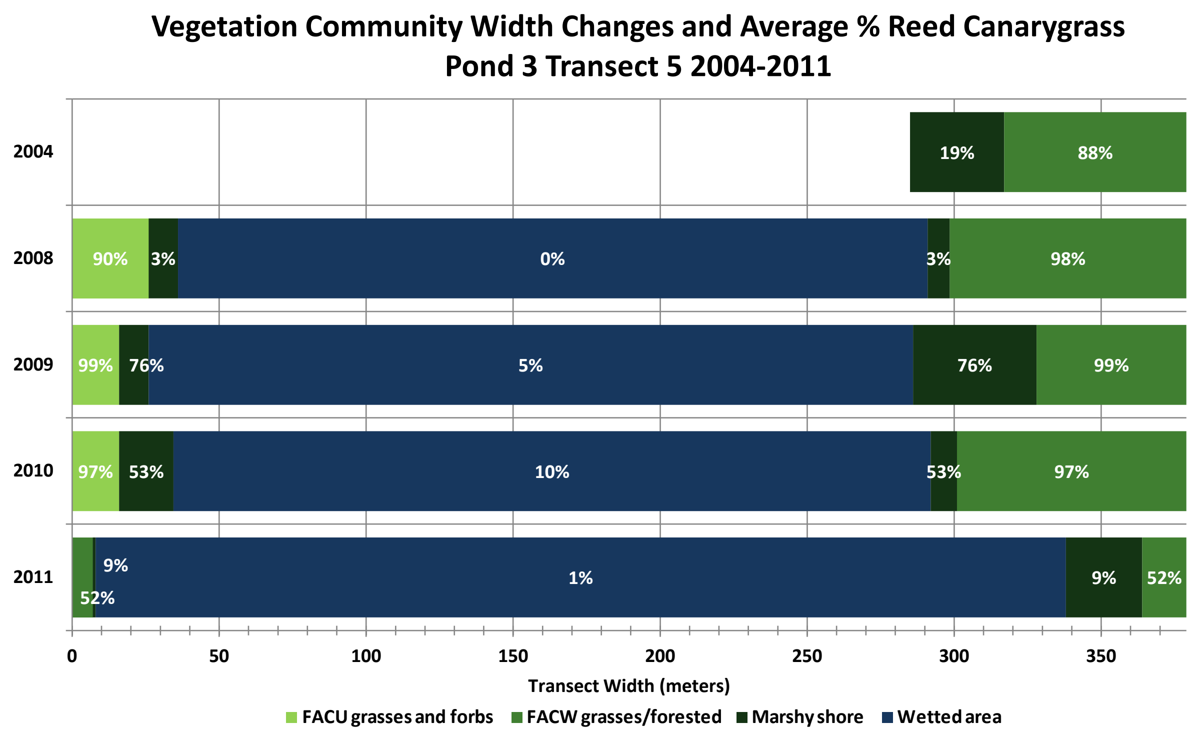
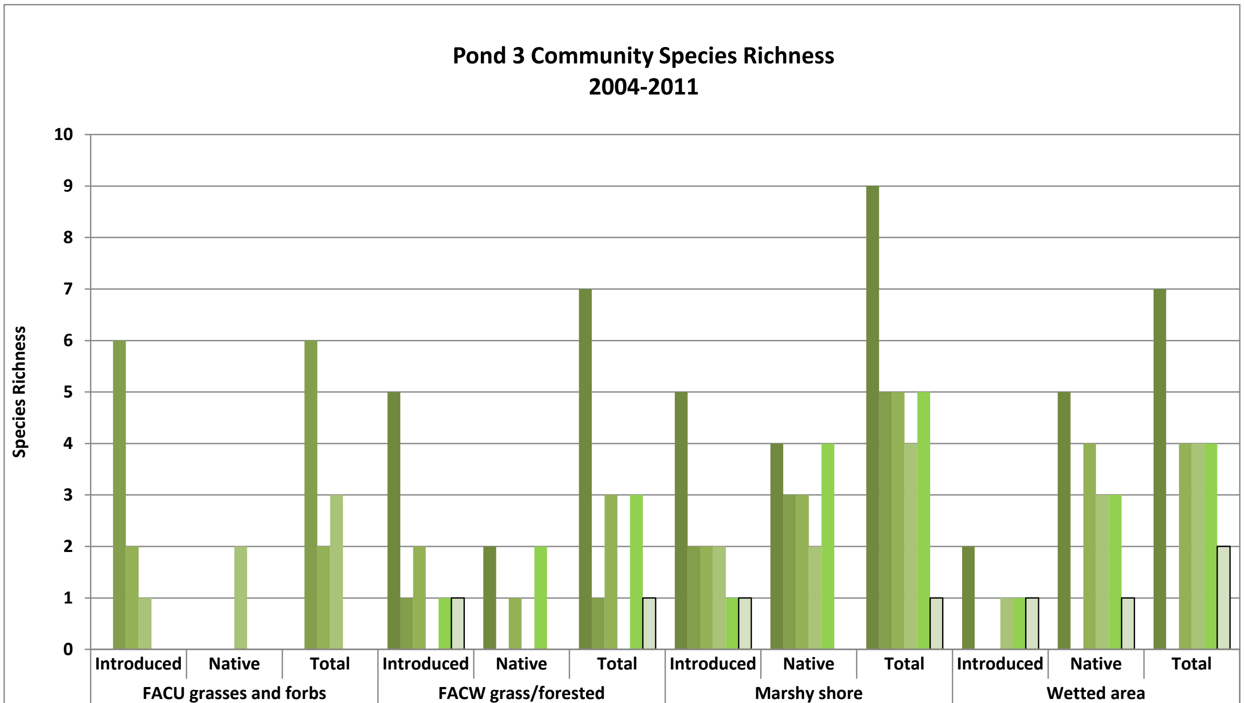


Figure 65. Pond 3 plant community widths along transect 5 and average % reed canarygrass cover for Pond 3 vegetation communities for 2004 and 2008-2011.

In 2011 species richness was much lower than in 2010 in all plant communities (Figure 66). Overall only three (2 native, 1 introduced) individual plant species were identified on Pond 3 in 2011 compared to 9 (7 native, 1 introduced, 1 unknown) species found in 2010 (Table 25). This loss in species richness is likely attributed to the abnormally high water on the site during the summer of 2011 (Figure 64). Plant community composition and species richness may recover to historic levels in the fall of this year or next summer depending on future hydrology and climate characteristics.



	FACU grasses and forbs			FACW grass/forested			Marshy shore			Wetted area		
	Introduced	Native	Total	Introduced	Native	Total	Introduced	Native	Total	Introduced	Native	Total
2004				5	2	7	5	4	9	2	5	7
2005	6	0	6	1	0	1	2	3	5			
2008	2	0	2	2	1	3	2	3	5	0	4	4
2009	1	2	3				2	2	4	1	3	4
2010				1	2	3	1	4	5	1	3	4
2011				1		1	1		1	1	1	2

Figure 66. Pond 3 native and non-native (introduced) plant species richness by plant community from 2004-2011. In 2004 and 2010 the FACU plant community was not distinguished from the FACW plant community. In 2009 the FACW plant community was not distinguished from the FACU plant community. In 2005 the wetted area was not surveyed.

Table 26. Pond 3 total species richness 2004-2011

Pond 3 Total Species Richness						
Year	2004	2005	2008	2009	2010	2011
Introduced	7	7	4	2	1	1
Native	8	3	5	5	7	2
Unknown	4	4	0	0	1	0
Total	19	14	9	7	9	3

Overall, Pond 3 has shown a shift from a plant community dominated by jointed rush (*Juncus articulates*, native) (31%), American speedwell (*Veronica americana*, native) (25%), and reed canarygrass (9%) in 2004, to a plant community dominated by reed canarygrass (25%), wapato (64%) and creeping spike rush (10%) in 2010 (see Report 2010). The 2011 total cover comparisons are not included in this report because this year's plant survey does not represent the true plant community composition of this pond due to the impacts of extreme high water during the typical wapato growing season (Figure 67). However it is expected that the plant community will be similarly (2010 data) dominated by wapato, creeping spike rush and reed canarygrass when normal hydrology is returned. Community based plant cover data for 2004-2011 is located in Appendix B.

Figure 67. North End of Pond 3 Looking South Along the Vegetation Transect Line August 4, 2011.

5.7 Vegetation Community Discussion

Ponds 1 & 2

After replacement of the water control structures and some changes to the boundary of Pond 2, both of these ponds have established new plant community zones with an outer ring dominated by reed canarygrass (FACW plant community); followed by a marshy zone dominated by reed canarygrass, creeping spike rush, and moneywort; and encompassing large areas of open water dominated by native and non-native aquatic plants. The strong influence of local water control structure regulation and the

Bonneville Dam water retention and release cycles on the hydrologic characteristics of these ponds makes is difficult to predict how the plant communities will continue to change in the future.

Wetted Area

The increased water level of Pond 1 and 2 since 2007 has increased the wetted area width, inundating areas that were previously marshy shore and FACW plant communities dominated by reed canarygrass (Appendix B, Figure 49, Figure 50, Figure 56, Figure 57). Depending on future water level fluctuations these new wetted areas may show a decrease in reed canarygrass cover over time, with high water (>.85m) suppressing reed canarygrass growth (Jenkins et al. 2008).

The only significant change in Pond 1's wetted area plant composition from 2010 was the drop in water purslane abundance from 17% (2010) to <1% in 2011. All other species abundances were slightly less than previous years (Appendix B). The wetted area of Pond 2 shifted from being co-dominated by 28% western water milfoil, 13% Canadian waterweed (*Elodea Canadensis*, native) and 12% Eurasian water milfoil (*Myriophyllum spicatum L.*, introduced) to only 1% Canadian waterweed, 12% Eurasian water milfoil, 10% coontail (*Ceratophyllum demersum*, native), and 9% water smart weed (*Polygonum amphibium*, native) (Appendix B). No western water milfoil was found in 2011. Reed canarygrass abundance in the wetted area was only 2% in 2011.

Marshy Shore

Between 2004 and 2011 the width of the marshy shore community on Pond 1 and 2 showed a trend of increasing and a shift in community composition to more reed canarygrass dominance. The marshy shore zone of Pond 1 shifted from 6% reed canarygrass in 2004 to 32% reed canarygrass cover in 2011.Pond 2's marshy plant community has also shifted through the years with 30% reed canarygrass dominance in 2010 and 2011. In 2010 some of the areas previously considered marshy shore have transitioned to FACW or wetted area plant communities due to the spread and abundance of reed canarygrass and changes in water levels from 2007. In 2011 extreme high water events increase the width of the marshy shore plant communities on both of the ponds.

FACW grasses/forested

Ponds 1 and 2 are ringed by a zone dominated by reed canarygrass, sparsely forested in places (FACW)(Appendix C). It appears the width of this zone is increasing in both Ponds (Figure 49 and Figure 55). In 2005 it was dominated by white clover but has since returned to reed canarygrass (2008-2011). In 2011 there was an overall increase in reed canarygrass cover and an increase in the FACW area's width on both Ponds. In Pond 1 reed canarygrass cover increased from 75% in 2004 to 83% in 2011. In Pond 2 the reed canarygrass cover increased from 40% in 2004 to 67% in 2011. The diversity of this plant community has increased since native plant seeding (and planting), however it is still dominated by reed canarygrass and moneywort (both introduced species) with other species composing a very small percent of the overall plant community (Appendix B).

FACU

In 2010 the facultative upland community on Ponds 1 and 2 was composed mainly of reed canarygrass, colonial bentgrass, selfheal (*Prunella vulgaris*, introduced), moneywort, creeping buttercup (*Ranunculus repens*, introduced), Canada thistle (*Cirsium arvense,* introduced), pennyroyal (*Mentha pulegium,* introduced*)*, and English plantain (*Plantago lanceolata)* and white clover (*Trifolium repens,* introduced). In 2011 only reed canarygrass, colonial bentgrass, and moneywort dominated this plant community. Many of the typical weedy field species found in previous years were not found in the 2011 survey (introduced species richness decreased by 50% in 2011) (Figure 53 and Figure 60). Reed canarygrass cover is dominant in this community increasing from 28% in 2004 to 44% in 2011 on Pond 1 and 18% in

2004 to 65% in 2011 on Pond 2 (Figure 52 and Figure 59). If this trend continues it is possible that the FACU plant community will transition into a FACW plant community within a few years.

Pond 3

All plant communities

In 2008, Pond 3 showed dramatic changes in plant community composition as a result of cattle exclusion. Before cattle exclusion this area was dominated by 55% jointed rush (*Juncus articulates,* native) and 40% American speedwell (*Veronica Americana,* native). In 2010, 3 years after exclusion, Pond 3's central wetted area continues to be dominated by wapato (80%, up from 54% in 2009) and creeping spike rush (10%, down from 36% in 2009) (Appendix B). There was a continued increase in the wetted area community's reed canarygrass cover from 1% in 2004 to 5% in 2009 and 10% in 2010. Because of the extreme high water during the wapato growing season in 2011 plant growth in all communities were delayed resulting in very little cover of all plant species recorded during the 2011 survey (1.5 % wapato and 0.8% reed canarygrass in the wetted area). It is expected that Pond 3's wetted area plant community characteristics will be similar to those of 2010 once water levels are reduced in the early fall of 2011.

The marshy edges of Pond 3 have shown a dramatic increase in reed canarygrass cover and have become hard to distinguish from the FACW grasses/forested plant community. In 2008 this zone was reported as being co-dominated by wapato (75%) and creeping spike rush (53% cover). In 2009 reed canarygrass (76%) was the most dominate plant with only a small percent of wapato (7%) and creeping spike rush (16%) cover. In 2010 the marshy shore zone decreased in width and was dominated by reed canarygrass (53%, down from 76%), creeping spike rush (18%) and wapato (10%). In 2011 the marshy shore zone increased in width and was dominated by reed canarygrass (9%, down from 53%) and mainly composed of dead organic matter. The grassy outer ring of Pond 3 continues to be dominated by reed canarygrass and in 2010 and 2011 was identified as FACW. However in 2011 the reed canarygrass abundance in the FACW plant community was reduced from 97% in 2010 to 52%, with the remaining ground cover composed of dead organic matter. Overall, the diversity of these communities has decreased since the first sampling period and reed canarygrass remains dominant. The grassy edges (FACW) of Pond 3 make up a relatively short distance along the transect compared to the wetted Pond center area (wetted area composes about 87% of the transect line in 2011). Indicating that overall this FACW plant community composes only a small part of the overall Pond area (Table 25).

Conclusions

Four years post cattle exclusion, the Hogan Ranch site continues to show signs of recovery. Major changes to the plant composition post cattle exclusion include restoration of Pond 3 to a wapato dominate wetland. This change has enhanced native food resources for water fowl and other wildlife in this wetland area. Alterations to the hydrology of Ponds 1 and 2 (though not a direct part of this restoration effort) has resulted in an increase in the wetted area and aquatic plant communities of these ponds. In 2011 the plant communities of all the ponds showed a significant shift in composition due to prolonged summer flooding (Figure 50, Figure 57, and Figure 64). Extreme prolonged flooding in wetlands can result in plant die off, reduced germination and delayed plant growth (Casanova and Brock 2000). The reduced species richness and shift in reed canarygrass abundance found in 2011 is a result of increased water depth and period of inundation in these wetlands due to this extreme flooding event (Jenkins et al. 2008). Plant community composition and species richness may recover to more recent (2010) levels in the fall of this year or next summer depending on future hydrology and climate characteristics. However, the strong influence of local water control structure regulation and the Bonneville Dam water retention and release cycles on the hydrologic characteristics of these ponds makes is difficult to predict how the plant communities will continue to change in the future.

An unintended consequence of cattle exclusion has been an increase in the dominance of reed canarygrass and a decrease in FACU and marshy shore plant community widths as the FACW community (reed canarygrass zone) increases around all of the Ponds (Appendix B). As the native tree and shrub plantings on this site mature the abundance of reed canarygrass may also be reduced by the resultant shading. To ensure the success of this restoration project long-term monitoring and weed management is suggested. This would allow the changes of dominant invasive species in these Ponds to be tracked (such as reed canarygrass and Eurasian milfoil) and controlled to make sure these species not hinder the long-term outcome of this restoration project. Long-term monitoring would also help identify how extreme hydrologic regulation of the area by the Bonneville Dam impacts these wetlands' plant community composition.

5.8 Planting Survival Results

Planting Survival and Vigor

The overall survival rate of plantings in 2011 on the Wilson/LaCombe property was 61% when adjusted for plants missing between the 2010 and 2011 surveys. This is comparable to the survival on plantings on this site from 2009 (adjusted survival 61%) and 2010 (adjusted survival 73%). Wilson/LaCombe had an APD of 0.17 plants/m^2 (688 plants/acre) which is a decrease of 0.08plants/m^2 (48 plants/acre) from 2010 (Figure 70, Table 27). On Hogan Ranch the overall survival was 58% with an APD of 0.13 plants/m^2 (529 plants/acre) this is low compared to previous years survival of 89-83% and can be attributed to impacts from abnormally long inundation (high water) and high loss from herbivory (Figure 68, Table 27). Table 27, Figure 68, and Figure 69 show the total surveyed planting survival and adjusted planting survival and the vigor of plantings for Hogan Ranch and Wilson/LaCombe properties from 2008 through 2011. In 2011 planting vigor was high with a majority of living plants being very healthy and robust on all planting sites (Figure 69, Table 27).

Table 27. Vigor of plantings, Survey Yearly Survival, Adjusted Survival and APD for Hogan Ranch and Wilson/LaCombe properties 2008-2011

SITE AND YEAR	YEARLY SURVEY PLANTING VIGOR				SURVIVAL		AVERAGE PLANTING DENSITY	
Wilson/LaCombe	**High**	**Medium**	**Low**	**Dead**	**Survey**	**Adjusted**	**APD (Plants/m2)**	**Plants/acre**
2008	25%	42%	16%	17%	80%	NA	0.42	1700
2009	24%	32%	21%	23%	77%	61%	0.33	1335
2010	66%	21%	9%	3%	97%	73%	0.25	1012
2011	68%	10%	13%	9%	91%	61%	0.17	688
Hogan Ranch	**High**	**Medium**	**Low**	**Dead**	**Survey**	**Adjusted**	**APD (Plants/m2)**	**Plants/acre**
2008	25%	38%	17%	20%	83%	NA	0.33	1335
2009	42%	35%	12%	11%	89%	NA	0.16	647
2010	30%	38%	16%	16%	84%	NA	0.21	850
2011	49%	8%	2%	42%	58%	NA	0.13	529

.

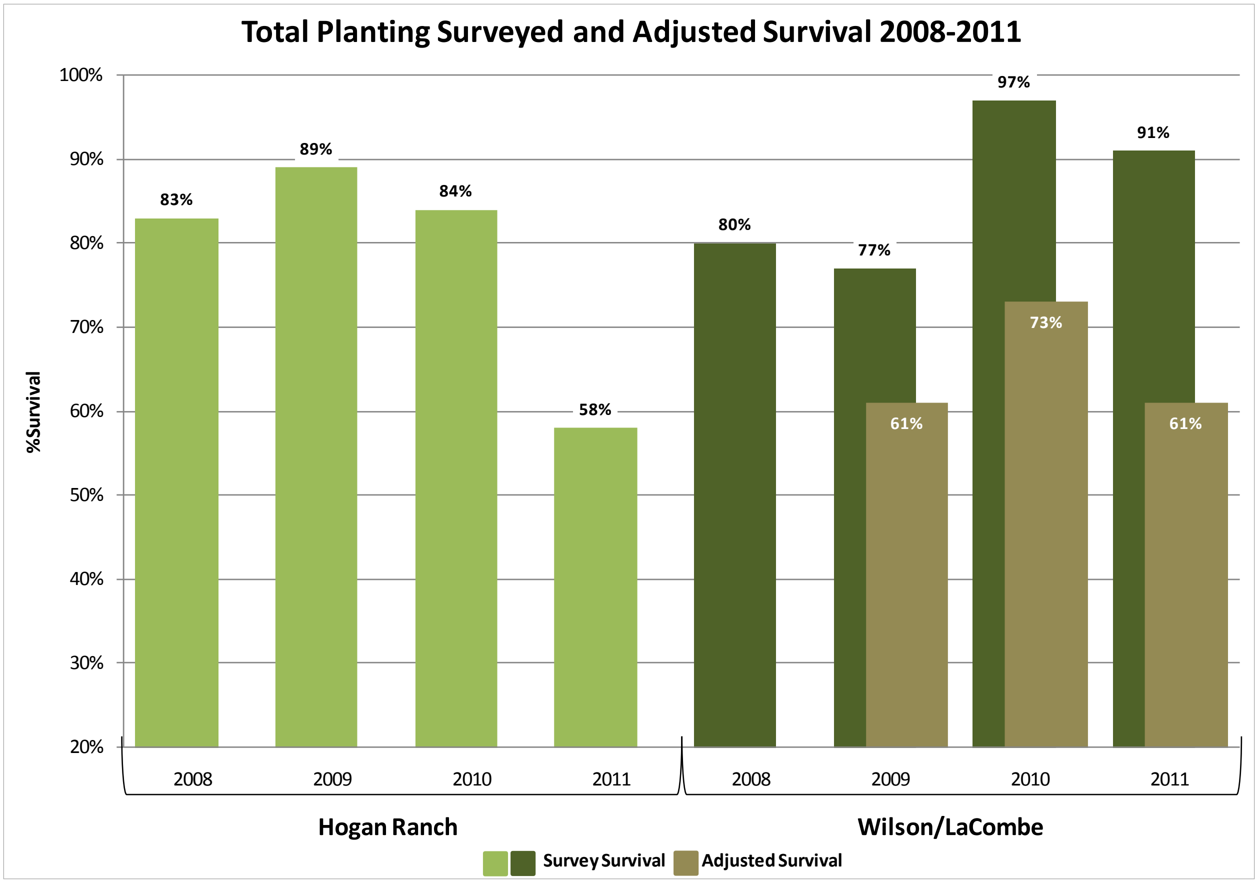


Figure 68. Total surveyed planting survival and adjusted survival for Hogan Ranch and Wilson/LaCombe properties from 2008-2011. Surveyed survival only accounts for plants living and dead found during the yearly survey. Adjusted survival accounts for a decrease in the number of plants found between yearly surveys on each site due to mortality, herbivory and natural removal from the site.

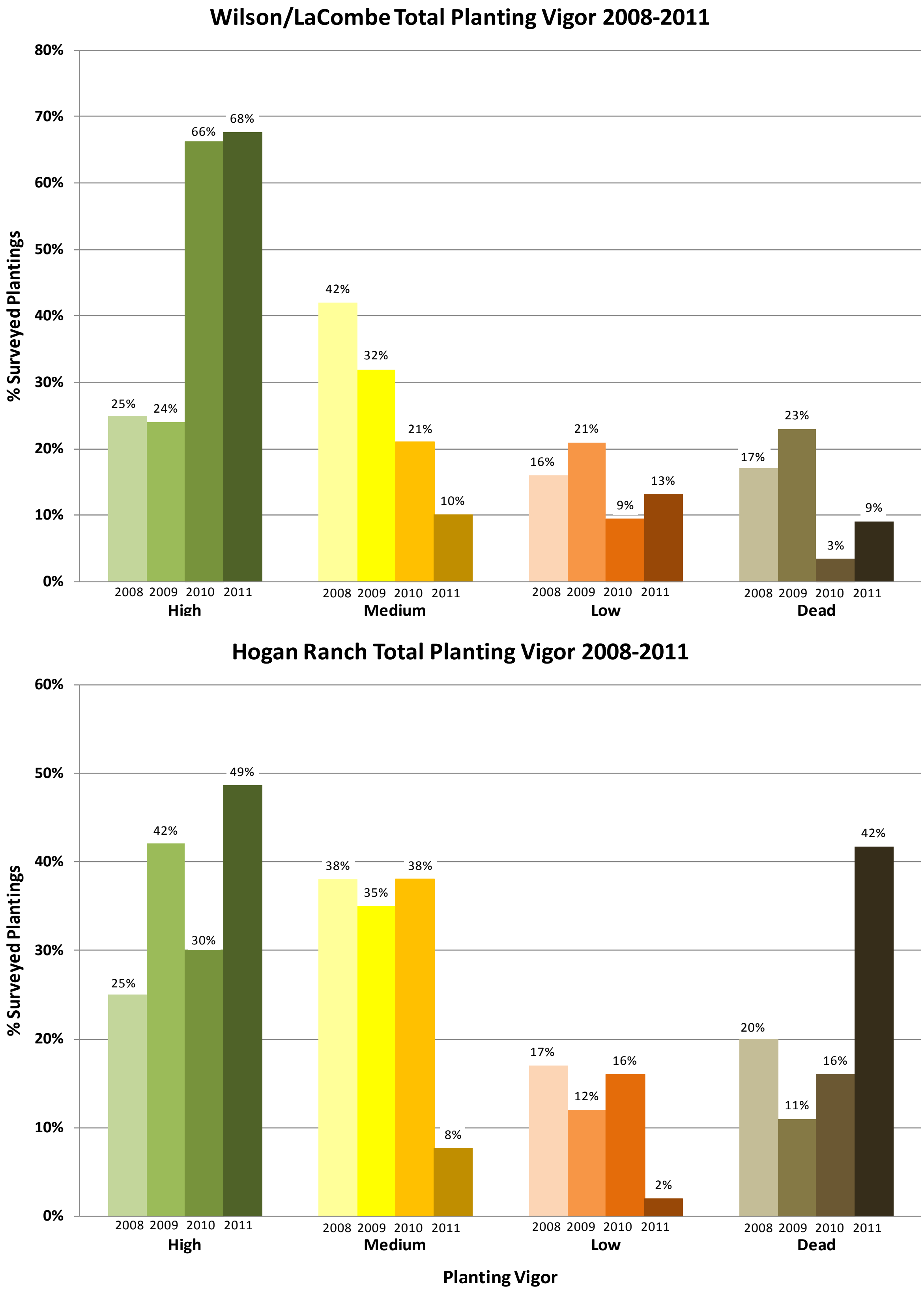


Figure 69. The vigor of plantings found on Wilson/LaCombe and Hogan Ranch properties 2008-2011.

Hogan Ranch Planting Communities

In 2011 the Hogan Ranch ash forest plant community had a surveyed survival of 36% with an APD of 0.09 plants/m^2 which is down significantly from the 71% survival and 0.12 plants/m^2 found in 2010. The willow plant community had a surveyed survival of 29% with an APD of 0.16 plants/m^{2}which is also significantly lower than the 89% survival of 0.49 plants/m^2 found in 2010.Both of these communities were highly impacted by the 2011 high water event and herbivory (such as beaver browsing). The shrub plant community had the highest surveyed survival of 80% with an APD of 0.20 plants/m^2 which is comparable to the 87% survival and 0.26 plants/m^2 found in 2010. All plant community survival and APD (plants/m^2) from 2008 through 2011 can be seen in Figure 70.

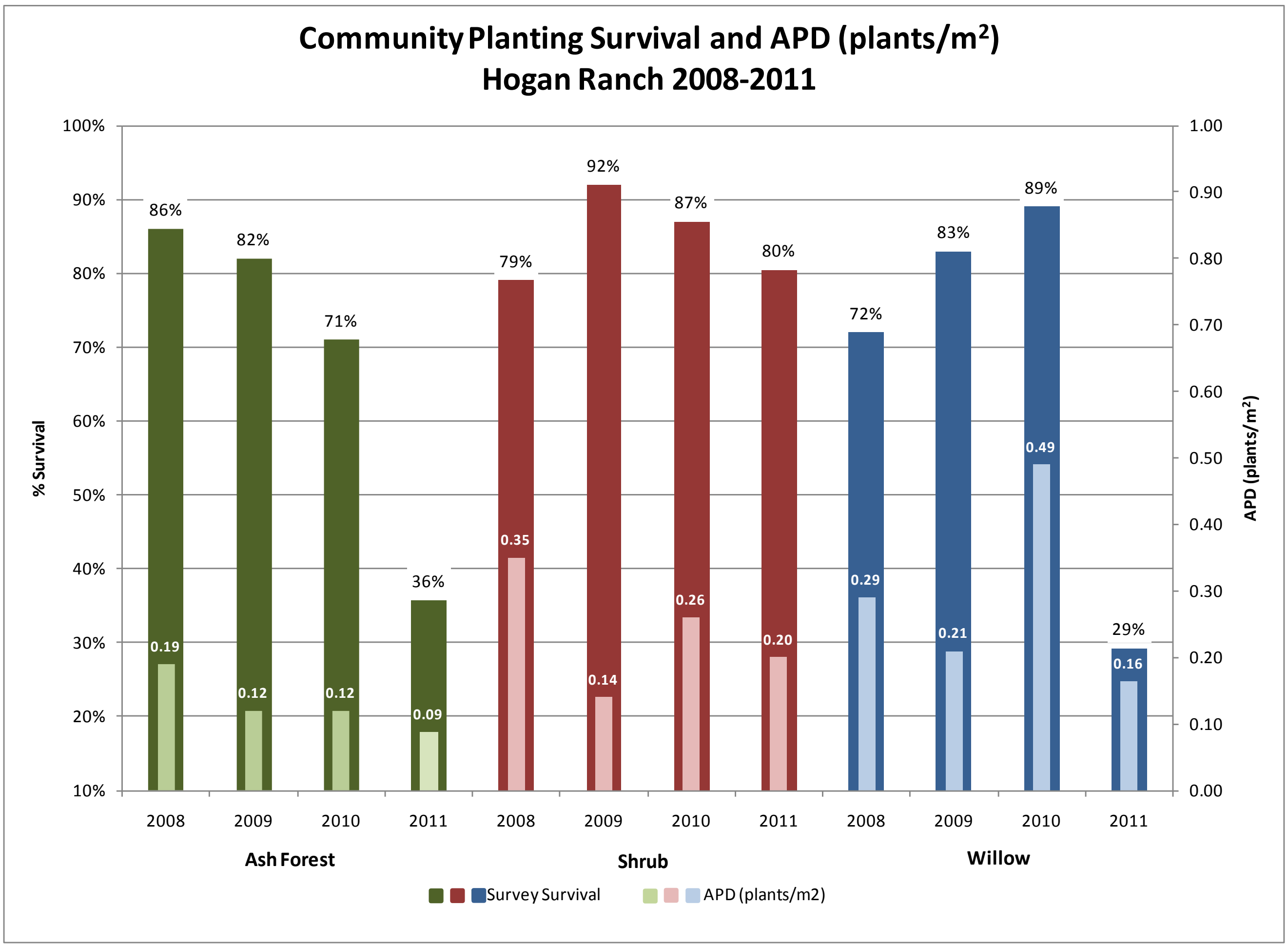


Figure 70. Community Planting Survival (based on yearly survival numbers) and APD (plants/m^2) for Hogan Ranch Ash Forest, Shrub and Willow Communities from 2008-2011.

Planting Species Survival

In 2011 extreme high water between April-July resulted in high planting mortality on both Wilson/LaCombe and Hogan Ranch. Between 2008-2010 planting species on Wilson/LaCombe had high average survival rates however, low survey numbers for some species such as Thimbleberry, Indian plum, Willows and Western serviceberry indicate that these species under performed and dead plants were missing during the survey inflating survival percentages. In 2011 Cascara, Willows, Ninebark and Western serviceberry showed signs of stress and mortality on Wilson/LaCombe due to the extreme high water earlier in the season (Thimbleberry and Indian plum were not found in 2011). On Hogan Ranch Black hawthorn, Cascara, Cluster rose, Elderberry, and Willows also showed signs of stress and mortality due to this high water event (Twinberry was not found in 2011). Over the 4 year monitoring period the most successful planting species on Hogan Ranch have been Oregon ash, Cottonwood, Douglas spirea, Willow and Western crabapple. The most successful planting species on Wilson/LaCombe have been Cluster rose, Douglas spirea, Ninebark, Ponderosa pine, Snowberry, Western crabapple. On both sites willow plantings suffered heavy herbivory from beaver and on Wilson/LaCombe Ponderosa pine also suffered from herbivory. For individual plant species survival details please see (Appendix D)

In 2011 some change to the herbaceous layer was found due to the impact of high water levels during April-July. Reed canarygrass (*Phalaris arundinacea*) was still found to be dominant on both sites but on Hogan Ranch its growth was stunted from these high flood waters and there was an increase in the amount of dead organic matter. On Wilson/LaCombe a slight increase in overall canopy cover from plantings was identified. As the plantings continue to grow in height and width more noticeable canopy cover will develop. No change in canopy cover or dominant herbaceous layer was observed between 2008 and 2010 on Wilson/LaCombe or Hogan Ranch.

5.9 Planting Survival Discussion

In 2011 plant species vigor and survival was lower than previous years on both Wilson/LaCombe and Hogan Ranch because of stress caused by the extreme high water levels from April-July. The herbaceous community on Wilson/LaCombe continues to be dominated by reed canarygrass in addition to a diverse mix of non-native grasses and forbs typical of recovering pasture areas, including species such as oxeye daisy, curly dock, Canada thistle, and Himalayan blackberry. Hogan Ranch herbaceous cover also continues to be dominated by reed canarygrass, however some reed canarygrass did die back (approximately 20%) in 2011 resulting in an increase in dead organic matter on the site due to the extended flooding event. It is expected that the reed canarygrass at Hogan Ranch will fill back into these areas if normal water levels return next year.

Monitoring indicates that the remaining native plantings are in good condition with high vigor. Continued maintenance with mowing is suggested for both of the sites until the plantings outgrow the suppressive reed canarygrass herbaceous layer, which can grow to a height of 2-3 meters (Lavergne and Molofsky 2004, WRMWG 2009). As these plantings mature an increase in canopy cover and a decrease reed canarygrass cover is expected (Kim et al. 2006). The transition area between the emergent marsh and the riparian forest canopy will continue to be dominated by reed canarygrass. This is an area that is difficult to mow and has a limited canopy cover consisting of clumps of willow and other shrub species. See photos in Appendix D for conditions of the sites in August 2011 after the high water has receded and the reed canarygrass is coming in.

High water events on Hogan Ranch limit the establishment of a diverse understory. Only some species seem to tolerate high water conditions during the growing period. Some species persist on the higher ridges, but others like cascara and red elderberry do not seem suited to this habitat type. We had significant losses of red-osier, swamp rose, and twinberry that are generally tolerant of wet riparian conditions. We also had significant losses in willows. We planted a mix of pacific, Sitka and Hooker willows. It would have been interesting to compare the survival of these species to Columbia River willow stock, but we were not able to purchase this species at the time of planting. When we developed a plan for the site, we hypothesized that the lack of understory diversity was primarily caused by cattle grazing. It now appears that highly variable water levels play a significant role in plant community establishment.

6.0 Salmon, Salmon Prey, and Habitat AEM at Fort Clatsop South Slough & Alder Creek

6.1 Introduction

In 2007 the Estuary Partnership and its partners replaced a failing tidegate with a bridge at Lewis and Clark National Historic Park's Fort Clatsop in order to reconnect South Slough (and 45 acres of diked pastureland) with the tidal influence of the Columbia River. Water velocities in the culvert were elevated, potentially limiting fish passage into the slough. A reconnection of the tidal influence to the slough had the potential to both open up access to the habitats in the slough for fish and improve those habitats. In 2007 the Columbia River Estuary Study Taskforce (CREST) implemented pre-project monitoring as a baseline for characterizing fish community assemblages, size class, and residency; for water quality conditions including temperature, tidal range/depth, DO and conductivity. CREST performed effectiveness monitoring in 2008, 2009, 2010, and 2011 after restoration actions were complete as part of the EP's Action Effectiveness Monitoring Program.

6.2 Sample Site Descriptions

AEM for the Ft Clatsop restoration project includes the restoration site (Ft Clatsop South Slough) and a nearby reference site (Alder Creek)

Ft. Clatsop South Slough

South slough resides between steep hillsides and the mainstem Lewis and Clark River (Figure 18). Year round freshwater input drains off the hillsides into the slough and its adjacent wetlands. The wetland on the south side of the channel was altered by the placement of fill, elevating this side a couple of feet higher than the wetland on the north bank of the slough. The site has been actively grazed with no restrictions from the riparian zone or slough. The change in elevation on the southern wetland has resulted in differences in plant community, land use, and both inundation frequency and duration between the two wetlands adjacent to the slough. The plant community on the south side is dominated by non-native pasture grass and common rush (*Juncus balticus*), while to the north the wetland is dominated by native plants such as small fruited bull rush (*Scirpus microcarpus*), douglas spirea (*Spirea douglasii*), and slough sedge (*Juncus effusus*).

Prior to restoration South Slough connected to the mainstem Lewis & Clark River through an undersized culvert; originally a tidegate whose lid fell off during the winter of 2006. The roadway and culvert posed an obstacle ("Passage/Flow Barrier" stressor) to fish passage and affected five controlling factors within South Slough: sediment, hydrodynamics, bathymetry/topography, water quality and temperature. Studies have stated that the amount and diversity of estuarine habitat that's accessible impacts the abundance and productivity of ESA listed salmon populations in the Columbia River Estuary (Fresh et al. 2005). Reconnecting South Slough to tidal influence restores increases habitat opportunity of emergent marsh and tidal slough habitat for juvenile life stages of salmon migrating through the estuary. Secondarily, livestock grazing and agriculture resulted in compacted soil, degraded riparian areas, a simplified channel network and degraded water quality. Tidal reconnection is expected to enhance the water quality, and restore access and quality of a variety of habitats including emergent marsh, complex tidal channels, and other periphery of the marsh (e.g. forested wetland, scrub-shrub and upland stream channel). The connectivity, size, and diversity of habitats within the South Slough project site will contribute to the diversity of life history strategies of ESA listed salmon populations in the LCRE.

Alder Creek

CREST selected this reference site based on its proximity to the restoration site, its tidal connectivity, and conditions at the site predicted to support salmonids (Figure 18). Conditions include side channels yield rearing opportunity, surrounding spruce trees provide shade, and riparian zones of native vegetation keep water in good condition and provide structure for macroinvertebrates, all of which should promote salmon usage. In 2008, monitoring efforts included fish community data, prey availability and utilization, and salmonid feeding behavior. In 2009, CREST added water quality data such as water temperature and DO. These data will be directly compared to results from the restoration site.

Figure 71. South Slough tidegate removal/bridge installation site, located on the Lewis and Clark River mainstem, including the nearby reference slough (Alder Creek) and current dike breach site, Otter Point.

6.3 Monitoring Methods

In 2007 pre-project monitoring was conducted at South Slough and Alder Creek; parameters included fish community, landscape changes, and water quality. In 2008 post-project monitoring was implemented at South Slough and Alder Creek. Metrics post-project included fish community, prey availability &

salmon diet, landscape changes, and water quality. All sample gear and fishing techniques were consistent with the methods described in "Monitoring Protocols for Salmon Habitat Restoration Projects in Lower Columbia River and Estuary" (Roegner et al. 2009).

6.3.1 Fish Community

The fish community was sampled in 2011 using a trap net with livebox at both South Slough and Alder Creek. Sites were fished on the same day. The nets were set at slack tide before the ebb, and fished until the water was shallow enough to seine. Seining was integrated into fish sampling for the first time this year. A pole seine was stretched across the channel a certain length above the trap (102 meters at South Slough and 92 meters at Alder Creek) and walked down to the mouth of the trap net, encouraging fish into the net. Fish were collected into black buckets using dip nets. The water conditions inside the buckets were maintained near stream conditions, particularly in regards to temperature DO. Portable aerators were used to maintain DO levels. Salmon were separated from the by-catch and processed first. One to two salmon at a time were anesthatised in a buffered tricaine methanesulfonate (MS222) solution. All juvenile salmonids were measured and weighed, checked for tags and markings, then allowed to recover before they were released back into the stream. All non-salmonid fish were identified to species, with the first 30 measured and the remainder counted. To better understand fish usage between stocks, caudal clips were taken for genetic analysis. Pre-labeled vials were loaded with non-denatured 95% ethanol for individual samples. Scissors were used to take the tip of the upper caudal fin and insert it into the prepared vial. Each sample was given an ID# that correlated to a particular fish.

For all salmonid species, Fulton's condition factor (K) (Fulton 1902; Ricker 1975) was calculated as an indicator of fish health and fitness, using the formula:

$$K = [\text{weight (g)}/\text{fork length (cm)}^3] \times 100$$

6.3.2 Prey Availability & Salmon Diet

Insect fall-out traps were utilized to evaluate the availability of terrestrial macroinvertebrates as a food source for juvenile salmonids at South Slough and Alder Creek. Fall-out traps were made of rectangular plastic tubs secured loosely by string to three PVC pipes, and filled with an inch of soapy water. The set up was designed so that the traps could rise and fall with tidal influence. Tubs were placed on the bank near the trap net sites. The traps work by disrupting the flight ability of insects that land on the surface. Samples were collected after 48hours and preserved in 90% Ethanol for lab analysis.

In conjunction with fall out traps benthic core samples were taken to identify the benthic component of prey availability at both sites. These samples were collected using 2inch diameter PVC pipe. One end is inserted approximately 4inches into the sediment of the channel at or near low tide, and a rubber stopper is placed on the other end of the pipe creating a vacuum suction used to contain the sample in the pipe while it was removed from the substrate. Five samples were collected, each adjacent to a fall out trap. The samples were rinsed through a 500 micro millimeter mesh sieve and preserved in individual plastic jars with 95% Ethanol. Rose bengal, an inert stain, was applied to facilitate sorting invertebrates from other debris in the sample.

Salmon diet is a critical component in understanding habitat use in restoration projects. Gut content samples were collected using a non-lethal gastric lavage method on salmonids 60 mm or greater in size. In this method, the tip of a sprayer containing filtered water was inserted down the salmon's throat and minimal pressure was applied to evacuate their stomach contents into a clean sieve. Contents were rinsed into a jar, and preserved with 95% ethanol for future lab analysis and comparison to prey availability samples taken from the same sampling site.

6.3.3 Sediment Accretion Stakes

Reconnecting a site to tidal influence restores natural processes such as sediment and nutrient transport. Sediment accretion stakes allow for the simple measurement of sediment aggradation and erosion as a result of hydrologic re-connection. Sediment accretion stakes were installed at South Slough in 2008. Sediment accretion measurements are taken at both sites to measure the changes in soil erosion and/or deposition along the bank, and to compare the changes in sediment transport between South Slough and Alder Creek. Two level stakes were placed in an area adjacent to the channel where inundation was expected to occur, and set one meter apart. The stakes are leveled, a meter stick placed on top of both, and the distance measured from the meter stick to the ground at 10cm intervals. In 2009 Pacific Northwest National Laboratories (PNNL) installed sediment accretion stakes at Alder Creek in the same manner as described above. Measurements were taken twice during the sampling season at both South Slough and Alder Creek to cumulatively reveal temporal and spatial shifts in sediment distribution.

6.3.4 Channel Morphology

Channel cross-sections were used to record changes in channel morphology as a product of changes in hydrology resulting from tidal reconnection. Cross sections consisted of transects that extended from bank to bank across the channel. The start and end points were marked with PVC or t-posts and GPS coordinates recorded (Table 28). Start and end points were set back far enough on the bank so that they would not be lost to erosion as the channel changed over time. An auto-level and stadia rod was used to measure the elevation at set intervals. Intervals were selected based in site topography the degree of change across the channel that is anticipated.

Table 28. Channel cross section GPS locations, labeled downstream to upstream.

Site	Cross section 1	Cross section 2	Cross section 3	Cross section 4	Cross section 5
South Slough	N46°7’44.6” W123°52’46.7” N46°7’43.8” W123°52’47.6”	N46°7’43.7” W123°52’43.6”, N46°7’44.0” W123°52’43.0”	N46°7’44.7” W123°52’50.2”, N46°7’43.7” W123°52’50.7”	N46°7’44.3” W123°52’52.0”, N46°7’43.9” W123°52’51.0”	N46°7’43.1” W123°52’52.2”, N46°7’43.1” W123°52’52.2”
Alder Creek	N46° 7' 53.472" W123° 52' 44.544"	N46° 7' 53.7594" W123° 52' 44.4354"	N46° 7' 54.264" 123° 52' 44.7594"	N46° 7' 55.0554" W123° 52' 44.6514"	N46° 7' 56.5674" W123° 52' 44.58"

6.3.5 Water Quality

An in situ, multi -parameter water quality meter was deployed approximately 75ft above the bridge, at N46°7’43.4” W123°52’42.9”, N46°7’43.7” W123°52’43.2”. As a result of theft in 2009, a new probe was deployed above the trap net site approximately 300m above the bridge. The probe at South Slough is currently located at N45°51’53.2” W122°44’43.2 (Figure 72). The probe collects water temperature, DO, depth and conductivity readings.

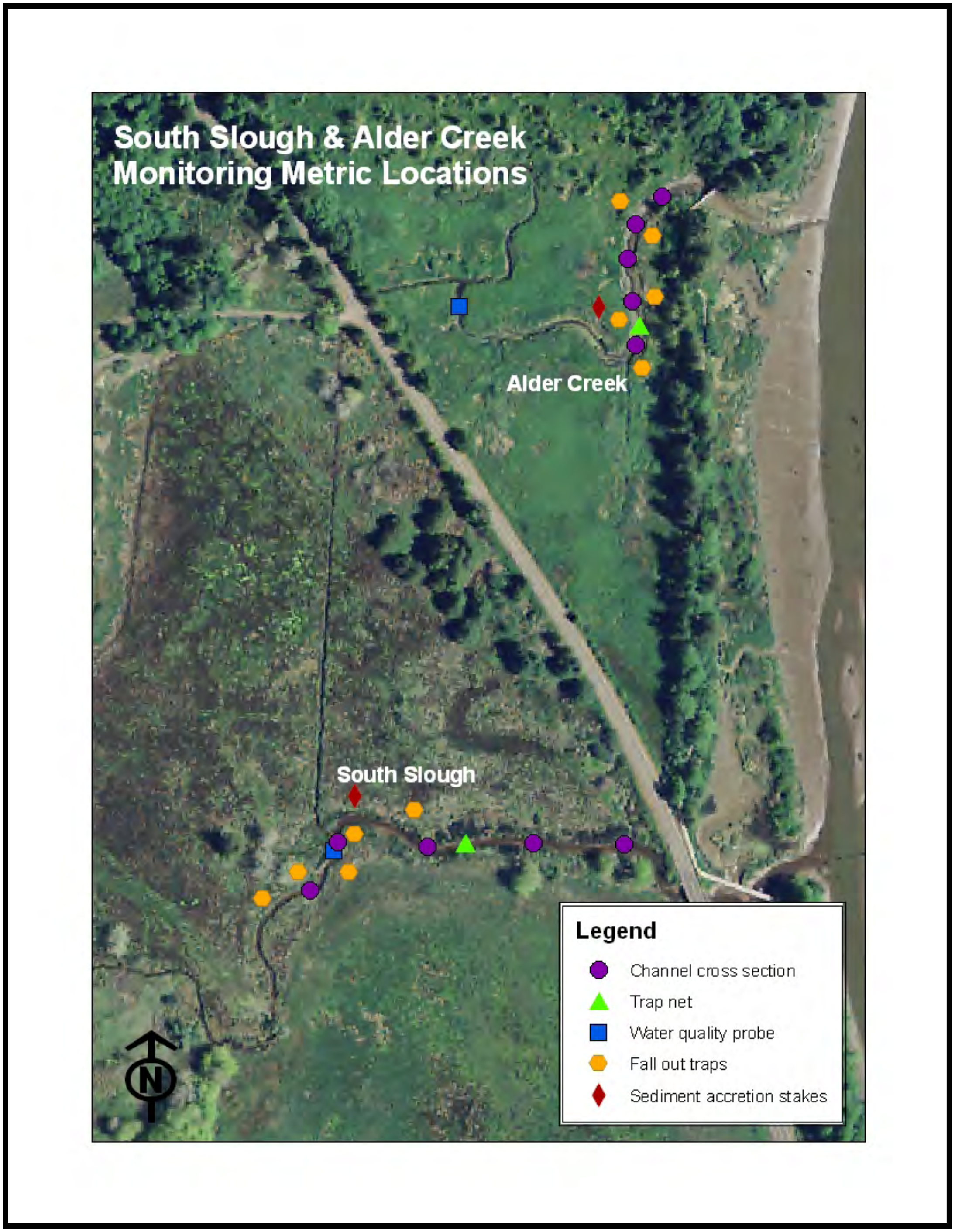


Figure 72. Location of sampling metrics at South Slough and Alder Creek.

6.4 Results

When comparing fish data between South Slough and Alder Creek it is important to recognize differences in site conditions that affect both water quality and habitat opportunity. Sough Slough is a deeper channel than Alder Creek. Alder Creek drains to less than 12inches in most of the channel at low tide, leading to warmer water and lower DO concentrations. This is particularly true in warmer summer months. It is possible that the smaller number of salmon at Alder Creek results from the smaller size of the channel in relation to South Slough. This may result in limited habitat opportunity when compared to South Slough.

6.4.1 Fish Community

Fish community sampling occurred twice a month between March and May, and once a month in June and July. Direct funding from BPA was used to supplement an extra sampling event. Sampling was implemented at South Slough and Alder Creek simultaneously. Terrestrial prey availability samples (fall-out traps and benthic cores) were also collected on the same day at both sites.

Table 29. Summary table showing number of native species, unmarked salmonid species, and non-native fish species captured by month at South Slough and Alder Creek, 2011.

Site	Date/ number of events	Number of native species	Number of salmonid species	Native species caught (total number)	Number of non-native species	Non-native species caught (total number)
South Slough	March (2)	4	2	Chinook, Coho, Chum, Cutthroat, Three spine stickleback, Peamouth chub (15,929)	0	Banded killifish, Sunfish (8)
	April (2)	3	2		0	
	May (2)	5	3		1	
	June (1)	4	2		1	
	July (1)	2	1		1	
Alder Creek	March (2)	2	1	Chinook, Coho, Three spine stickleback, Peamouth chub, Large scale sucker (1,114)	0	Banded killifish, Sunfish (4)
	April (2)	3	2		1	
	May (2)	5	2		1	
	June (1)	4	2		1	
	July (1)	3	1		1	

The species composition, diversity, and the total number captured varied between South Slough and Alder Creek (Table 29). South Slough expressed a greater diversity of unmarked juvenile salmonids, while Alder Creek had a greater diversity of native, non-salmonid, species in the by-catch. The same two species of non-native fish were present at both sites, although their numbers were greater at South Slough, as were the total numbers of native non-salmonid species. Five different salmonid species were observed at South Slough between 2007 and 2011, Chinook, coho, chum, cutthroat, and steelhead. Chinook and coho were the only salmonid species observed at Alder Creek. In 2011, 4 species of juvenile salmon were observed at South Slough, and 2 species at Alder Creek; Chinook and coho were observed at both sites while chum and cutthroat were only observed at South Slough.

The total number of all fish species captured was lower at Alder Creek than at the South Slough. This may be due to the smaller channel at Alder Creek, as well as the low depth in the channel at low tide. Three spine stickleback consistently dominated catches at both sites, while coho were the most abundant salmonid species. The proportions of non-native species caught at South Slough and Alder Creek varied, although the species were the same. Non-native species include banded killifish and sunfish. Non-native species comprised 0.35% of the total catch at Alder Creek and 0.063% at South Slough (Table 30). This low percentage was the result of large numbers of native three spine sticklebacks, and very low catches of non-natives, generally 1 to 3 individuals per sampling event. Native fish species include Chinook, coho, chum, cutthroat, three spine stickleback, peamouth chub, and large scale suckers.

Table 30. Total number of each species captured as a percentage of the total number of all individual fish captured at South Slough and Alder Creek.

Site	Date	Chinook	Coho	Chum	Cutthroat	Stickleback	Banded Killifish	Peamouth Chub	Large Scale Sucker	Sunfish Sp.
	14-Mar		2.3	0. 6		97.2				
	28-Mar	0. 7	2.9			93.7				
	12-Apr	0. 2	1.1			98.8				
	28-Apr	0. 1	9.3			89.8				
South Slough	**12-May**	0. 2	12.4		0. 1	87.3	0.1	0.1		
	24-May	0. 2	3.4		0. 1	97.0	0.1			
	9-Jun	0. 1	2.9			97.0	0.1	0.1		
	22-Jul		2.3			97.6				0.1
	14-Mar		2.0			94.7				
	28-Mar		9.1			90.9				
	12-Apr	0.7	0.2			98.8			0.2	
	28-Apr	0.3	5.4			94.3				
Alder Creek	**12-May**	0.2	13.0			83.8	0.2	0.7		
	24-May	1.2	2.9			95.4				0.6
	9-Jun	0.25	7.1			91.9		0.5	0.3	
	22-Jul		4.4			93.4		1.1	1.1	

Table 31. Summary table showing number of unmarked juvenile Chinook caught at each site by month, their mean length, mean weight, and condition factor.

Site	Month	Number Chinook caught	Number Measured & weighed	Fork length (mm)	Weight (g)	Condition factor
South Slough	April	3	3	49.8±25.6	25.6±6.4	0.9±0.4
	May	6	6	41.8±10.1	2.9±4.7	0.9±0.3
	June	2	2	54.3±8.9	1.9±1.3	1.0±0.2
Alder Creek	April	4	4	98.75±31.2	13.8±8.6	0.9±0.04
	May	11	9	46.5±20.7	3.4±7.5	1.0±0.4

South Slough and Alder Creek are heavily comprised of stickleback (Table 30). Coho ranged from 0.2% to 13% of the total catch and three spine sticklebacks made up 89% to 95%. The percentage and timing of species collected was consistent for coho and sticklebacks between sites, with moderate variations in percentages and timing for catches of Chinook, chum, cutthroat, banded killifish, peamouth chub, large-scale suckers, and sunfish.

6.4.1.1 Size, Weight & Condition (K) Factor

Table 32. Summary table showing number of unmarked juvenile coho caught at each site by month, their mean length and weight, and their condition factor.

Site	Month	Number coho caught	Number Measured & weighed	Fork length (mm)	Weight (g)	Condition factor
South Slough	March	13	11	39.1±0.5	0.5±0.1	0.9 ±0.2
	April	27	27	48.5±23.9	2.4±2.4	0.9±0.3
	May	459	136	42.3±8.8	1.31±2.2	0.9±0.2
	June	148	150	50.7±8.9	1.5±1.3	1.0±0.2
	July	80	80	60.8±5.4	2.6±0.8	1.1±0.1
Alder Creek	March	4	4	43.5±5.3	0.9±0.6	1.0±0.3
	April	18	18	48.6±26.9	2.9±6.2	1.0±0.2
	May	73	37	45.5±19.1	2.5±6.4	0.9±0.4
	June	30	30	62.1±19.6	3.5±3.2	1.1±0.2
	July	4	4	65.5±8.7	3.6±1.5	1.2±0.1

Different size classes of Chinook were observed at South Slough and Alder Creek. During April at both sites larger Chinook were present, whereas in May and June size dropped considerably. This indicates that both stream and ocean-type Chinook were utilizing the habitat at South Slough. Based on their size and timing these are most likely stream type yearlings utilizing the shallow water habitat on their way to the estuary to begin smoltification. The smaller sized Chinook, chum, and coho utilizing the habitat were likely a variety of ocean and stream type life history strategies, utilizing the habitat as they both migrate to the estuary at small sizes or search for forage and refuge during their prolonged stay in freshwater (Bottom et al 2005). Size increased consistently between May and July for Chinook and coho at South Slough and Alder Creek. The largest coho were sampled in July. Condition factor was similar for coho at both sites throughout the sampling season. The largest Chinook observed at South Slough occurred in the June sampling event, while the largest Chinook at Alder Creek was sampled in April.

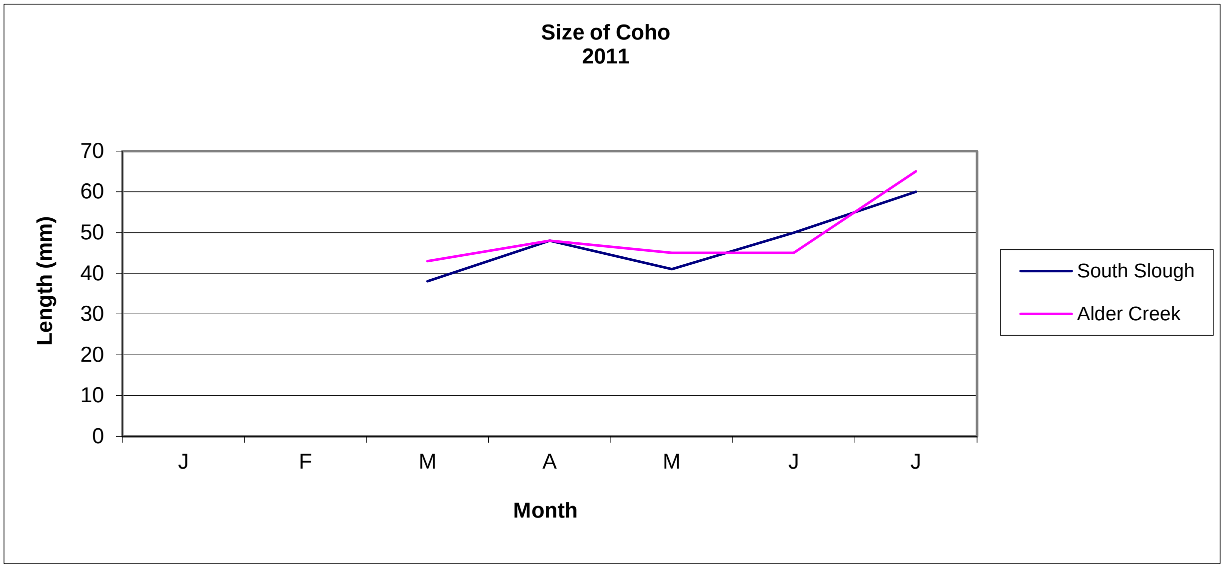


Figure 73. Average size of coho by month at South Slough and Alder Creek, 2011.

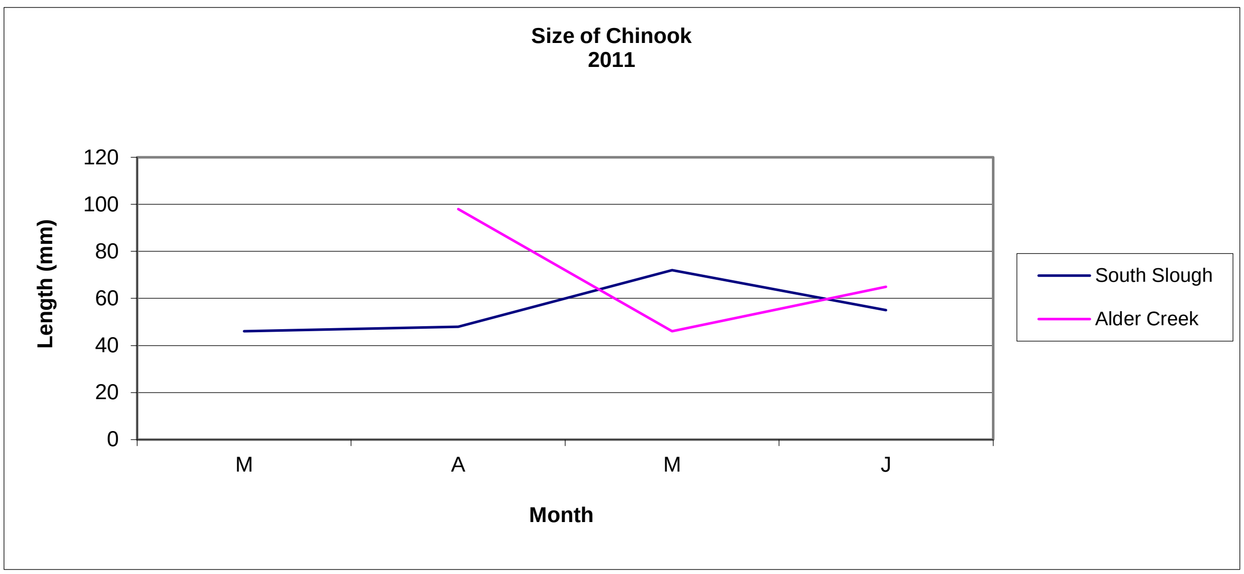


Figure 74. Average size of Chinook by month at South Slough and Alder Creek, 2011.

Coho and sticklebacks were caught during every sampling event at both sites. Chinook were present at South Slough sampling events from March through June, while only being present in Alder Creek sampling from April through June in 2011. Chum and cutthroat were present in very small numbers at the restoration site but not present at any time at Alder Creek. Large-scale suckers were only observed at Alder Creek, and peamouth chub and sunfish numbers were greater at Alder Creek as well. Frequency of capture for banded killifish, peamouth chub, large-scale suckers, and sunfish were sporadic at and between the two sites. Percentages of these species were consistent at South Slough but varied at Alder Creek.

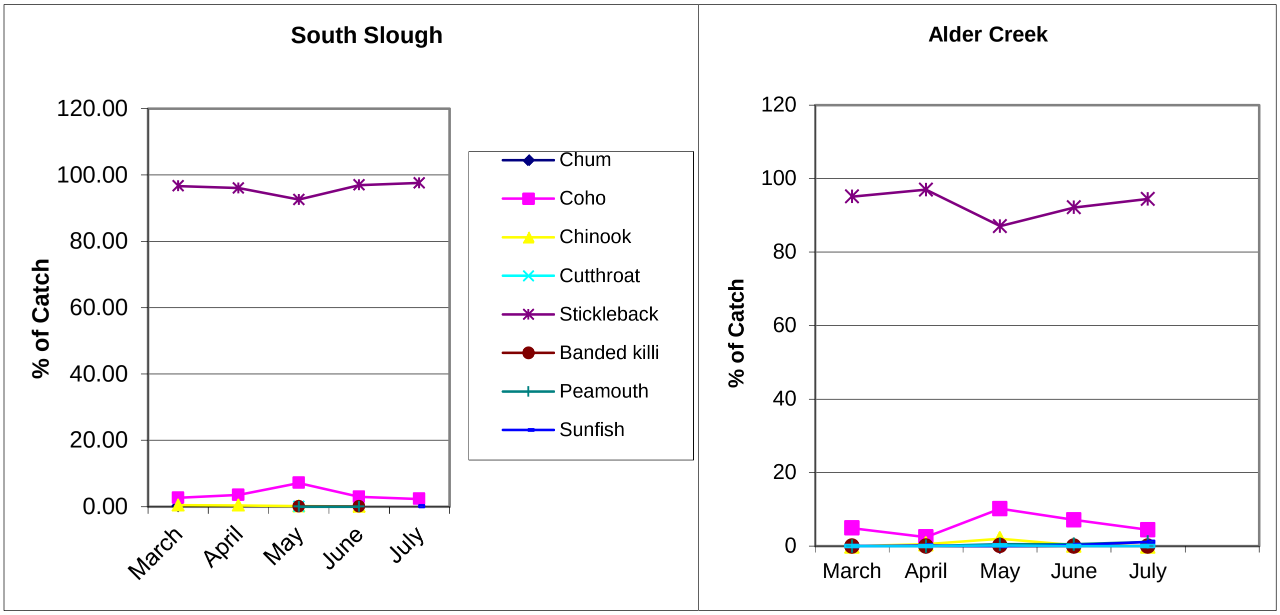


Figure 75. Percentage of each species in total catch by month at South Slough and Alder Creek, 2011.

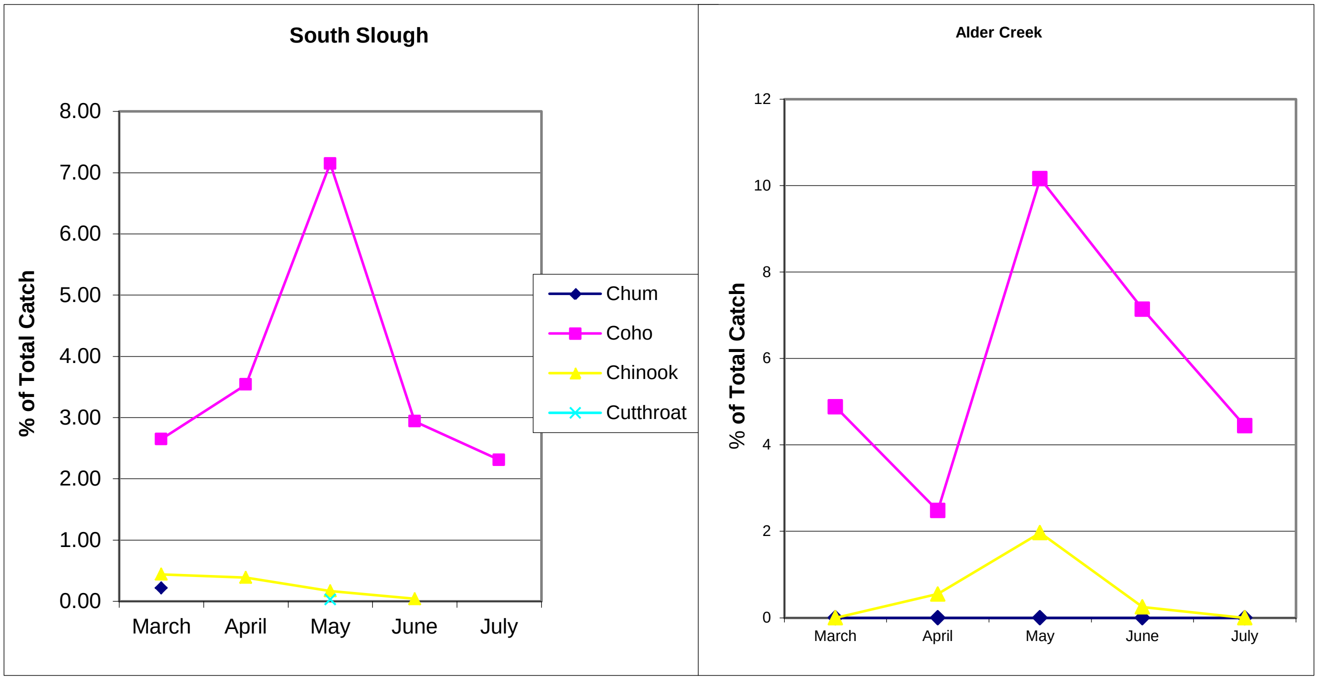


Figure 76. Juvenile salmon as percentages of the total catch at by month at South Slough and Alder Creek, 2011.

Marked salmon were observed at South Slough and Alder Creek, albeit in very small numbers and frequency. Two marked Chinook were observed at South Slough in May of 2011, and 1 at Alder Creek. The presence of marked Chinook coincided with the presence of unmarked Chinook at both sites.

Table 33. Comparison of lengths and weights for marked and unmarked Chinook at South Slough and Alder Creek, 2011. **Only one fish caught.*

Unmarked and marked Chinook Lengths and Weights (SD) at South Slough and Alder Creek					
		2011			
		Length (SD)		**Weight (SD)**	
	Month	**Unmarked**	**Marked**	**Unmarked**	**Marked**
South Slough	**May**	72 (±33.5)	98.5 (±12.02)	7.92 (±0.58)	9.15 (±3.75)
Alder Creek	**May**	45.5 (±19.1)	102*	5.68 (±8.24)	14.10*

6.4.1.2 Temporal Distribution

Coho abundance increased between March and May at South Slough. Abundance peaked in May, after which it declined through July. Coho at Alder Creek demonstrated a similar curve in regards to abundance, peaking in May and declining afterwards. Chinook abundance peaked in April at South Slough and Alder Creek, one month earlier than coho, and declined gradually afterwards. The peak abundance of Chinook is similar to other migration and abundance patterns studied in the Columbia River Estuary (Johnson et. al. 2011)

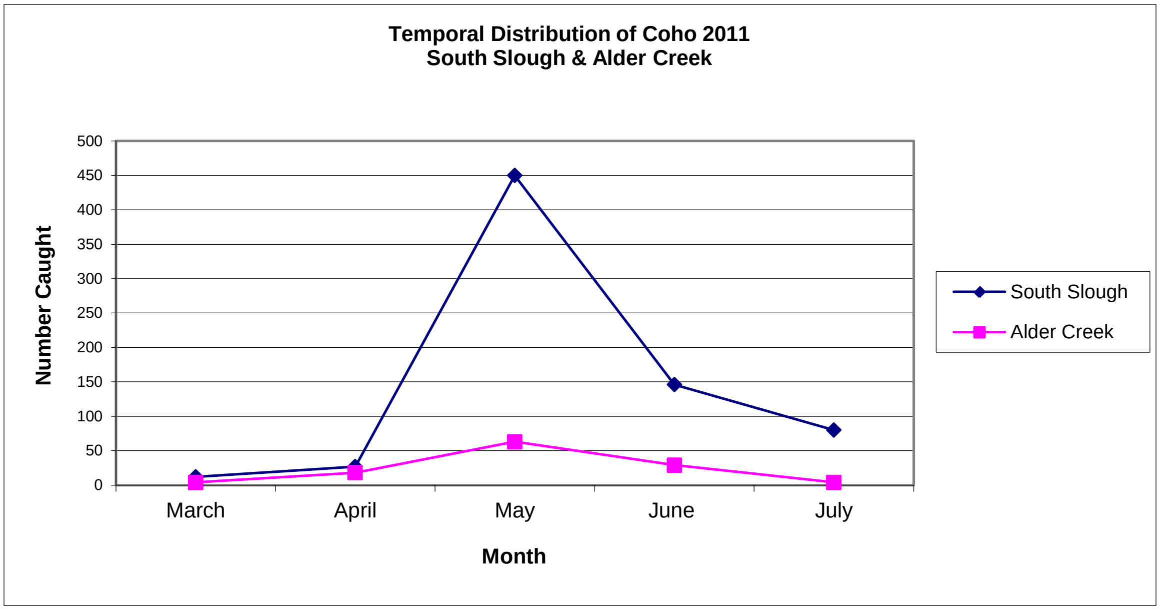


Figure 77. Temporal distribution of coho at South Slough and Alder Creek, 2011.

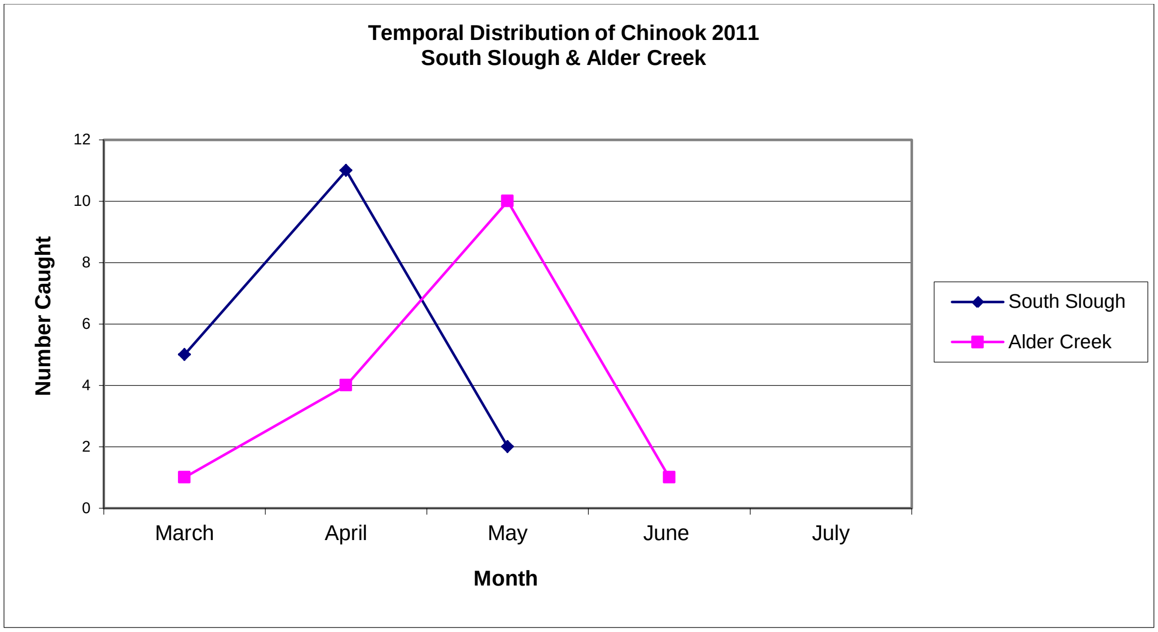


Figure 78. Temporal distribution of Chinook at South Slough and Alder Creek, 2011.

6.4.1.3 Catch Per Unit Effort

Catch per unit of effort (CPUE) was calculated as fish caught/meter^2 for South Slough and Alder Creek. Previously CPUE was calculated as the number of fish caught divided by the number of hours fished. In 2011 fish sampling methods were modified to include seining down the channel into the trap net before the final pull. This distance was used in combination with stream channel width to calculate the area fished in m^2. While this method gives a more definable density of fish than CPUE based on hours fished, it still fails to account for the entire upstream reach that salmon may be using during high tide.

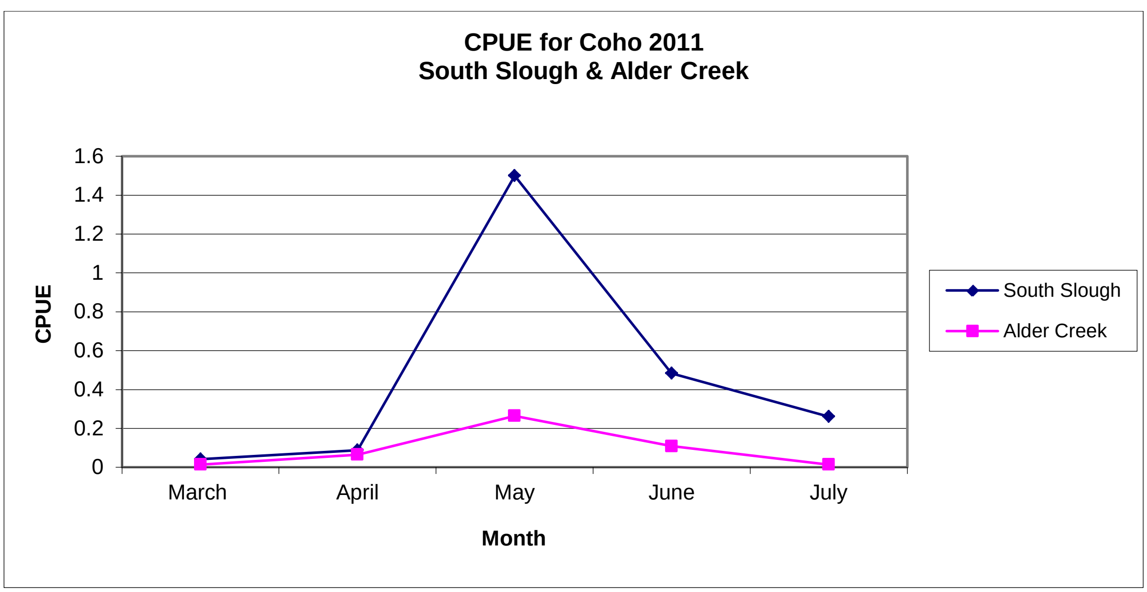


Figure 79. CPUE for coho (fish/m2) at South Slough and Alder Creek, 2011.

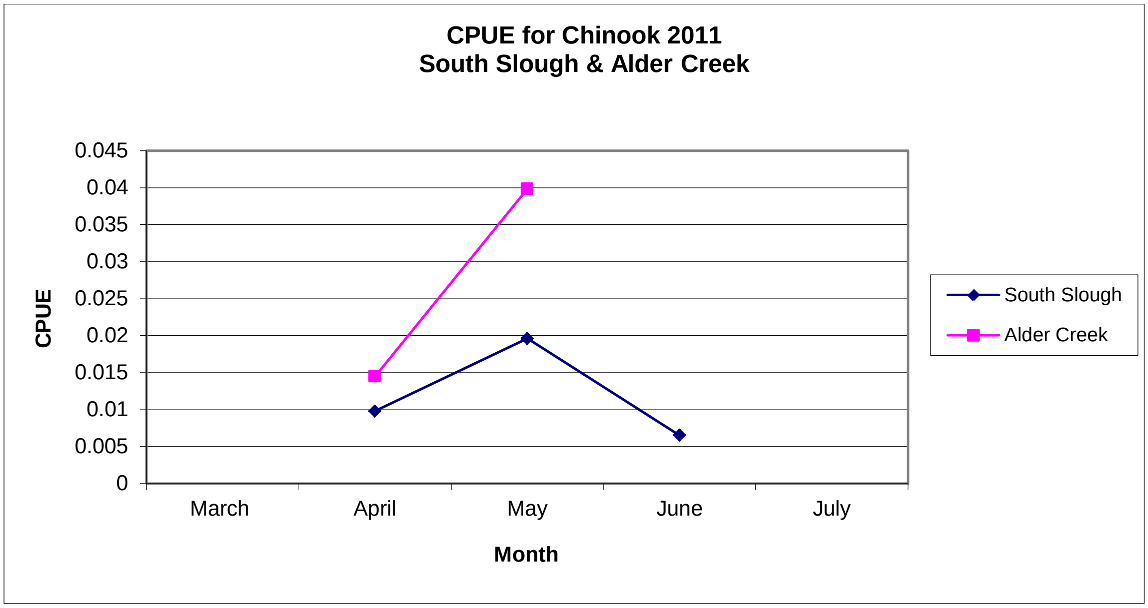


Figure 80. CPUE for Chinook (fish/m2) at South Slough and Alder Creek, 2011.

6.4.1.4 Species Diversity

Species diversity (Figure 81) as calculated by the Shannon-Weiner diversity index was the lowest at lower at South Slough than Alder Creek, although the two were similar. A total of 8 different species were observed at South Slough, not much different than the 7 individual species observed at Alder Creek. The lower indices observed at South Slough was due to the large numbers of three spine stickleback, with this individual species comprising between 89% and 98% of the total catch. Consequently, while the number of different species within the fish community at South Slough was higher, the proportions of individual species within that community were dramatically uneven, resulting in a lower diversity index. The total number of three spine sticklebacks captured at South Slough was substantially greater than the number caught at Alder Creek, resulting in a greater diversity index at the Alder Creek.

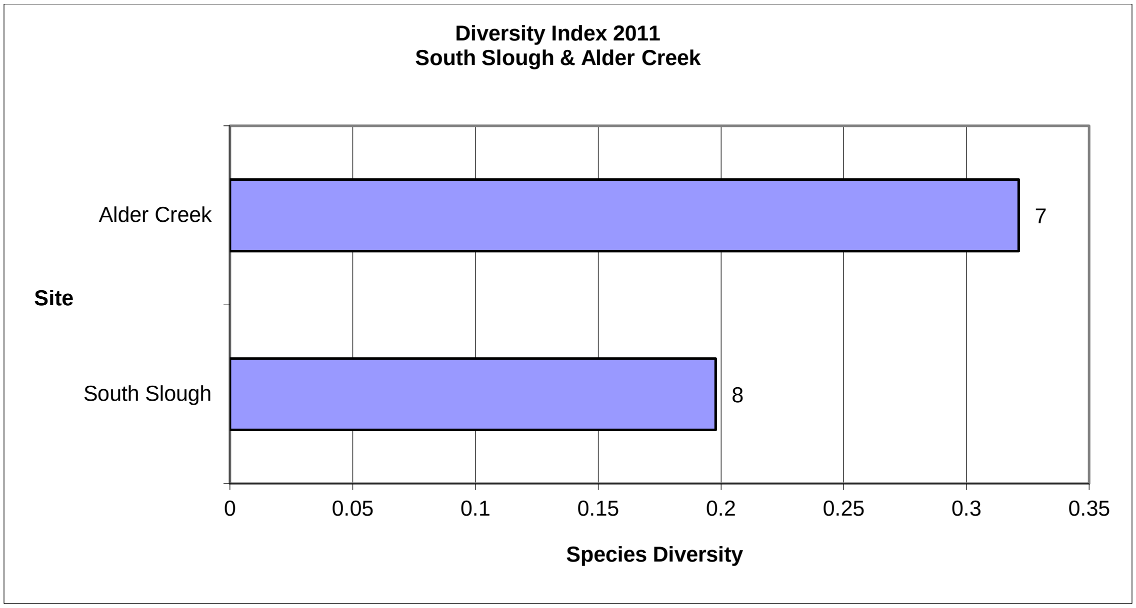


Figure 81. Fish species diversity (Shannon-Wiener Diversity Index) at South Slough and Alder Creek, 2011. Numbers at the end of each bar represent numbers of species captured.

6.4.2 Prey Availability & Salmon Diet

Fall-out traps provide a means to analyze the presence, absence and diversity of terrestrial invertebrates at South Slough and Alder Creek. Prey availability samples were collected to coincide with fish community sampling events. Five samples were collected monthly for both fall-out traps and benthic cores. Species diversity peaked in May and abundance peaked in July. Aphids (53%) and chironomids (22%) were the most abundant prey available at South Slough, while chironomids (29%) and dolichopodids (20%) were the most abundant prey at Alder Creek. Future research will attempt to include abundance per a set area in order to quantitatively measure the actual productivity.

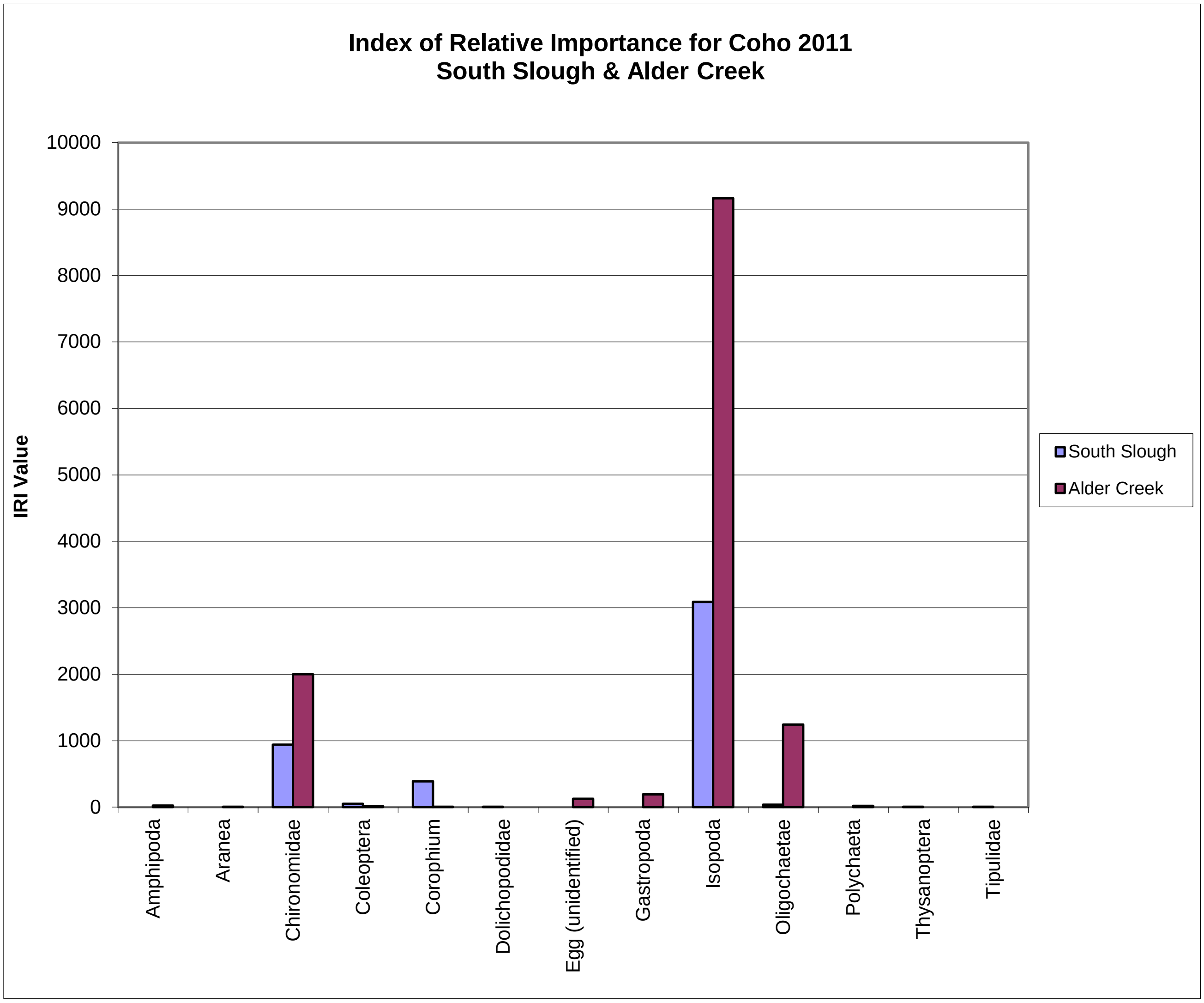


Figure 82. Index of Relative Importance (IRI) for coho diet samples at South Slough and Alder Creek, 2011.

Benthic taxa such as oligocheats and polychaetes were not utilized as a prey source for Chinook at either site, and represented only 3% to 5% of coho diets at South Slough and Alder Creek respectively. Aquatic taxa, particularly isopods were the most utilized prey species and source for both Chinook and coho; this is consistent with sampling data collected in previous years. As benthic prey is a minute component of juvenile salmon diets and aquatic taxa are a predominant component we recommend discontinuing benthic sampling and instead sample the water column to measure abundance and density of aquatic prey taxa at both sites.

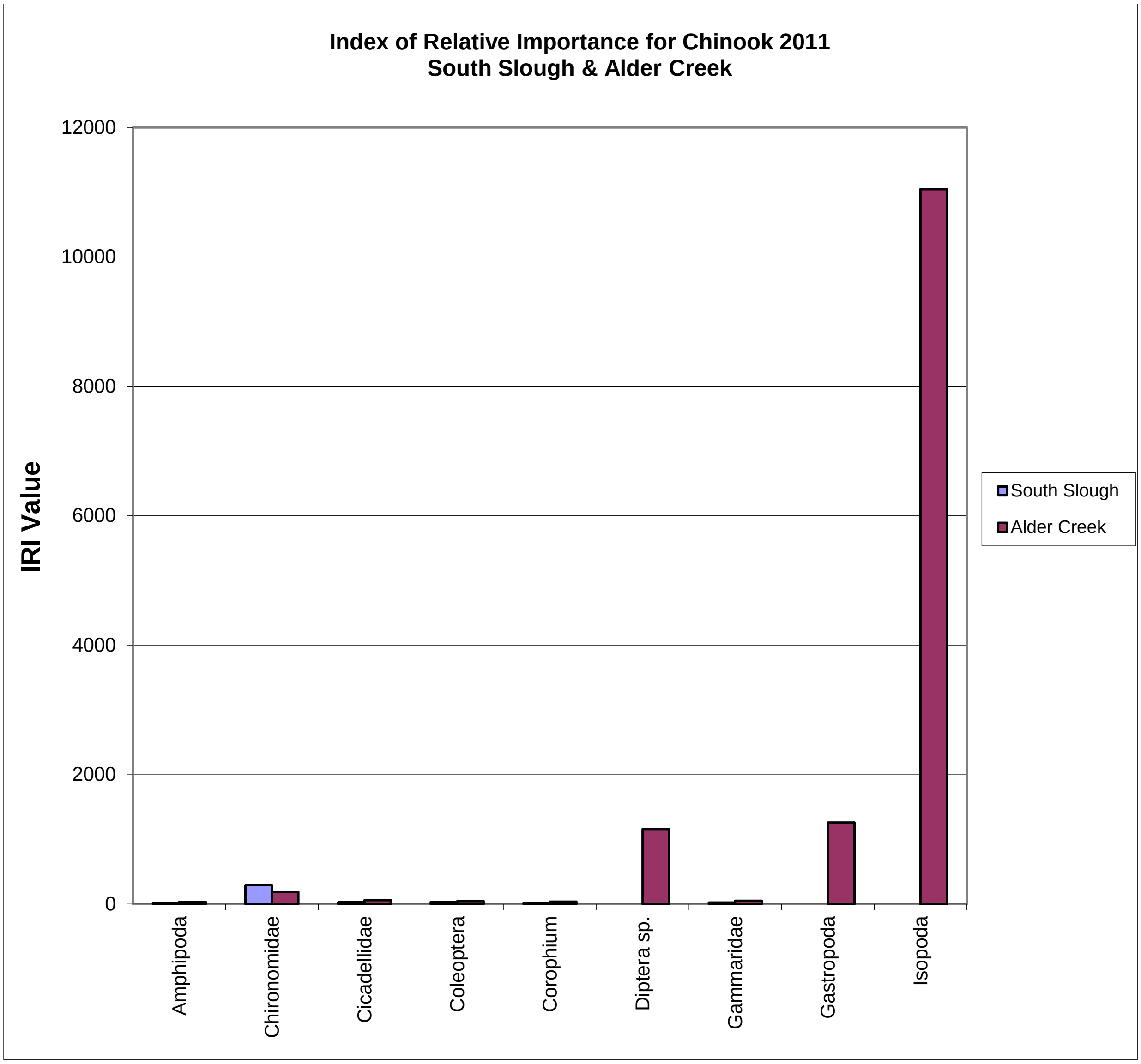


Figure 83. Index of Relative Importance (IRI) for Chinook diet samples at South Slough and Alder Creek, 2011.

Table 34. Diversity of terrestrial invertebrates at South Slough and Alder Creek, 2011.

2011	Prey availability Fall out traps		6.4.2.1 Prey Consumed; Gut contents			
Site	South Slough	Alder Creek	South Slough	Alder Creek	South Slough	Alder Creek
# Of samples (FOT's or stomachs)	17	20	2	8	14	10
Species			Chinook		Coho	
6.4.3 # of Species	26	31	2	5	9	10
Mean proportion by taxa						
Acari		0.3				
Amphipoda				1.70		0.87
Aphidoidea	53.4	0.4				
Aranea		1.2				0.87
Braconidae	0.3	0.2			2.45	
Carabidae	0.5					
Cecidomyiidae	1.0	1.7				
Ceratopogonidae	0.2	0.3				
Chalcoidea		2.5				
Chironomidae	22.3	29.4	11.63	7.50	22.86	21.74
Chloropidae		0.3				
Cicadellidae	1.7	12.7				
Coleoptera		0.6		1.70	2.04	0.87
Copepoda	0.2					
Corophium				1.70	9.39	0.87
Coroxidae	0.5					
Curculionidae	0.2	0.2				
Cynopoidae	0.2					
Delphacidae		0.5				
Dolichopodidae	2.3	20.6			0.41	
Egg (unidentified sp)						7.82
Empididae	0.5	0.4				
Ephydridae	0.5	8.6				
Gastrapoda	1.5	0.9				4.35
Hymenoptera		0.1				
Ichnuemoidea	0.5	0.3				
Isopoda	0.2		88.37	85.80	51.84	57.39
Mesovellidae	0.2					
Muscidae		0.3				
Mymiridae	1.0	1.1				
Oligocheata					2.86	4.35
Phoridae		0.2				
Polycheata						0.87
Psychodidae	5.0	14.1				
Ptychopteridae	5.2	0.6				
Sciaridae	0.7	0.6				
Sphaeroceridae	0.7	0.1				
Staphylinidae	0.2	0.6				
Syrphidae		0.1				
Thysanoptera	0.5	0.6			0.41	
Tipulidae		0.2			0.41	
Trichoptera	0.2	2.8				

6.4.4 Habitat

6.4.4.1 Sediment Accretion

Micro-topographic changes have been seen at South Slough, with sediment eroding several centimeters in 2009, and aggrading in 2010 and 2011. The average change in soil depth was 0.22 (±1.49) cm in 2010, and 0.44 (±1.24) cm in 2011 at South Slough. Alder Creek experienced consistent erosion at a rate of 2.85 (±0.97) cm per year between 2009 and 2010, and a mix of erosion and aggradation between 2010 and 2011 with an average change in soil depth of 0.57 (±3.49) cm per year.

Table 35. Sediment deposition/erosion, average (SD), changes at South Slough and Alder Creek measured in centimeters.

Change in sediment deposition/aggradation in centimeters					
	South Slough			Alder Creek	
	2009	2010	2011	2010	2011
Mean (SD)	-0.2 (±1.49)	+2.2 (±1.24)	+4.4 (±2.39)	+2. 9 (±0.97)	+5.7 (±3.49)

6.4.4.2 Channel Morphology

The following series of figures illustrates the changes in channel width and depth starting downstream and working upstream. South Slough holds water at all times making it accessible to salmonids year round. The lowest channel cross sections, those nearest the bridge, have undergone significant channel deepening, allowing the channel to hold more water during low water events which has resulted in improved access to the site. The lower elevation of the channel near the bridge may decrease water velocity as the head differential in the slough and outside is reduced as well. Lower water velocity will allow small juvenile salmon easier access to the site. It should be noted however that water velocity measurements have not been taken and this hypothesis is based solely on the channel profile.

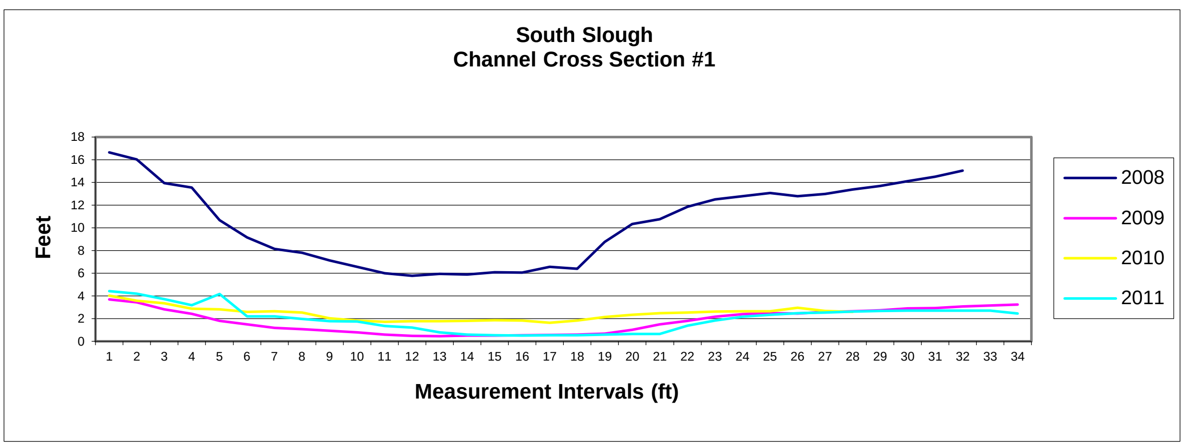


Figure 84. Downstream most channel cross section, #1, at South Slough, 2008 - 2011.

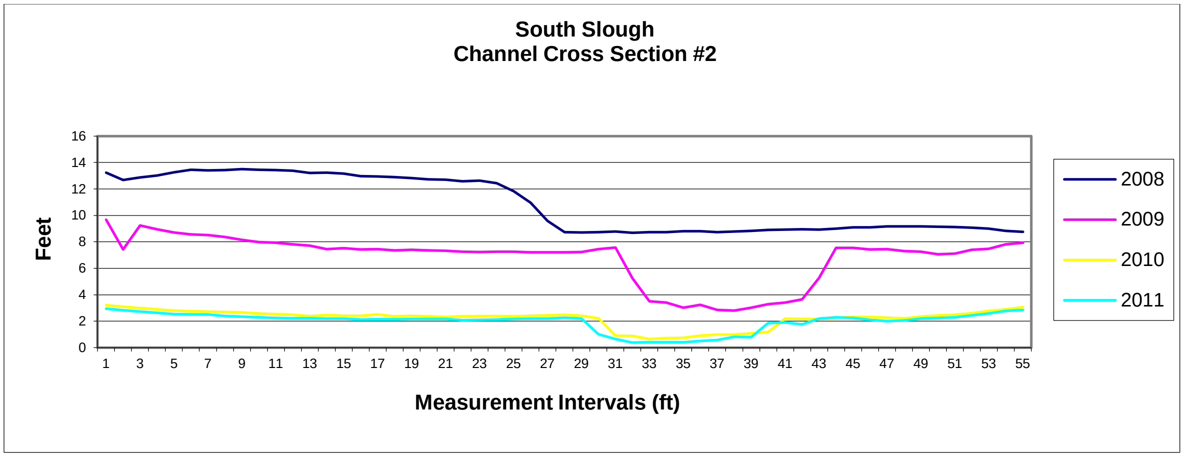


Figure 85. Channel cross section #2 at South Slough, 2008 - 2011.

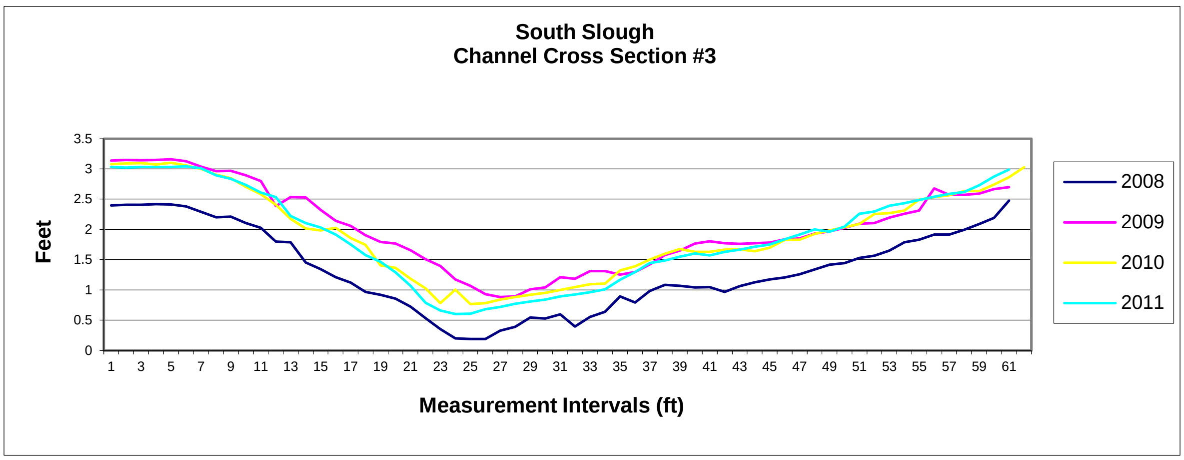


Figure 86. Channel cross section #3 at South Slough, 2008-2011.

Channel cross sections #4 and #5 are upstream in South Slough near the fish sampling site (Figure 87 and Figure 88). These show changes in the channel bottom aggrading over the past five years, as opposed to the previous cross section, which underwent significant erosion in the channel.

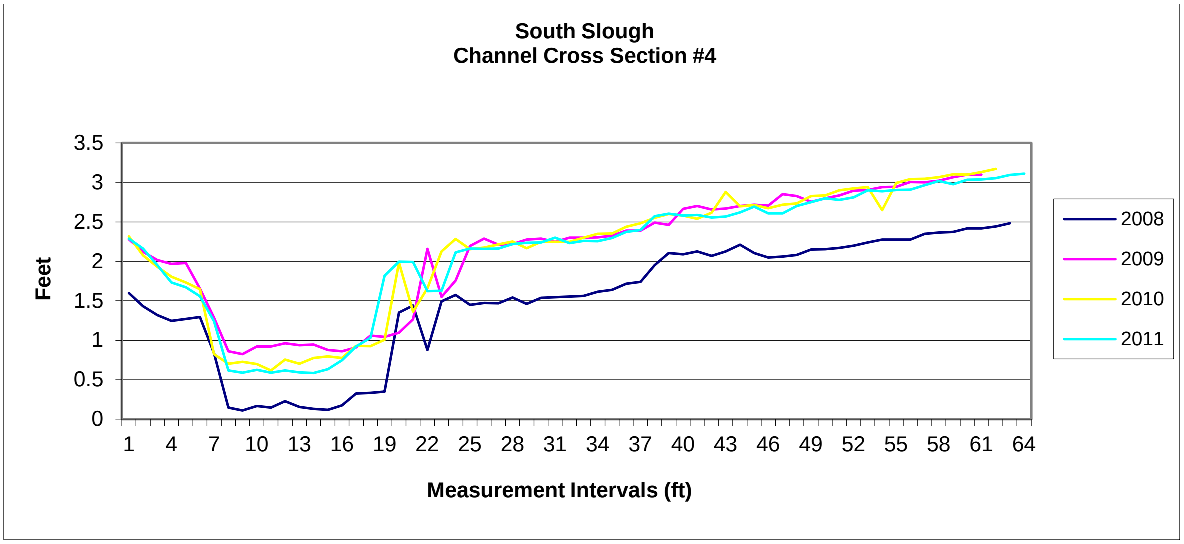


Figure 87. Channel cross section #4 at South Slough, 2007-2011.

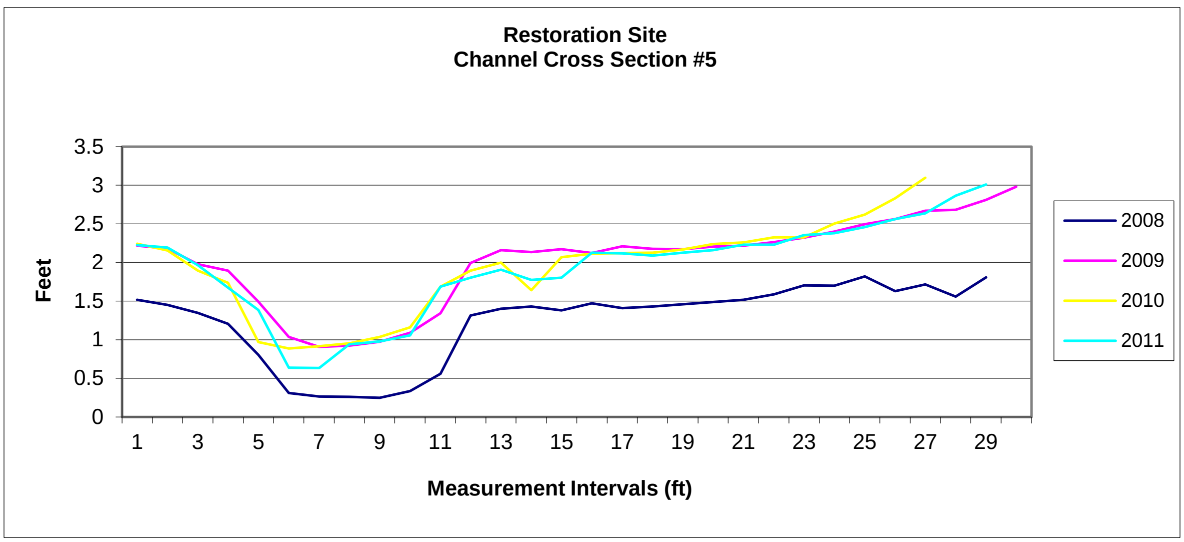


Figure 88. Upstream most channel cross section, #5, at South Slough, 2007-2011.

Channel cross sections at the Alder Creek demonstrated surprising results. The degree of expected change in channel erosion and aggradation were small, however the actual degree of change was substantial. This signifies the continuous dynamic environment of tidal channels in the lower estuary. Unlike the South Slough Alder Creek has demonstrated some slight channel migration as well as consistent erosion along all five cross sections. The level of change is in smaller increments, Sough Slough eroded down 6 ft. in some areas, while the reference site eroded only 1 ft.

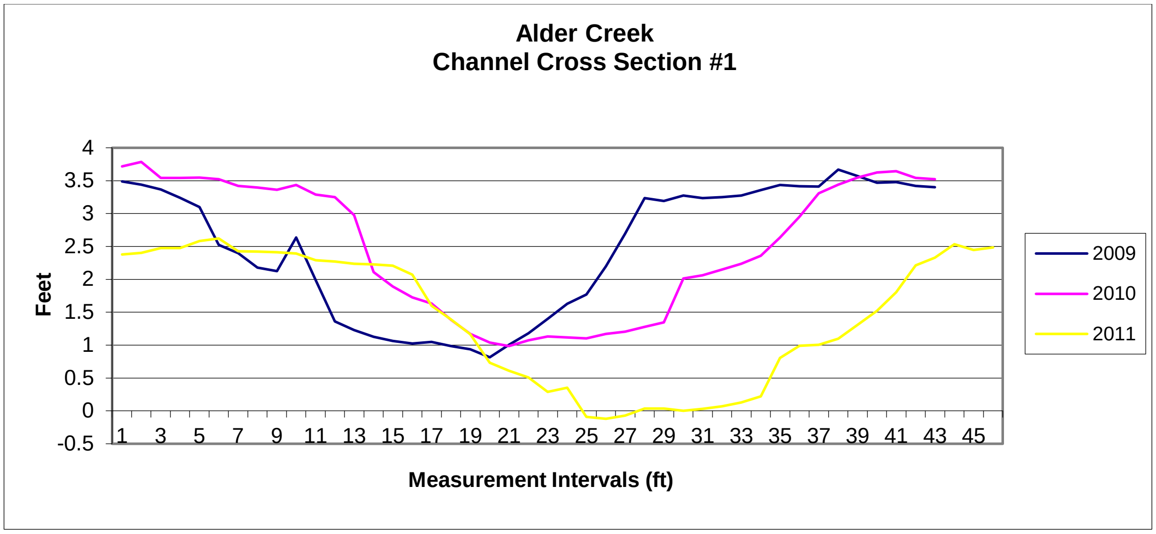


Figure 89. Downstream most channel cross section, #1, at Alder Creek, 2009-2011.

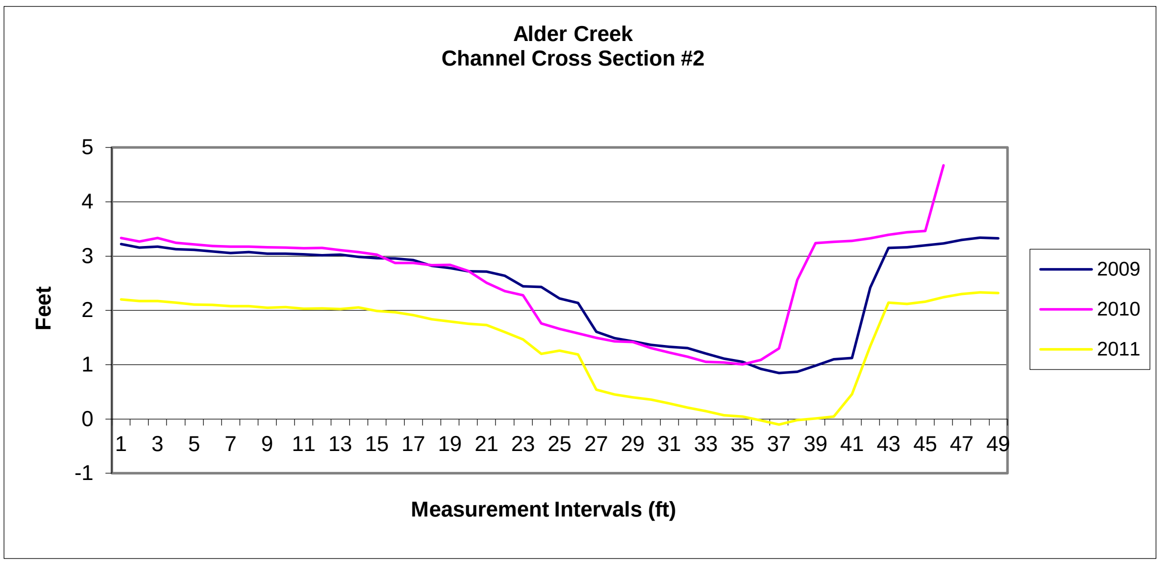


Figure 90. Channel cross section #2 at Alder Creek, 2009-2011.

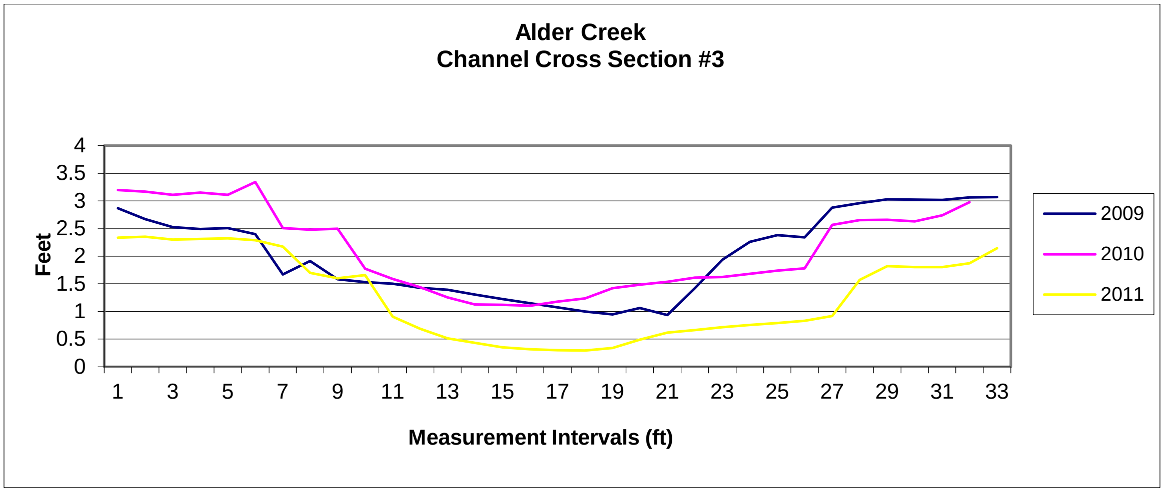


Figure 91. Channel cross section #3 at Alder Creek, 2009-2011.

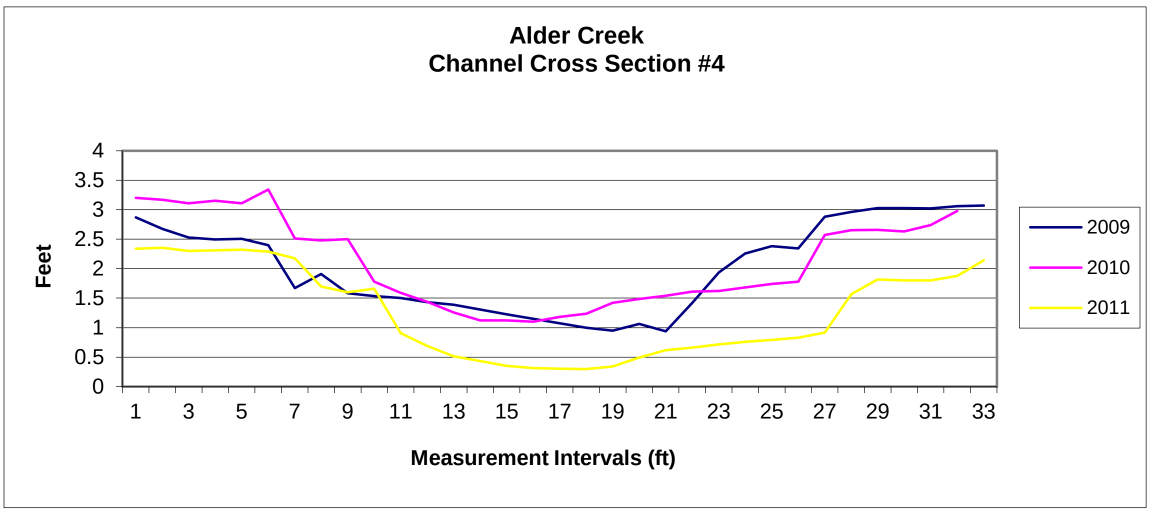


Figure 92. Channel cross section #4 at Alder Creek, 2009-2011.

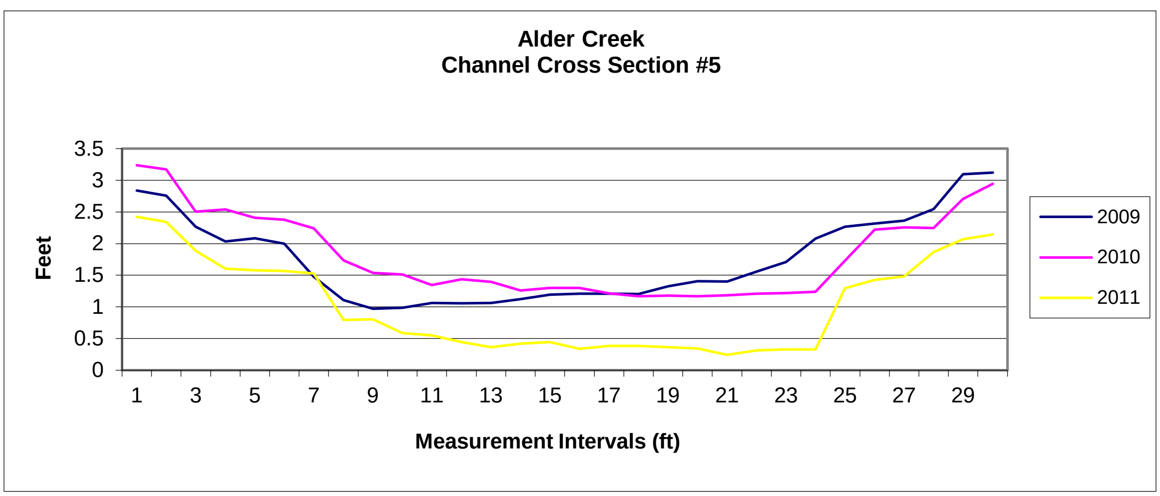


Figure 93. Upstream most channel cross section, #5, at Alder Creek, 2009-2011.

6.4.4.3 Water Quality

Water quality parameters including temperature, DO, depth (pressure), and conductivity have been measured pre and post restoration at South Slough to evaluate the changes resulting from reconnection of tidal influence and the ensuing benefits to salmon. Juvenile salmon have a water temperature range of around 0° C to 24° C (Johnson et. al. 2011). Water temperature influences the metabolism, behavior, and mortality of fish and the other organisms in their environment (Mihursky and Kennedy 1967). For salmonids and other fish species, no single environmental factor affects development and growth rate more than water temperature, and many salmonids change behavior with increases or decreases in temperature (Bjornn1991). Low temperatures in the winter can result in casualties of stream type Chinook and coho, and high temperatures in the summer can limit the distribution and growth capacity of juvenile salmonids. Annual temperature changes impact many biological processes for juvenile and adult salmonids; including but not limited to feeding potential, growth rates, spawning, smoltification, hatching, out migration timing and success.

Prior to restoration activities South Slough had limited tidal connectivity which restricted the degree of water and nutrient exchange with the mainstem Lewis & Clark River, and decreased the amount of sediment transportation (no data available to support this). Post restoration temperature maximums were consistently lower than 2007 temperatures at South Slough (Figure 94). Alder Creek maintained higher temperature maximums throughout the year (Figure 95), a reflection of the site conditions, the shallow channel and lack of woody vegetation along the riparian zone. It is important to take the differences in site conditions into consideration when comparing South Slough and Alder Creek. South Slough is a much deeper channel than Alder Creek, which may explain the differences in water temperature between the two sites during similar times of the year. It is also important to note that water quality data was not collected at Alder Creek in 2007, while it can be assumed that annual variation in temperature at South Slough would remain relatively consistent from one year to the next we have no data to confirm this assumption.

Comparing South Slough temperatures to those of Alder Creek, trends in 7-Day moving average (7-DMA) temperatures clearly become more analogous after restoration (Figure 94). From 2007 through 2011, temperatures in South Slough were monitored and contrasted with temperatures at Alder Creek. Temporal trends in 7-DMA temperature time series during the period of time in which salmonids are in high abundance demonstrated similar temporal trends within and across all years post restoration (Figure 94). Each year, the 7-DMA temperatures approached or exceeded the generally acceptable tolerance range for salmonids in the late summer months at both sites.

The data indicates that temperatures at South Slough are more similar to temperatures of Alder Creek post-restoration and at times even cooler due in part to differences in channel morphology and sensor placement. Maximum temperatures at South Slough remained 1 to 3 °C lower than temperatures of the adjacent Alder Creek, particularly in the later months of June through August. As mentioned previously the channel at South Slough retains greater water depth than the channel at Alder Creek. South Slough also has a consistent freshwater input from a well shaded upstream reach, while Alder Creek is fed by water that travels in very shallow channel across a large wetland. The differences in upstream freshwater input may contribute to differences in water temperature in the summer months when air temperatures and solar radiation are greater.

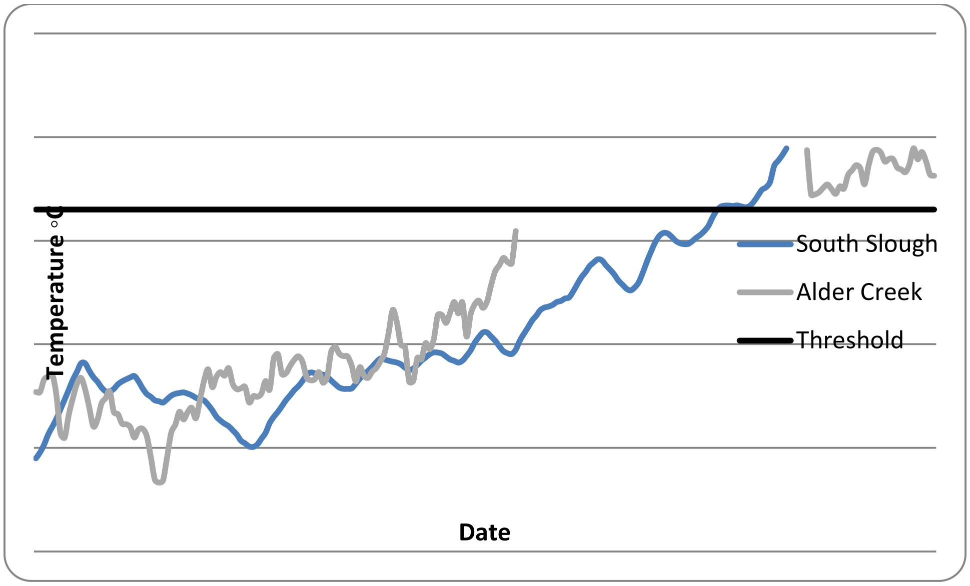


Figure 94. 7 day moving average for temperature at South Slough and Alder Creek, 2011. Threshold is set at 16.5˚C.

The optimal DO level for salmonids is 11 mg/L (ODEQ 2003). A range of 7-8mg/L will result in impairment in production, while 3-6 mg/L is considered lethal (ODEQ2003). DO levels at South Slough remain within acceptable levels averaging 8.23 mg/L. Due to equipment fouling, DO levels at the Alder Creek are not as well defined. The water quality probe requires a minimum depth of 10 inches to keep the sensors in water. Alder Creek water levels drop to several inches in the majority of the channel, exposing the sensors to air, which results in fouling of the DO sensor and decreased accuracy. During the time period in which data was gathered at Alder Creek the average DO has been recorded at 8.86 mg/L. A comparison of South Slough DO levels to that of Alder Creek reveals trends in 7-Day moving average (7-DMA) DO to be rather analogous (Figure 95).

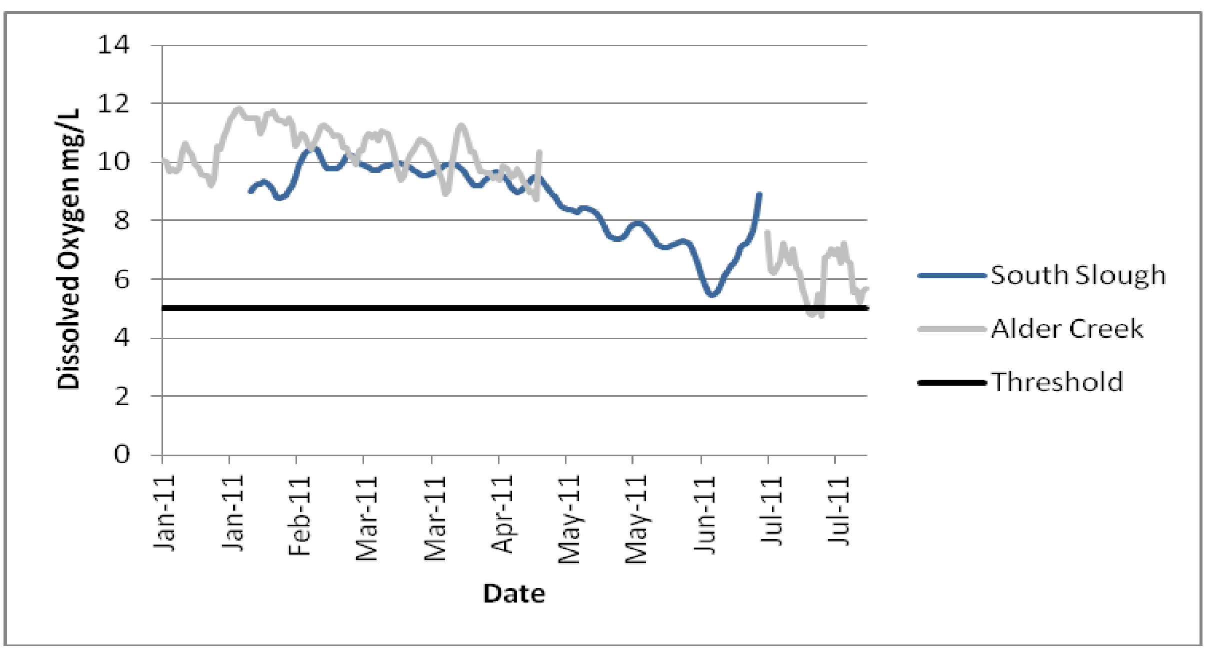


Figure 95. 7 day moving average for dissolved oxygen at South Slough and Alder Creek, 2011. Threshold is set at 5 mg/L (Bjornn 1991).

Table 36. Temperature maximums and average (SD) for South Slough and Alder Creek, 2007-2011. **No data collected in 2007.*

In stream temperature ranges in South Slough and Alder Creek

		Max Temp					**Mean (SD) Temp**				
		2007	**2008**	**2009**	**2010**	**2011**	**2007**	**2008**	**2009**	**2010**	**2011**
South Slough	Jan	16.0	8.19	8.0	9.92	10.17	4.36 (±0.77)	4.32 (±1.74)	5.17 (±0.91)	8.14 (±0.83)	8.53 (±0.67)
	Feb	16.11	9.95	8.76	11.02	9.43	7.03 (±2.83)	6.98 (±1.22)	12.77 (±1.93)	8.36 (±0.87)	6.53 (±1.43)
	Mar	13.22	10.83	10.98	14.52	12.04	8.89 (±1.74)	7.98 (±1.05)	11.35 (±2.26)	9.33 (±1.48)	8.09 (±1.20)
	Apr	15.96	14.97	16.95	15.46	14.23	11.98 (±1.54)	9.51 (±1.67)	11.17 (±1.81)	10.47 (±1.83)	9.54 (±1.29)
	May	21.0	21.22	17.48	18.59	15.06	14.75 (±2.03)	13.69 (±2.33)	12.5 (±1.62)	12.8 (±2.01)	12.67 (±1.35)
	Jun	21.68	21.28	21.63	20.56	20.48	17.39 (±0.77)	14.67 (±2.63)		14.29 (±2.27)	15.73 (±1.81)
	Jul	25.68	22.91		22.54	22.71	20.34 (±0.77)	18.46 (±1.64)		17.25 (±2.03)	18.65 (±2.21)
	Aug	25.57	23.8		19.13		19.29 (±0.77)	18.76 (±1.43)			
Alder Creek	**Jan**	*			8.81		*		6.37 (±1.24)	8.07 (±0.82)	6.52 (±1.62)
	Feb					13.29		8.88 (±0.56)		7.50 (±0.53)	7.38 (±1.46)
	Mar					16.83		8.28 (±0.69)			9.16 (±1.32)
	Apr			17.11		18.01			10.98 (±2.02)		11.54 (±2.17)
	May			23.36					11.79 (±1.74)		
	Jun			22.33				17.94 (±1.49)	17.33 (±1.62)		
	Jul			21.47		24.36		19.57 (±0.96)	19.03 (±2.03)		18.21 (±1.74)
	Aug			22.34		24.01		19.59 (±0.92)	18.86 (±1.55)		18.80 (±1.53)

6.4.5 Discussion

6.4.5.1 Fish Community

The modification in fish sampling methods in 2011 increased catch totals and provided a more accurate representation of the fish density, abundance and composition. Seining down the channel accomplished this by reducing escapement and provided a measureable area to base fish density estimates. This method will be continued in upcoming seasons at South Slough and Alder Creek.

The differences between South Slough and Alder Creek were apparent in comparing data from 2011, and previous years sampled. Alder Creek was selected as a reference site as a result of its similarities in landscape position, tidal regime, and proximity to South Slough. The channel at Alder Creek is wide and very shallow at low tide, reducing the habitat opportunity and quality. South Slough retains several feet of water, and receives regular freshwater input from two small streams residing in well-shaded ravines above South Slough. The freshwater input and lower channel elevation provide more habitat opportunity and better habitat quality than Alder Creek. The higher abundance of fish at South Slough is a reflection of these differences. Larger numbers of fish were caught at South Slough in 2011, which is consistent with previous years fished.

Overall fish community composition, timing and diversity were consistent with previous year's data. The greatest difference between 2011 and previous years was the abundance of juvenile salmon, particularly coho, caught at both sites. It is believed to be due to improved fishing methods, but data will need to be collected during upcoming years using the same sampling methods in 2011 before any reliable inferences can be established. The large numbers of coho observed at South Slough were mostly between 35mm and 50mm. These small coho are utilizing the habitat earlier in the summer and either residing in the slough and growing in size or migrating farther up/out of the slough as larger size fish migrate in.

Size class and timing of Chinook and coho demonstrated similar trends at South Slough and Alder Creek. Peak abundance coincided with smaller sized juvenile salmon, and as average size increased abundance decreased throughout the sampling season.

6.4.5.2 Prey Availability & Salmon Diet

Chinook demonstrated a preference for isopods and chironomids; isopods were favored at Alder Creek, chironomids were selected more at South Slough. Coho primarily selected isopods and chironomids at both sites. Coho demonstrated a wider range of prey selectivity, suggesting they may be more opportunistic feeders, and Chinook more selective. This may also be due to a greater number of diet samples from coho than Chinook. Aphids (53%) represented the largest percentage of prey available at South Slough, followed by chironomids (22.3%). Alder Creek exhibited a more uniform distribution of percentages of prey available. Chironomids represented the largest percentage of terrestrial prey (29.4%), followed by dolichopodids (20.6%), psychodids (14.1%), and cicadellids (12.7%).

Isopods represented the most common prey species found in gut content samples. Interestingly, the species was not found in similar abundances in prey availability samples proportional to those found within the gut content samples. Terrestrial macroinvertebrate prey sampling is a useful prey availability monitoring method. However, the data collected from such methods does not accurately reflect the quantity utilized by salmonids. A combination of terrestrial and aquatic sampling methods could provide a more accurate portrayal of the prey species available to salmonids. It is recommended that additional aquatic invertebrate sampling (i.e., neuston tows) be implemented in upcoming monitoring years in order to capture the availability (abundance) and density of prey species such as isopods at both sites.

6.4.5.3 Sediment Accretion & Channel Morphology

Sediment accretion revealed an increase in sediment deposition in the adjacent floodplain at both Sough Slough (+4.4 cm) and Alder Creek (+5.7 cm). Changes in channel morphology were smaller between 2010 and 2011 than in previous years. Successional change in channel depth was dramatic between 2008 and 2010 in South Slough. The decrease in measureable change may signify the channel is near historic conditions (elevation, width). Change is anticipated to continue as the banks gradually subside and sediment is moved within the channel and floodplain.

6.4.5.4 Water Quality

It is evident that water temperature, a critical component influencing fish fitness and utilization of shallow-water areas, reacted to the re-establishment of natural tidal hydrodynamics. The contrast in temperature data from 2007 to 2008 at South Slough revealed the benefits of a more complete tidal hydrological connection in terms of restoring natural water temperatures. The temperatures inside South Slough were much warmer than those in Alder Creek previous to restoration, which indicated restricted connection with water from the Lewis and Clark River. Higher water temperatures indicate that the water held in South Slough probably was stagnant at times because of the disrupted connection. DO was not accurately measured before restoration but we suspect that lower flushing rates and longer residence times would result in lower DO levels.

Reconnection of tidal influence to South Slough has resulted in lower water temperatures, increased DO levels, and restored tidal signature to the site. South Slough had more optimal water quality conditions for salmon than did Alder Creek. Key differences in landscape characteristics are likely a contributing factor. South Slough is deeper, particularly after tidal reconnection, and is fed by a consistent source of cold fresh water year round. Alder Creek has full tidal connectivity; however the main freshwater source is wetland runoff/very small and shallow streams that run through the wetland. Alder Creek holds several inches of water during low tide while South Slough holds at least a couple feet and in most stream reaches more. This again is a reflection of differences in channel elevation between the two sites.

Water temperature is a key factor affecting the growth and survival of salmonids (OWEB 2001). The optimal temperature range for juvenile salmonid habitat is 7.2-15.6°C and the 7-DMA maximum temperature for salmonid rearing habitat is 18°C (OWEB 2001, ODEQ 2003). The Washington Department of Ecology (WDE) suggest that the best estimate of threshold for a healthy summer rearing temperature ranged between 14.78-18.08°C with a mean value of 16.5°C. Temperature data for South Slough and Alder Creek (Figure 94) reveal the 7-DMA to approach and surpass WDE best estimate of juvenile rearing threshold (16.5°C), but remains below the maximum 7-DMA for ODEQ. Data exceeding this threshold does not come within the range considered as lethal (25°C) to salmonids (Table 36), but does imply that both sites exceed the temperatures preferred by rearing juveniles in the warm summer months. It should be noted however that the maximum temperatures in Table 10 are commonly seen at low tide when there is little water in the channel. During those times (specifically at Alder Creek) it is reasonable to assume that most fish species have evacuated the site with the outgoing tide, seeking the cooler temperatures of the adjacent Lewis and Clark River.

7.0 Literature Cited

3.0 Fish-passage Improvement and LWD AEM at Mirror Lake

Biro P.A., A.E. Morton, J.R. Post, and E.A. Parkinson. 2004. Over-winter lipid depletion and mortality of age-0 rainbow trout (*Oncorhynchus mykiss*). Can. J. Fish. Aquat. Sci. 2004; 61:1513-1519.

Carter, J. A., G. A. McMichael, I. D. Welch, R. A. Harnish, and B. J. Bellgraph. 2009. Seasonal Juvenile Salmonid Presence and Migratory Behavior in the Lower Columbia River. PNNL-18246, Pacific Northwest National Laboratory, Richland, WA.

Elskus, A., T.K. Collier, and E. Monosson. 2005. Interactions between lipids and persistent organic pollutants in fish. Pages 119-152 in Environmental Toxicology, Elsevier, San Diego.

Fulton, T. 1902. Rate of growth of seas fishes. Sci. Invest. Fish. Div. Scot. Rept. 20.

Gadomski, D.M. and P.G. Wagner. 2009. Factors affecting the age-0 resident fish community along shorelines of the Hanford Reach of the Columbia River. Northwest Science, 83: 180-188.

Jones, K.L., C.A. Simenstad, ,J.L. Burke, T.D. Counihan, I.R. Waite, J.L. Morace, A.B. Borde, K.L., Sobocinski, N. Sather, S. A. Zimmerman, L.L. Johnson, P.M. Chittaro, K.H. Macneale, O.P. Olson, Sean Y. Sol, David J. Teal, Gina M. Ylitalo, Laura Johnson. 2008. Lower Columbia River Ecosystem Monitoring Project Annual Report for Year 5 (September 1, 2007 to August 31, 2008). Prepared by the Lower Columbia River Estuary Partnership with support from the Bonneville Power Administration. Lower Columbia River Estuary Partnership, Portland, OR. 128 pp.

Johnson, L.L. P.M. Chittaro, K. H. Macneale, O. P. Olson, S. Y. Sol, D.J. Teel and G. M. Ylitalo. 2011. Fish Monitoring Component of the Lower Columbia River Ecosystem Monitoring project 2007-2010. Prepared by NOAA's Northwest Fisheries Science Center for the Lower Columbia River Estuary Partnership and the Bonneville Power Administration. December 2011

Johnson O.W., W.S. Grant, R.G. Kope, K. Neely, F.W. Waknitz, and R.S. Waples. 1997. *Status Review of Chum Salmon from Washington, Oregon, and California*. NOAA Technical Memorandum NMFS-NWFSC-32, Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington.

Kalinowski, S.T., K.R. Manlove, and M.L. Taper. 2007. ONCOR a computer program for genetic stock identification. Montana State University, Department of Ecology, Bozeman. Available: montana.edu/kalinowski/Software/ONCOR.htm.

Lassiter, R.R., and T.G. Hallam. 1990. Survival of the fattest: implications for acute effects of lipophilic chemicals on aquatic populations. Environmental Toxicology and Chemistry 9: 585–595.

LaVigne, H.R., R.M. Hughes, R.D. Wildman, S.V. Gregory, and A.T. Herlihy. 2008.Summer Distribution and Species Richness of Non-native Fishes in the Mainstem Willamette River, Oregon, 1944–2006. Northwest Science, 82(2):83-93.

Margalev R. 1958. Information theory in ecology. General Systems, 3, 36-71.

Manel, S., O.E. Gaggiotti, and R.S. Waples. 2005. Assignment methods: matching biological questions with appropriate techniques. Trends in Ecology and Evolution 20:136–142.

Rannala B. and J.L. Mountain. 1997. Detecting immigration by using multilocus genotypes. Proceedings of the National Academy of Sciences 94: 9197-9201.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:1-382.

Roegner, G.C., E.W. Dawley, M. Russell, A. Whiting, D.J. Teel. 2010. Juvenile salmonid use of reconnected tidal freshwater wetlands in Grays River, lower Columbia River basin. Transactions of the American Fisheries Society 139:1211-1232.

Roegner, G.C., H.L. Diefenderfer, A.B. Borde, R.M. Thom, E.M. Dawley, A.H. Whiting, S.A. Zimmerman, and G.E. Johnson. 2009. Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-97, 63 pp.

Seeb, L.W., A. Antonovich, M.A. Banks, T.D. Beacham, M.R. Bellinger, S.M. Blankenship, M.R. Campbell, N.A. Decovich, J.C. Garza, C.M. Guthrie III, T.A. Lundrigan, P. Moran, S.R. Narum, J.J. Stephenson, K.T. Supernault, D.J. Teel, W.D. Templin, J.K. Wenburg, S.F. Youngs, and C.T. Smith. 2007. Development of a standardized DNA database for Chinook salmon. Fisheries 32:540–552.

Sloan, C. A., D. W. Brown, G. M. Ylitalo, J. Buzitis, D. P. Herman, D. G. Burrows, G. K. Yanagida, R. W. Pearce, J. L. Bolton, R. H. Boyer, M. M. Krahn. 2006. Quality assurance plan for analyses of environmental samples for polycyclic aromatic compounds, persistent organic pollutants, fatty acids, stable isotope ratios, lipid classes, and metabolites of polycyclic aromatic compounds. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-77, 30 pp.

Sloan, C. A., D. W. Brown, R. W. Pearce, R. H. Boyer, J. L. Bolton, D. G. Burrows, D. P. Herman, M. M. Krahn. 2004. Extraction, cleanup, and gas chromatography/mass spectrometry analysis of sediments and tissues for organic contaminants. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-59, 47 pp.

Sol, S.Y, O.P. Olson, K.H. Macneale, P. Chittaro, D. Teel and L.L. Johnson. 2009. Summary of Results of the Fish Monitoring Component of the Lower Columbia River Effectiveness Monitoring Project 2007-2008. Contract Report submitted to LCREP January 2009.

Sol, S.Y., A. Cameron, O.P. Olson, K.H Macneale, D. Teel, Y. Hanagida, G. Ylitalo, and L.L. Johnson. 2010. Summary of Results of the Fish Monitoring Component of the Lower Columbia River Effectiveness Monitoring Project 2009. Contract Report submitted to LCREP August 2010.

Sol, S.Y., A. Cameron, O.P. Olson, K.H Macneale, D. Teel, Y. Hanagida, G. Ylitalo, and L.L. Johnson. 2011. Summary of Results of the Fish Monitoring Component of the Lower Columbia River Restoration Effectiveness Monitoring Project 2010.

Strayer, D.L. 2010. Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. Freshwater Biology (2010), 55 (Suppl. 1), 152–174.

Taylor, J. N., W. R. Courtenay, and J. A. McCann. 1984. Distribution, Biology, and Management of Exotic Fishes. The Johns Hopkins University Press, Baltimore, MD.

Teel, D.J., C. Baker, D.R. Kuligowski, T.A. Friesen, and B. Shields. 2009. Genetic stock composition of subyearling Chinook salmon in seasonal floodplain wetlands of the Lower Willamette River. Transactions of the American Fisheries Society 138:211-217.

van Wezel A.P., D.A.M. de Vries, S. Kostense, D.T.H.M. Sijm, and Q. Opperhuizen. 1995. Intraspecies variation in lethal body burdens of narcotic compounds. Aquatic Toxicology 33:325–342.

Ylitalo, G. M., G. K. Yanagida, L. C. Hufnagle Jr., M. M. Krahn. 2005. Determination of lipid classes and lipid content in tissues of aquatic organisms using a thin layer chromatography/flame ionization detection (TLC/FID) microlipid method. Pages 227-237 in Ostrander, G. K. (Ed.) Techniques in Aquatic Toxicology. CRC Press, Boca Raton, FL

4.0 Planting Success AEM at Mirror Lake and Sandy River Delta

Roegner et al in "Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary", 2009, Section 4.0, Monitoring Protocol: 4.5, Plant Community.

5.0 Vegetation and Habitat AEM at Scappoose Bottomlands

Chaneton, E.J. and J.M. Facelli. 1991. Disturbance effects on plant community diversity: spatial scales and dominance hierarchies. Vegetation 93: 143-155.

Casanova, M.T., and M.A. Brock. 2000. How do depth, duration and frequency of flooding influence the establishment of wetland communities? Plant Ecology 147: 237–250.

Cowardin, LM, V Carter, FC Golet, and ED LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Publication FWS/OBS-79/31. US Department of Interior, Fish and Wildlife Service, Office of Biological Services, Washington, DC.

David Evans and Associates (DEA). 2000. Scappoose Bay Watershed Assessment. David Evans and Associates, Portland, OR.

Dosskey, MG, P Vidon, NP Gurwick, CJ Allan, TP Duval, and R Lowrance. 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. Journal of the American Water Resources Association(JAWRA) 46(2):261-277.

Egna, HS and CE Boyd. 1997. Dynamic of Ponds Aquaculture. CRC Press Salem, 415 pp.

Environmental Protection Agency (EPA). 2001. Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Rivers and Streams in Ecoregion I and II. EPA-0822-B-01-012. Accessed online at:
http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_1.pdf.
http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_2.pdf.
http://water.epa.gov/type/rsl/monitoring/vms59.cfm

Guard, B. 1995.Wetland Plants of Oregon and Washington.Lone Pine Publishing, Redmond, WA.

Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

Jenkins, N.J., Yeakley, J.A., and Stewart, E.M. 2008. Responses of Phalaris Arundinacea L. to managed flooding of wetlands in the Columbia Slough in Portland, Oregon, USA. Wetlands 28:1018-1027.

Kim, KD, K Ewing, and DE Giblin. 2006. Controlling Phalaris arundinacea (reed canarygrass) with live willow stakes: a density-dependent response. Ecol. Eng. 27(3):219–227.

Lavergne, S and J Molofsky. 2004. Reed canary grass (Phalaris arundinacea) as a biological model in the study of plant invasions. Crit. Rev. Plant Sci 23:415–429.

Ludwig, J.A. & Reynolds, J.F. 1988 Statistical ecology: a primer on methods and computing. New York: John Wiley and Sons.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia and Alaska. Lone Pine Publishing, British Columbia, Canada.

Oregon Department of Environmental Quality (ODEQ). 2003. Water quality standards: Beneficial uses, policies, and criteria for Oregon. OAR 340-041. Accessed online at: http://arcweb.sos.state.or.us/rules/OARs_300/OAR_340/340_041.html.

Oregon Watershed Enhancement Board (OWEB). 2001. Water quality monitoring, technical guide book, Version 2.0. Accessed online at: http://www.oregon.gov/OWEB/docs/pubs/wq_mon_guide.pdf

Roegner GC, HL Diefenderfer, AB Borde, RM Thom, EM Dawley, AH Whiting, SA Zimmerman, GE Johnson. 2008. Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary. PNNL-15793. Report by Pacific Northwest National Laboratory, National Marine Fisheries Service, and Columbia River Estuary Study Taskforce submitted to the US Army Corps of Engineers, Portland District, Portland OR.

Schindler DE, Scheuerell MD, Moore JW, et al. 2003. Pacific salmon and the ecology of coastal ecosystems. Front Ecol Environ 1: 31–37.

Singleton. 2001. Ambient water quality guidelines for turbidity, suspended, and benthic sediments. British Columbia Ministry of Environment. Accessed online: <http://www.env.gov.bc.ca/wat/wq/BCguidelines/turbidity/turbidity.html#tab1>

Tiner, R. W. 1991.The concept of hydrophyte for wetland identification. Bioscience 41, 236-247.

University of Wisconsin Extension (UWE). 2006. Water Action Volunteers Fact Sheet—Turbidity. Accessed online:<http://watermonitoring.uwex.edu/pdf/level1/FactSeries-Turbidity.pdf>

Welch, B., Davis C., Gates R. 2006. Dominant environmental factors in wetland plant communities invaded by Phragmites australis in East Harbor, Ohio, USA. Wetlands Ecology and Management (2006) 14:511 –525

Wisconsin Reed Canary Grass Management Working Group (WRMWG). 2009. Reed Canary Grass (Phalaris arundinacea) Management Guide: Recommendations for Landowners and Restoration Professionals. PUB-FR-428 2009.

6.0 Salmon, Salmon Prey, and Habitat AEM at Scappoose Bottomlands and Fort Clatsop

Bjornn, T. C. and D. W. Reiser, 1991. Influences of Forest and Rangeland Management on Salmonid fishes and Their Habitats. American Fisheries Society Special Publication 19:83-138.

Borde, A. B., E. M. Dawley, B. D. Ebberts, C. G. Roegner, M. T. Russell, J. R. Skalski, R. M. Thom, J. Vavrinec III, and S. A. Zimmerman. 2008. Evaluating Cumulative Ecosystem Response to

Restoration Projects in the Lower Columbia River and Estuary. Pacific Northwest National Laboratory, Marine Sciences Laboratory.

Fresh, K., E. Casillas, L. Johnson, and D. Bottom. 2005. Role of the Estuary in the Recovery Columbia River Basin Salmon and Steelhead: An Evaluation of Selected Factors on Population Viability. U.S. Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS-NWFSC-69, Northwest Fisheries Science Center, Seattle, Washington.

Johnson, G. E., A. J. Storch, J. R. Skalski, A. J. Bryson, C. Mallette, A. B. Borde, E. S. Van Dyke, K. L. Sonocinski, N. K. Sather, D. J. Teel, E. M. Dawley, G. R. Ploskey, T. A. Jones, S. A. Zimmerman, and D. R. Kulingowski. 2011. Ecology of Juvenile Salmon in Shallow Tidal Freshwater Habitats of the Lower Columbia River, 2007-2010. Pacific Northwest National Laboratories.

Hicks, M. 2000. Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards Temperature Criteria Draft Discussion Paper and Literature Summary. Washington Department of Ecology. 00-10-070.

McMahon, T. E. 1983. Habitat Suitability Index Models: Coho Salmon. U.S. Dept. Int., Fish & Wildlife Serv. FWS/OBS-82/10.49. 29 pp.

Mihursky, J.A. and V.S. Kennedy. 1967. Water temperature criteria to protect aquatic life. American Fisheries Society, Special Publication No. 4:20-32.

Raleigh, R. F., W. J. Miller, and P. C. Nelson. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Chinook Salmon. Instream Flow and Aquatic Systems Group, U.S. Fish & Wildlife Service.

Roegner, G. C., H. L. Diefenderfer, A. B. Borde, R. M. Thom, E. M. Dawley, A. H. Whiting, S. A. Zimmerman, and G. E. Johnson. 2009. Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Technical Memorandum NMFS-NWFSC-97, Northwest Fisheries Science Center, Seattle, Washington.

Thomas D. W. 1983. Changes in the Columbia River Estuary Habitat Types over the Past Century. Columbia River Data Development Program 51.

8.0 Appendices

Appendix A. List of species captured at Mirror Lake sites in 2011.

Common Name	Scientific Name	Taxonomic Group
largescale sucker	*Catostomus snyderi*	Catostomidae
bluegill	*Lepomis macrochirus*	Centrarchidae
crappie sp	*Pomoxis spp*	Centrarchidae
smallmouth bass	*Micropterus dolomieu*	Centrarchidae
American shad	*Alosa sapidissima*	Clupeidae
sculpin sp	*Cottus spp.*	Cottidae
pumpkinseed	*Lepomis Gibbosus*	Cucurbitaceae
chiselmouth	*crocheilus alutaceus*	Cyprinidae
common carp	*Cyprinus carpio*	Cyprinidae
golden shiner	*Notemigonus crysoleucas*	Cyprinidae
lake chub	*Couesius plumbeus*	Cyprinidae
northern pikeminnow	*Ptychocheilus oregonensis*	Cyprinidae
peamouth	*Mylocheilus caurinus*	Cyprinidae
tui chub	*Gila bicolor*	Cyprinidae
banded killifish	*Fundulus diaphanus*	Cyprinodontidae
threespine stickeback	*Gasterosteus aculeatus*	Gasterosteidae
bullhead sp	*Ameiurus spp*	Ictaluridae
walleye	*Stizostedion Vitreum*	Percidae
yellow perch	*Perca flavescens*	Percidae
mosquitofish	*Gambusia affinis*	Poeciliidae
Chinook	*Oncorhynchus tshawytscha*	Salmonidae
coho	*Oncorhynchus kisutch*	Salmonidae
steelhead	*Oncorhynchus mykiss*	Salmonidae

Appendix B. Species and Cover on Hogan Ranch 2004-2011

Pond	Description	Common	Latin	Native	Wetland Indicator	2004	2005	2008	2009	2010	2011
1	FACU	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	28%	1%	43%	77%	46%	44%
1	FACU	Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC	36%		10%		28%	16%
1	FACU	Creeping buttercup	*Ranunculus repens*	Introduced	FACW	T		T	T	2%	
1	FACU	Moneywort	*Lysimachi anummularia*	Introduced	FACW	7%		1%	7%	2%	2%
1	FACU	White clover	*Trifolium repens*	Introduced	FAC*	31%	67%		3%	2%	T
1	FACU	Canada thistle	*Cirsium arvense*	Introduced	FACU+			T		2%	
1	FACU	Sheep sorrel	*Rumex acetosella*	Introduced	FACU+			T	T	T	
1	FACU	Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*				T	T	
1	FACU	Pennyroyal	*Mentha pulegium*	Introduced	OBL	T		1%	1%	T	
1	FACU	Unknown grass	*Unknown*					9%		T	
1	FACU	Common velvet grass	*Holcus lanatus*	Introduced	FAC		1%			T	
1	FACU	Self heal	*Prunella vulgaris*	Native	FACU+		T			T	
1	FACU	Meadow foxtail	*Alopecurus pratensis*	Introduced	FACW					T	
1	FACU	Cheat grass	*Bromus sp*	Introduced	FACU					T	
1	FACU	Black hawthorn (Planting)	*Crataegus douglasii Lindl.*	Native	FAC					T	
1	FACU	Quackgrass	*Elytrigia repens*	Introduced	FAC-					T	6%
1	FACU	Horsetail	*Equisetum avaris*	Native	FAC					T	1%
1	FACU	Geranium molle	*Geranium molle*	Introduced	FACU					T	T
1	FACU	Meadow barley	*Hordeum brachyantherum*							T	
1	FACU	Timothy Grass	*Phleum pratense*	Introduced	FAC-					T	5%
1	FACU	Unknown seedling	*Unknown*							T	
1	FACU	Pointed rush	*Juncus oxymeris*	Native	FACW+	T		T	T		
1	FACU	English plantain	*Plantago lanceolata*	Introduced	FAC		1%		T		
1	FACU	Geranium	*Geranium sp.*				T		T		
1	FACU	Willow Herb sp.	*Epilobium sp.*	Native	OBL				T		
1	FACU	Yellow Parentucellia	*Parentucellia viscose (L.) Caruel*	Introduced	FAC-				T		
1	FACU	Ninebark (planting)	*Physocarpus opulifolius (L.)*	Native	FACW+				T		

1	FACU	Fescue	*Festuca sp.*			16%	40%		7%		
1	FACU	Swamp rose (planting)	*Rosa palustris*	Native	OBL				4%		
1	FACU	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	7%	3%	T			
1	FACU	Field bindweed	*Convolvulus arvensis*	Introduced				T			
1	FACU	Orchard grass	*Dactylis glomerata*	Introduced	FACU			T			
1	FACU	Water smartweed	*Polygonum amphibium*	Native	OBL			T			
1	FACU	Dock	*Rumex occidentalis*	Native	FACW+			T			
1	FACU	Pasture grasses	*Unknown*					13%			
1	FACU	Mix grass (Fescue and Poa)	*Unknown*				3%	7%			
1	FACU	Creeping bentgrass	*Agrosti sstolonifera*	Introduced	FAC*			3%			
1	FACU	Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			1%			
1	FACU	Poa	*Poa sp.*				2%				
1	FACU	Dandelion	*Taraxacum officinale*	NI	FACU	T	T				
1	FACU	Unk sedge	*Carex sp.*				T				
1	FACU	"small" Rush	*Juncus sp.*				T				
1	FACU	Broadleaf plantain	*Plantago major*	Introduced	FACU+	T					
1	FACU	Water pepper	*Polygonumhy dropiper*	Introduced	OBL	T					
1	FACU	Thistle	*Unknown*			T					
1	FACU	Unk #4	*Unknown*			T					
1	FACU	Vetch	*Vicia sp.*			T					
1	FACU	Jointed rush	*Juncus articulatus*	Native	OBL	2%					
1	FACU	Unk #2	*Unknown*			1%					
1	FACU	Organic Matter (dead)									25%
1	FACU	Creeping spike rush	*Eleochari spalustris*	Native	OBL						1%
1	FACU	Curly dock	*Rumex crispus*	Introduced	FAC+						T
1	FACU	Red osier dogwood (planting)	*Cornus sericea*	Native	FACW						T

Pond	Description	Common	Latin	Native	Wetland Indicator	2004	2005	2008	2009	2010	2011
1	FACW	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	75%	1%	58%	93%	75%	83%
1	FACW	Moneywort	*Lysimachia nummularia*	Introduced	FACW	70%	1%	4%	2%	13%	11%
1	FACW	Pacific willow (Mature)	*Salix lucida*	Native	FACW				T	7%	

1	FACW	Creeping spike rush	*Eleocharis palustris*	Native	OBL	4%		8%		2%	1%
1	FACW	Willow (Planting)	*Salix sp.*	Native	FACW				T	1%	
1	FACW	White clover	*Trifolium repens*	Introduced	FAC*	1%	59%	T		T	
1	FACW	Creeping buttercup	*Ranunculus repens*	Introduced	FACW		1%			T	
1	FACW	Water pepper	*Polygonum hydropiper*	Introduced	OBL	1%		T	T	T	
1	FACW	Horsetail	*Equisetum avaris*	Native	FAC			T	T	T	
1	FACW	Water purslane	*Ludwigia palustris*	Native	OBL				2%	T	
1	FACW	Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC			T		T	
1	FACW	Water smartweed	*Polygonum amphibium*	Native	OBL			T		T	
1	FACW	Unknown Seedling	*Unknown*					T		T	
1	FACW	Black hawthorn (Planting)	*Crataegus douglasii Lindl.*	Native						T	
1	FACW	Slender rush	*Juncus tenuis*	Native	FACW-					T	
1	FACW	Eurasian watermilfoil	*Myriophyllum spicatum L.*	Introduced	OBL					T	
1	FACW	Timothy Grass	*Phleum pratense*	Introduced						T	T
1	FACW	Yellow Flag Iris	*Iris Pseudacorus*	Introduced	OBL				3%		
1	FACW	Broadleaf plantain	*Plantago major*	Introduced	FACU+	T		T			
1	FACW	Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			T			
1	FACW	Unk sedge	*Carex sp.*					T			
1	FACW	Small forget-me-not	*Myosotis laxa*	Native	OBL			T			
1	FACW	Unk grass	*Unknown*					T			
1	FACW	Fescue	*Festuca sp.*				17%				
1	FACW	Unk OBL plant	*Unknown*				13%				
1	FACW	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	T	6%				
1	FACW	Poa	*Poa sp.*				4%				
1	FACW	Pointed rush	*Juncus oxymeris*	Native	FACW+		3%				
1	FACW	Geranium	*Geranium sp.*				2%				T
1	FACW	Self heal	*Prunella vulgaris*	Native	FACU+		1%				
1	FACW	English plantain	*Plantago lanceolata*	Introduced	FAC		T				
1	FACW	Small buttercup	*Ranunculus sp.*				T				
1	FACW	Vetch	*Vicia sp.*				T				

1	FACW	Unk #1	*Unknown*			T					
1	FACW	Jointed rush	*Juncus articulatus*	Native	OBL	10%					
1	FACW	Pennyroyal	*Mentha pulegium*	Introduced	OBL	4%					
1	FACW	Oregon ash tree (planting)	*Fraxinus latifolia*	Native	FACW						T
1	FACW	Unknown Seedling									T
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
1	Marshy shore	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	6%	24%	48%	71%	48%	32%
1	Marshy shore	Moneywort	*Lysimachia nummularia*	Introduced	FACW		13%	13%	2%	3%	
1	Marshy shore	Water purslane	*Ludwigia palustris*	Native	OBL	79%			3%	2%	1%
1	Marshy shore	Water smartweed	*Polyganum amphibium*	Native	OBL					2%	
1	Marshy shore	Creeping spike rush	*Eleocharis palustris*	Native	OBL			3%	4%	1%	
1	Marshy shore	Common duckweed	*Lemna minor L.*	Native	OBL				T	T	
1	Marshy shore	Water pepper	*Polygonum hydropiper*	Introduced	OBL	41%		T	2%		
1	Marshy shore	Water starwort	*Callitriche stagnalis Scop.*	Introduced	OBL				T		
1	Marshy shore	Broad leaf wapato	*Sagittaria latifolia*	Native	OBL				T		
1	Marshy shore	Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			8%			
1	Marshy shore	Pointed rush	*Juncus oxymeris*	Native	FACW+			3%			
1	Marshy shore	English plantain	*Plantago lanceolata*	Introduced	FAC		T				
1	Marshy shore	White clover	*Trifolium repens*	Introduced	FAC*		31%				
1	Marshy shore	Poa	*Poa sp.*				8%				
1	Marshy shore	Three-square bulrush	*Scirpus americanus*	Native	OBL		5%				
1	Marshy shore	Fescue	*Festuca sp.*				4%				
1	Marshy shore	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		3%				
1	Marshy shore	Tapertip rush	*Juncus acuminatus*	Native	OBL		1%				
1	Marshy shore	Pennyroyal	*Mentha pulegium*	Introduced	OBL	T					
1	Marshy shore	Yellow pond lily	*Nuphar polysepala*	Native	OBL	2%					
1	Marshy shore	Jointed rush	*Juncus articulatus*	Native	OBL	1%					
1	Marshy shore	Unknown Rush	*Unknown*						T		
1	Marshy shore	Organic Matter (dead)									65%
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**

1	Wetted area	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW				6%	19%	17%
1	Wetted area	Water purslane	*Ludwigia palustris*	Native	OBL			24%	36%	17%	T
1	Wetted area	Water pepper	*Polygonum hydropiper*	Introduced	OBL			12%	27%	4%	T
1	Wetted area	Water pepper lady's thumb	*Polygonum persicaria*	Introduced	OBL					11%	9%
1	Wetted area	Canadian waterweed	*Elodea Canadensis*	Native	OBL					6%	2%
1	Wetted area	Algae	*Unknown*					13%		5%	7%
1	Wetted area	Yellow pond lily	*Nuphar polysepala*	Native	OBL				7%	3%	2%
1	Wetted area	Pacific willow (Mature)	*Salix lucida*	Native	FACW					3%	
1	Wetted area	Creeping spike rush	*Eleocharis palustris*	Native	OBL					T	
1	Wetted area	Common Duckweed	*Lemna minor L.*	Native	OBL					T	
1	Wetted area	Western milfoil	*Myriophyllum hippuroides*	Native	OBL					T	
1	Wetted area	Eurasian watermilfoil	*Myriophyllum spicatum L.*	Introduced	OBL					T	
1	Wetted area	Curly pondweed	*Potamogeton crispus*	Introduced	OBL					T	
1	Wetted area	Water starwort	*Callitriche stagnalis Scop.*	Introduced	OBL				T		
1	Wetted area	Water smartweed	*Polygonum amphibium*	Native	OBL			2%			
1	Wetted area	Organic Matter (dead)									
1	Wetted area	Coontail	*Ceratophyllu demersum*	Native	OBL						T
1	Wetted area	Moneywort	*Lysimachia nummularia*	Introduced	FACW						T
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
2	FACU	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	18%	18%	29%	48%	24%	65%
2	FACU	Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC	5%		4%		15%	9%
2	FACU	Self heal	*Prunella vulgaris*	Native	FACU+	1%	T	T	1%	11%	
2	FACU	English plantain	*Plantago lanceolata*	Introduced	FAC	6%	2%	4%	8%	10%	
2	FACU	Horsetail	*Equisetum avaris*	Native	FAC	T	T	2%	1%	8%	3%
2	FACU	White clover	*Trifolium repens*	Introduced	FAC*	45%	63%			8%	
2	FACU	Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*	5%	T	T	T	5%	
2	FACU	Pennyroyal	*Mentha pulegium*	Introduced	OBL	1%		6%	10%	4%	
2	FACU	Moss	*family Hypnaceae*							4%	
2	FACU	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	1%	3%		T	3%	
2	FACU	Creeping buttercup	*Ranunculus repens*	Introduced	FACW	T			1%	3%	

2	FACU	Slender rush	*Juncus tenuis*	Native	FACW-					2%	
2	FACU	Water purslane	*Ludwigia palustris*	Native	OBL	T			1%	1%	
2	FACU	Meadow barley	*Hordeum brachyantherum*	Native	FACW-*		T			1%	
2	FACU	Hairy crabgrass	*Digitaria sanguinalis (L.) Scop*	Introduced						1%	
2	FACU	Field bindweed	*Convolvulus arvensis*	Introduced					1%	T	
2	FACU	Creeping spike rush	*Eleocharis palustris*	Native	OBL		T			T	
2	FACU	Sedge	*Carex sp.*				3%			T	
2	FACU	Quackgrass	*Elytrigia repens*	Introduced						T	
2	FACU	Dovefoot geranium	*Geranium molle*	Introduced	FACU					T	
2	FACU	Broadleaf plantain	*Plantago major*	Introduced	FAC					T	
2	FACU	Fescue	*Festuca sp.*				17%		14%		
2	FACU	Moneywort	*Lysimachia nummularia*	Introduced	FACW	8%		2%	7%		18%
2	FACU	Clover sp.	*Trifolium sp.*	Introduced	FAC*				2%		
2	FACU	Curly dock	*Rumex crispus*	Introduced	FAC+			T	T		
2	FACU	Yellow Parentucellia	*Parentucellia viscosa (L.) Caruel*	Introduced	FAC-				T		
2	FACU	Unk grass	*Unknown*			5%	1%	T			
2	FACU	Geranium	*Geranium sp.*				1%	T			
2	FACU	Small forget-me-not	*Myosotis laxa*	Native	OBL	T		T			
2	FACU	Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			12%			
2	FACU	Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			10%			
2	FACU	Meadow foxtail	*Alopecurus pratensis*	Introduced	FACW			T			
2	FACU	Pointed rush	*Juncus oxymeris*	Native	FACW+			T			
2	FACU	Timothy	*Phleum pratense*	Introduced	FAC-			T			
2	FACU	Smartweed	*Polygonum sp.*					T			
2	FACU	Dandelion	*Taraxacum officinale*	NI	FACU			T			
2	FACU	Bugleweed	*Lycopus sp.*			T	2%				
2	FACU	Unk #1	*Unknown*				1%				
2	FACU	Cudweed	*Gnaphalium macrocephalum*	Native			T				
2	FACU	Poa	*Poa sp.*				T				
2	FACU	Small buttercup	*Ranunculus sp.*				T				

2	FACU	Northern starwort	*Stellaria calycantha*	Native	FACW+		T				
2	FACU	Annual chickweed	*Stellaria media*	Introduced	FACU		T				
2	FACU	White puffball fungi	*Unknown*				T				
2	FACU	unk "barley grass"	*Unknown*			2%					
2	FACU	Unk (photos)	*Unknown*			2%					
2	FACU	Chicory	*Cichorium intybus*	Introduced		1%					
2	FACU	Marsh speedwell	*Veronica scutellata*	Native	OBL	1%					
2	FACU	Unk	*Unknown*			T					
2	FACU	Unk #11	*Unknown*			T					
2	FACU	unk small violet flower	*Unknown*			T					
2	FACU	Organic Matter (dead)									6%
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
2	FACW	Reed canarygrass	*Phalari sarundinacea*	Introduced	FACW	40%	T	100%		60%	67%
2	FACW	Moneywort	*Lysimachia nummularia*	Introduced	FACW	13%	3%	1%		26%	22%
2	FACW	Water purslane	*Ludwigia palustris*	Native	OBL	13%				6%	
2	FACW	Horsetail	*Equisetum avaris*	Native	FAC		T			3%	3%
2	FACW	Moss	*family Hypnaceae*							3%	
2	FACW	Self heal	*Prunella vulgaris*	Native	FACU+		1%			2%	
2	FACW	Colonial Bentgrass	*Agrostis capillaris*	Introduced	FAC					2%	T
2	FACW	Creeping spike rush	*Eleocharis palustris*	Native	OBL					2%	1%
2	FACW	English plantain	*Plantago lanceolata*	Introduced	FAC					2%	1%
2	FACW	Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*	5%	T	T		1%	
2	FACW	Slough Sedge	*Carex obnupta*	Native	OBL					1%	
2	FACW	Slender rush	*Juncus tenuis*	Native	FACW-					1%	T
2	FACW	Broadleaf plantain	*Plantago major*	Introduced	FACU+					1%	
2	FACW	White clover	*Trifolium repens*	Introduced	FAC*	31%	39%			T	
2	FACW	Meadow barley	*Hordeum brachyantherum*	Native	FACW-*		T			T	
2	FACW	Creeping buttercup	*Ranunculus repens*	Introduced			T			T	
2	FACW	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	3%				T	
2	FACW	Pennyroyal	*Mentha pulegium*	Introduced	OBL	3%				T	T

2	FACW	Meadow foxtail	*Alopecurus pratensis*	Introduced	FACW					T	
2	FACW	Chicory	*Cichorium intybus*	Native	OBL					T	
2	FACW	Hairy crabgrass	*Digitaria sanguinalis (L.) Scop*	Introduced	FACU					T	
2	FACW	Ovate spike rush	*Eleocharis ovata*	Native	OBL					T	
2	FACW	English rye grass	*Lolium perenne*	Introduced	FACU					T	
2	FACW	Small forget-me-not	*Myosotis laxa*	Native	OBL					T	
2	FACW	Water pepper	*Polygonum hydropiper*	Introduced	OBL					T	
2	FACW	Water pepper lady's thumb	*Polygonum persicaria*	Introduced	OBL					T	T
2	FACW	Wapato	*Sagittaria latifolia*	Native	OBL					T	
2	FACW	Bur-reed	*Sparganium emersum*	Introduced	OBL					T	
2	FACW	Fescue	*Festuca sp.*				45%				
2	FACW	Bog Saint Johnswort?	*Hypericum anagalloides*	Native	OBL		8%				
2	FACW	Sedge	*Carex sp.*				4%				
2	FACW	Thistle	*Unknown*				4%				
2	FACW	Geranium	*Geranium sp.*				3%				
2	FACW	Pointed rush	*Juncus oxymeris*	Native	FACW+		3%				
2	FACW	Vetch	*Vicia sp.*				2%				
2	FACW	Bugleweed	*Lycopus sp.*				1%				
2	FACW	Water smartweed	*Polygonum amphibium*	Native	OBL		1%				T
2	FACW	Northern starwort	*Stellaria calycantha*	Native	FACW+		1%				
2	FACW	Small buttercup	*Ranunculus sp.*				T				
2	FACW	Unk	*Unknown*			8%					
2	FACW	Tapertip rush	*Juncus acuminatus*	Native	OBL	3%					
2	FACW	Unk #5	*Unknown*			T					
2	FACW	Organic Matter (dead)									4%
2	FACW	Quackgrass	*Elytrigia repens*	Introduced							T
2	FACW	Curly dock	*Rumex crispus*	Introduced	FAC+						T
2	FACW	Willow Smartweed	*Polygonum lapathifolium L.*	Native	FACW						T
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
2	Marshy shore	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW		45%	5%	47%	30%	30%

2	Marshy shore	Creeping spike rush	*Eleocharis palustris*	Native	OBL			7%	12%	26%	
2	Marshy shore	Water purslane	*Ludwigia palustris*	Native	OBL	63%		24%	15%	24%	3%
2	Marshy shore	Water smartweed	*Polygonum amphibium*	Native	OBL			T	7%	3%	
2	Marshy shore	Water pepper	*Polygonum hydropiper*	Introduced	OBL	30%		1%	3%	3%	
2	Marshy shore	Moneywort	*Lysimachia nummularia*	Introduced	FACW			1%	2%	3%	1%
2	Marshy shore	Water pepper lady's thumb	*Polygonum persicaria*	Introduced	OBL					2%	1%
2	Marshy shore	Western water milfoil	*Myriophyllum hippuroides*	Native	OBL	15%		8%		1%	
2	Marshy shore	Eurasian Watermilfoil	*Myriophyllum spicatum L.*	Introduced	OBL				T	T	1%
2	Marshy shore	Pennyroyal	*Mentha pulegium*	Introduced	OBL			T	3%	T	1%
2	Marshy shore	Pointed rush	*Juncus oxymeris*	Native	FACW+	2%		T		T	
2	Marshy shore	Curly dock	*Rumex crispus*	Introduced	FAC+			T	T		
2	Marshy shore	Horsetail	*Equisetum avaris*	Native	FAC				T		3%
2	Marshy shore	Small forget-me-not	*Myosotis laxa*	Native	OBL		1%		T		
2	Marshy shore	Wapato	*Sagittaria latifolia*	Native	OBL	7%		T	3%		
2	Marshy shore	Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			T			
2	Marshy shore	Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			36%			
2	Marshy shore	Fescue	*Festuca sp.*				20%				
2	Marshy shore	Self heal	*Prunella vulgaris*	Native	FACU+		5%				T
2	Marshy shore	White clover	*Trifolium repens*	Introduced	FAC*		3%				
2	Marshy shore	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		1%				
2	Marshy shore	Geranium	*Geranium sp.*				T				
2	Marshy shore	American speedwell	*Veronica Americana*	Native	OBL	17%					
2	Marshy shore	Yellow pond lily	*Nuphar polysepala*	Native	OBL	3%					
2	Marshy shore	Unk	*Unknown*			2%					
2	Marshy shore	Organic Matter (dead)									35%
2	Marshy shore	Moss	*family Hypnaceae*								6%
2	Marshy shore	Colonial Bentgrass	*Agrostis capillaris*	Introduced	FAC						4%
2	Marshy shore	English plantain	*Plantago lanceolata*	Introduced	FAC						T
2	Marshy shore	Willow Smartweed	*Polygonum lapathifolium L.*	Native	FACW						T
2	Marshy shore	Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*						T

2	Marshy shore	Cudweed	*Gnaphalium macrocephalum*	Native							T
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
2	Wetted area	Western water milfoil	*Myriophyllum hippuroides*	Native	OBL			8%		28%	
2	Wetted area	Canadian waterweed	*Elodea Canadensis*	Native	OBL					13%	1%
2	Wetted area	Eurasian Watermilfoil	*Myriophyllum spicatum L.*	Introduced	OBL				4%	12%	12%
2	Wetted area	Algae	*Unknown*							7%	1%
2	Wetted area	Water smartweed	*Polygonum amphibium*	Native	OBL			6%	14%	6%	9%
2	Wetted area	Water purslane	*Ludwigia palustris*	Native	OBL	87%	40%	21%	7%	4%	T
2	Wetted area	Coontail	*Ceratophyllum demersum*	Native	OBL					3%	10%
2	Wetted area	Water pepper	*Polygonum hydropiper*	Introduced	OBL	31%	10%	18%	10%	1%	T
2	Wetted area	Water pepper lady's thumb	*Polygonum persicaria*	Introduced	OBL					5%	7%
2	Wetted area	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW			T	5%	1%	2%
2	Wetted area	Bur-reed	*Sparganium emersum*	Introduced	OBL	6%				T	
2	Wetted area	Curly pondweed	*Potamogeton crispus*	Introduced	OBL					T	
2	Wetted area	Unknown seedling	*Unknown*							T	
2	Wetted area	Creeping spike rush	*Eleocharis palustris*	Native	OBL				1%		T
2	Wetted area	Moneywort	*Lysimachia nummularia*	Introduced	FACW			T			T
2	Wetted area	Small forget-me-not	*Myosotis laxa*	Native	OBL			T			
2	Wetted area	Unk #6	*Unknown*			25%					
2	Wetted area	Broad leaf wapato	*Sagittaria latifolia*	Native	OBL	4%					
2	Wetted area	Rush	*Unknown*			2%					
2	Wetted area	Common Duckweed	*Lemna minor L.*	Native	OBL						T
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
3	FACU	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW		30%	90%	99%		
3	FACU	Horsetail	*Equisetum avaris*	Native	FAC				T		
3	FACU	Willow (planting)	*Salix sp.*	Native	FACW				T		
3	FACU	Moneywort	*Lysimachi anummularia*	Introduced	FACW		T	2%			
3	FACU	Fescue	*Festuca sp.*				33%				
3	FACU	Unk grass	*Unknown*				24%				
3	FACU	White clover	*Trifolium repens*	Introduced	FAC*		18%				

3	FACU	Timothy grass	*Phleum pratense*	Introduced	FAC-		3%				
3	FACU	Big red-stemmed moss	*family Hypnaceae*				2%				
3	FACU	Small buttercup	*Ranunculus sp.*				2%				
3	FACU	Himalayan blackberry	*Rubus armeniacus*	Introduced	FACU		2%				
3	FACU	Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		1%				
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
3	FACW	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	88%	100%	98%		97%	52%
3	FACW	Pacific willow (Planting)	*Salix lucida*	Native	FACW					2%	
3	FACW	Forget me not	*Myosotis laxa*	Native	OBL					T	
3	FACW	Unknown seedling	*Unknown*							T	
3	FACW	Creeping spike rush	*Eleocharis palustris*	Native	OBL			1%			
3	FACW	Water pepper	*Polygonum hydropiper*	Introduced	OBL			T			
3	FACW	Moneywort	*Lysimachia nummularia*	Introduced	FACW	45%					
3	FACW	Water purslane	*Ludwigia palustris*	Native	OBL	23%					
3	FACW	Mountain sneezeweed	*Helenium autumnale*	Native	FACW	15%					
3	FACW	Unk #9 or 10	*Unknown*			4%					
3	FACW	Pennyroyal	*Mentha pulegium*	Introduced	OBL	3%					
3	FACW	Broadleaf plantain	*Plantago major*	Introduced	FACU+	3%					
3	FACW	White clover	*Trifolium repens*	Introduced	FAC*	T					
4	FACW	Organic Matter (dead)									48%
5	FACW	Horsetail	*Equisetum avaris*	Native	FAC						T
Pond	**Description**	**Common**	**Latin**	**Native**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
3	Marshy shore	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	19%	40%	3%	76%	53%	9%
3	Marshy shore	Creeping spike rush	*Eleocharis palustris*	Native	OBL		20%	53%	16%	18%	
3	Marshy shore	Broad leaf wapato	*Sagittaria latifolia*	Native	OBL			75%	7%	10%	
3	Marshy shore	Water purslane	*Ludwigia palustris*	Native	OBL	34%	65%	1%		T	
3	Marshy shore	Horsetail	*Equisetum avaris*	Native	FAC					T	
3	Marshy shore	Water pepper	*Polygonum hydropiper*	Introduced	OBL	10%	20%		T		
3	Marshy shore	Bur-reed	*Sparganium emersum*	Introduced	OBL			1%			
3	Marshy shore	Tapertip rush	*Juncus acuminatus*	Native	OBL		20%				

3	Marshy shore	American speedwell	*Veronica Americana*	Native	OBL	30%					
3	Marshy shore	Pennyroyal	*Mentha pulegium*	Introduced	OBL	9%					
3	Marshy shore	Rush	*Unknown*			9%					
3	Marshy shore	Beak rush	*Unknown*			6%					
3	Marshy shore	Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL	4%					
3	Marshy shore	Scarlet pimpernel	*Analgallis arvensis*	Introduced	FAC	1%					
3	Marshy shore	Needle spike rush	*Eleocharis acicularis*	Native	OBL	1%					
3	Marshy shore	Moneywort	*Lysimachia nummularia*	Introduced	FACW	1%					
3	Marshy shore	Unk grass	*Unknown*			1%					
3	Marshy shore	Organic Matter (dead)									91%

Pond	Description	Common	Latin	Native	Wetland Indicator	2004	2005	2008	2009	2010	2011
3	Wetted area	Wapato	*Sagittaria latifolia*	Native	OBL			50%	54%	80%	2%
3	Wetted area	Creeping spike rush	*Eleocharis palustris*	Native	OBL			30%	36%	10%	
3	Wetted area	Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	1%			5%	10%	1%
3	Wetted area	Hard stem bulrush	*Scirpus acutus*	Native	OBL			1%	5%	1%	
3	Wetted area	Willow	*Salix sp.*	Native	FACW			1%			
3	Wetted area	Jointed rush	*Juncus articulatus*	Native	OBL	55%					
3	Wetted area	American speedwell	*Veronica Americana*	Native	OBL	40%					
3	Wetted area	Forget me not	*Myosotis laxa*	Native	OBL	15%					
3	Wetted area	Yellow pond lily	*Nuphar polysepala*	Native	OBL	15%					
3	Wetted area	Water pepper	*Polygonum hydropiper*	Introduced	OBL	5%					
3	Wetted area	Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL	5%					
3	Wetted area	Organic Matter (dead)									57%

Pond 1 Species List 2004-2011

Common	Latin	Native Status	Wetland Indicator	2004	2005	2008	2009	2010	2011
Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC	X		X		X	X
Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			X			

Meadow foxtail	*Alopecurus pratensis*	Introduced	FACW					X	
Cheat grass	*Bromussp*	Introduced	FACU					X	
Water starwort	*Callitriche stagnalis Scop.*	Introduced	OBL				X		
Unk sedge	*Carex sp.*				X	X			
Coontail	*Ceratophyllum demersum*	Native	OBL						X
Canada thistle	*Cirsium arvense*	Introduced	FACU+			X		X	
Field bindweed	*Convolvulus arvensis*	Introduced				X			
Red osier dogwood (planting)	*Cornus sericea*	Native	FACW						X
Black hawthorn (planting)	*Crataegus douglasii Lindl.*	Native	FAC					X	
Orchard grass	*Dactylis glomerata*	Introduced	FACU			X			
Creeping spike rush	*Eleocharis palustris*	Native	OBL	X		X	X	X	X
Canadian waterweed	*Elodea canadensis*	Native	OBL					X	X
Quackgrass	*Elytrigia repens*	Introduced	FAC-					X	X
Willow Herb sp.	*Epilobium sp.*	Native	OBL				X		
Horsetail	*Equisetum avaris*	Native	FAC			X	X	X	X
Fescue	*Festuca sp.*			X	X		X		
Oregon ash tree (planting)	*Fraxinus latifolia*	Native	FACW						X
Geranium molle	*Geranium molle*	Introduced	FACU					X	X
Geranium	*Geranium sp.*				X		X		X
Common velvet grass	*Holcus lanatus*	Introduced	FAC		X			X	
Meadow barley	*Hordeum brachyantherum*	Native	FACW-*					X	
Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*				X	X	
Yellow Flag Iris	*Iris Pseudacorus*	Introduced	OBL				X		
Tapertip rush	*Juncus acuminatus*	Native	OBL		X				
Jointed rush	*Juncus articulatus*	Native	OBL	X					
Pointed rush	*Juncus oxymeris*	Native	FACW+	X	X	X	X		
"small" Rush	*Juncus sp.*				X				
Slender rush	*Juncus tenuis*	Native	FACW-					X	
Common duckweed	*Lemna minor L.*	Native	OBL				X	X	
Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	X	X	X			
Water purslane	*Ludwigia palustris*	Native	OBL	X		X	X	X	X

Moneywort	*Lysimachia nummularia*	Introduced	FACW	X	X	X	X	X	X
Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			X			
Pennyroyal	*Mentha pulegium*	Introduced	OBL	X		X	X	X	
Small forget-me-not	*Myosotis laxa*	Native	OBL			X			
Western milfoil	*Myriophyllum hippuroides*	Native	OBL					X	
Eurasian watermilfoil	*Myriophyllum spicatum L.*	Introduced	OBL					X	
Yellow pond lily	*Nuphar polysepala*	Native	OBL	X			X	X	X
Yellow Parentucellia	*Parentucellia viscosa (L.) Caruel*	Introduced	FAC-				X		
Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	X	X	X	X	X	X
Timothy Grass	*Phleum pratense*	Introduced	FAC-					X	X
Ninebark (planting)	*Physocarpus opulifolius (L.)*	Native	FACW+				X		
English plantain	*Plantago lanceolata*	Introduced	FAC		X		X		
Broadleaf plantain	*Plantago major*	Introduced	FACU+	X		X			
Poa	*Poa sp.*				X				
Water smartweed	*Polyganum amphibium*	Native	OBL			X		X	
Water pepper	*Polygonum hydropiper*	Introduced	OBL	X		X	X	X	X
Water pepper lady's thumb	*Polygonum persicaria*	Introduced	OBL					X	X
Curly pondweed	*Potamogeton crispus*	Introduced	OBL					X	
Self heal	*Prunella vulgaris*	Native	FACU+		X			X	
Creeping buttercup	*Ranunculus repens*	Introduced	FACW	X	X	X	X	X	
Small buttercup	*Ranunculus sp.*				X				
Swamp rose (Planting)	*Rosa palustris*	Native	OBL				X		
Sheep sorrel	*Rumex acetosella*	Introduced	FACU+			X	X	X	
Curly dock	*Rumex crispus*	Introduced	FAC+						X
Dock	*Rumex occidentalis*	Native	FACW+			X			
Broad leaf wapato	*Sagittaria latifolia*	Native	OBL				X		
Pacific willow (Mature)	*Salix lucida*	Native	FACW				X	X	
Willow (Planting)	*Salix sp.*	Native	FACW				X	X	
Three-square bulrush	*Scirpus americanus*	Native	OBL		X				
Dandelion	*Taraxacum officinale*	Introduced	FACU	X	X				
White clover	*Trifolium repens*	Introduced	FAC*	X	X	X	X	X	X

Algae	*Unknown*			X		X	
Unknown Grasses	*Unknown*		X	X		X	
Thistle	*Unknown*	X					
Unk #1	*Unknown*	X					
Unk #2	*Unknown*	X					
Unk #4	*Unknown*	X					
Unk OBL plant	*Unknown*		X				
Unknown rush	*Unknown*				X		
Unknown seedling	*Unknown*			X		X	X
Vetch	*Vicia sp.*	X	X				

Pond 2 Species List 2004-2011

Common	**Latin**	**Native Status**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC	X		X		X	X
Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			X			
Meadow foxtail	*Alopecurus pratensis*	Introduced	FACW			X		X	
Slough Sedge	*Carex obnupta*	Native	OBL					X	
Sedge	*Carex sp.*				X			X	
Coontail	*Ceratophyllum demersum*	Native	OBL					X	X
Chicory	*Cichorium intybus*	Introduced		X				X	
Field bindweed	*Convolvulus arvensis*	Introduced					X	X	
Hairy crabgrass	*Digitaria sanguinalis (L.) Scop*	Introduced	FACU					X	
Creeping spike rush	*Eleocharis palustris*	Native	OBL		X	X	X	X	X
Ovate spike rush	*Eleocharis ovata*	Native	OBL					X	
Canadian waterweed	*Elodea canadensis*	Native	OBL					X	X
Quackgrass	*Elytrigia repens*	Introduced						X	X
Horsetail	*Equisetum avaris*	Native	FAC	X	X	X	X	X	X
Moss	*family Hypnaceae*							X	X
Fescue	*Festuca sp.*				X		X		
Dovefoot geranium	*Geranium molle*	Introduced	FACU					X	

Geranium	*Geranium sp.*				X	X			
Cudweed	*Gnaphalium macrocephalum*	Native			X				X
Meadow barley	*Hordeum brachyantherum*	Native	FACW-*					X	
Bog Saint Johnswort	*Hypericum anagalloides*	Native	OBL		X				
Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*	X	X	X	X	X	X
Tapertip rush	*Juncus acuminatus*	Native	OBL	X					
Pointed rush	*Juncus oxymeris*	Native	FACW+	X	X	X		X	
Slender rush	*Juncus tenuis*	Native	FACW-					X	X
Common Duckweed	*Lemna minor L.*	Native	OBL						X
English rye grass	*Lolium perenne*	Introduced	FACU					X	
Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	X	X		X	X	
Water purslane	*Ludwigia palustris*	Native	OBL	X	X	X	X	X	X
Bugleweed	*Lycopus sp.*			X	X				
Moneywort	*Lysimachia nummularia*	Introduced	FACW	X	X	X	X	X	X
Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			X			
Pennyroyal	*Mentha pulegium*	Introduced	OBL	X		X	X	X	
Small forget-me-not	*Myosotis laxa*	Native	OBL	X	X	X	X	X	
Western water milfoil	*Myriophyllum hippuroides*	Native	OBL	X		X		X	
Eurasian Watermilfoil	*Myriophyllum spicatum L.*	Introduced	OBL				X	X	X
Yellow pond lily	*Nupha rpolysepala*	Native	OBL	X					
Yellow Parentucellia	*Parentucellia viscosa (L.) Caruel*	Introduced	FAC-				X		
Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	X	X	X	X	X	X
Timothy grass	*Phleum pratense*	Introduced	FAC-			X			
English plantain	*Plantago lanceolata*	Introduced	FAC	X	X	X	X	X	X
Broadleaf plantain	*Plantago major*	Introduced	FAC					X	
Poa	*Poa sp.*				X				
Water smartweed	*Polygonum amphibium*	Native	OBL	X	X	X	X	X	X
Water pepper	*Polygonum hydropiper*	Introduced	OBL	X	X	X	X	X	X
Water pepper lady's thumb	*Polygonumpersicaria*	Introduced	OBL					X	X
Smartweed	*Polygonum sp.*					X			
Willow Smartweed	*Polygonum lapathifolium L.*	Native	FACW						X

Curly pondweed	*Potamogeton crispus*	Introduced	OBL					X	
Self heal	*Prunella vulgaris*	Native	FACU+	X	X	X	X	X	X
Creeping buttercup	*Ranunculus repens*	Introduced	FACW	X	X		X	X	
Small buttercup	*Ranunculus sp.*				X				
Curly dock	*Rumex crispus*	Introduced	FAC+			X	X		X
Wapato	*Sagittaria latifolia*	Native	OBL	X		X	X	X	
Bur-reed	*Sparganium emersum*	Introduced	OBL	X				X	
Northern starwort	*Stellaria calycantha*	Native	FACW+		X				
Annual chickweed	*Stellaria media*	Introduced	FACU		X				
Dandelion	*Taraxacum officinale*	NI	FACU			X			
White clover	*Trifolium repens*	Introduced	FAC*	X	X	X	X	X	
Clover sp.	*Trifolium sp.*	Introduced	FAC*				X		
Algae	*Unknown*							X	X
Rush	*Unknown*			X					
Thistle	*Unknown*				X				
Unknown	*Unknown*			X	X				
Unknown grasses	*Unknown*			X	X	X			
Unknown small violet flower	*Unknown*			X					
Unknown seedling	*Unknown*							X	
White puffball fungi	*Unknown*				X				
American speedwell	*Veronica americana*	Native	OBL	X					
Marsh speedwell	*Veronica scutellata*	Native	OBL	X					
Vetch	*Vicia sp.*				X				

Pond 3 Species List 2004-2011									
Common	**Latin**	**Native Status**	**Wetland Indicator**	**2004**	**2005**	**2008**	**2009**	**2010**	**2011**
Scarlet pimpernel	*Analgallis arvensis*	Introduced	FAC	X					
Needle spike rush	*Eleocharis acicularis*	Native	OBL	X					
Creeping spike rush	*Eleocharis palustris*	Native	OBL		X	X	X	X	
Horsetail	*Equisetum avaris*	Native	FAC				X	X	X

Big red-stemmed moss	*family Hypnaceae*				X				
Fescue	*Festuca sp.*				X				
Mountain sneezeweed	*Helenium autumnale*	Native	FACW	X					
Tapertip rush	*Juncus acuminatus*	Native	OBL		X				
Jointed rush	*Juncus articulatus*	Native	OBL	X					
Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		X				
Water purslane	*Ludwigia palustris*	Native	OBL	X	X	X		X	
Moneywort	*Lysimachia nummularia*	Introduced	FACW	X	X	X			
Pennyroyal	*Mentha pulegium*	Introduced	OBL	X					
Small forget me not	*Myosotislaxa*	Native	OBL	X				X	
Yellow pond lily	*Nuphar polysepala*	Native	OBL	X					
Reed canarygrass	*Phalaris arundinacea*	Introduced	FACW	X	X	X	X	X	X
Timothy grass	*Phleum pratense*	Introduced	FAC-		X				
Broadleaf plantain	*Plantago major*	Introduced	FACU+	X					
Water pepper	*Polygonum hydropiper*	Introduced	OBL	X	X	X	X		
Small buttercup	*Ranunculus sp.*				X				
Himalayan blackberry	*Rubus armeniacus*	Introduced	FACU		X				
Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL	X					
Wapato	*Sagittaria latifolia*	Native	OBL			X	X	X	X
Pacific willow (Planting)	*Salix lucida*	Native	FACW					X	
Willow	*Salix sp.*	Native	FACW			X			
Willow (Planting)	*Salix sp.*	Native	FACW				X		
Hard stem bulrush	*Scirpus acutus*	Native	OBL			X	X	X	
Bur-reed	*Sparganium emersum*	Introduced	OBL			X			
White clover	*Trifolium repens*	Introduced	FAC*	X	X				
Beak rush	*Unknown*			X					
Rush	*Unknown*			X					
Unknown	*Unknown*			X					
Unknown grass	*Unknown*			X	X				
Unknown seedling	*Unknown*							X	
American speedwell	*Veronica americana*	Native	OBL	X					

Appendix C. Photo Point Monitoring of Scappoose Creek and Hogan Ranch Ponds

Scappoose Bay Watershed, Oregon
August 2011

Introduction

The purpose of this report is to describe the seasonal and yearly changes in the landscape of the riparian restoration site along Scappoose Creek (Wilson and LaCombe properties) from July 2007 through August 2011and of three tidal freshwater Ponds on Hogan Ranch from June 2005 through August 2011. Photo points were set up to capture changes in the landscape before and after restoration. Restoration of riparian vegetation was conducted in 2007 and 2008 along approximately 560 meters of Scappoose Creek's southern edge. Restoration construction and riparian plantings took place around the three ponds on Hogan Ranch between 2007 and 2010. Riparian vegetation influences stream water chemistry and habitat quality through many processes including; direct water and chemical uptake, increasing bank stability and decreasing erosion, increasing stream cover and shade, supplying organic matter to the soils and channels, increasing channel complexity, and modifying stream flow (Dosskey et al. 2010). As the riparian vegetation matures on the restoration sites the water quality and salmonid habitat conditions are expected to improve (Dosskey et al. 2010). The photo points will help to document changes in the landscape over time including the development of the riparian corridor.

Background

The Scappoose Creek riparian vegetation restoration project is located on two adjacent private properties (Wilson and LaCombe) which compose a total of 18.5 acres. Scappoose Creek runs along these properties' northern border for approximately 560 meters (Figure 1). Riparian vegetation restoration was conducted along the stream's southern edge (8-10 meters wide) for a total of approximately 1 acre of riparian plantings. Prior to restoration, this area was used for pasture and agriculture (hay crops). The pasture and hay planting areas are now set back from the stream's edge and restoration vegetation is fenced to protect it from grazing. Through a partnership between the landowners, Scappoose Bay Watershed Council (SBWC), Oregon Watershed Enhancement Board (OWEB), and the Lower Columbia River Estuary Partnership (LCREP) the restoration area was fenced (to exclude livestock) in 2007, and then planted with native riparian vegetation in 2007 and the spring of 2008. Maintenance of the site in 2009-2011 was paid for with funds from the Oregon Department of Environmental Quality (ODEQ). As the restoration plantings mature it is expected that the riparian area will become fully shaded and non-native species will be suppressed. The nature of riparian restoration work makes it difficult to observe significant habitat and water quality changes over a short period of time (Dosskey et al. 2010). Documenting changes on the site with photo points will help determine the long-term impacts of these restoration efforts.

Restoration of the wetland Ponds at the Hogan Ranch has been conducted in partnership with Lower Columbia River Estuary Partnership (LCREP), Oregon Watershed Enhancement Board (OWEB), Natural Resources Conservation Service (NRCS), Ducks Unlimited, Bureau of Land Management (BLM), the owner of Hogan Ranch, and the Scappoose Bay Watershed Council. In 2004 the NRCS acquired a conservation easement for the Hogan Ranch property through the Wetlands Reserve Program (WRP). In 2005 fencing was installed around the easement, partially excluding livestock. In 2007 additional fencing was installed and livestock were fully excluded from the restoration area. In 2009 Ducks Unlimited replaced the failed water control structures on Ponds 1 and 2, reconfigured a dike on the south end of Pond 2, and excavated the west side of Pond 2 to create additional wetlands. Pond 3 has maintained natural hydrology throughout the restoration process. The excavated areas were seeded with native wetland plants. In 2007, 2008 and 2009 native trees and shrubs were planted around the Ponds. In 2007, 2008, 2009 and 2010 native plantings were maintained by mowing and weed suppression. Water levels in Ponds 1 and 2 have been controlled by the property owner since the control structures were replaced in 2009.

Methods

Photo point monitoring protocols have been adapted from Riparian and Aquatic Ecosystem Monitoring (Lindbo et al., 2003) and those outlined in the Monitoring Protocols for Salmon Habitat Restoration Projects in the Lower

Columbia River and Estuary (PNNL--15793, 2006).The idea is to attach the photo point to a given land mark so it may be found for several years.

Results

Scappoose Creek

The photo points on the Mainstem of Scappoose Creek were established in April 2007 to track the changes to the banks of Scappoose Creek to follow a native plant restoration project that was to be completed. Five photo points were set with GPS points at (or near) the major curves in the stream in order to get a long linear view of the stream banks. They are numbered from 1 to 5 and are located along the stream from the downstream edge of the project site progressing towards the upstream edge of the property. These locations have been established with GPS points. Please see Photo map (Figure 1) for locations. Photos are taken at 90˚ intervals (4 pictures) at each site. Photos are taken once each season for a total of 4 times per year. The photo points were established to track long-term changes to the environment along the stream channel.

High water events along Scappoose Creek have high velocity and enough debris that make fence posts inappropriate to place along the edge of the stream. Landowners preferred to not install fence posts in areas that do not have livestock because the posts can damage equipment if they are hidden by tall grass. GPS points and original photos were used to replicate the photo points. Bank sloughing and other changes to the banks made it complicated to stand in the same location each time, so photos were taken as close to the original photo as possible.

Hogan Ranch

Photo points were established at Hogan Ranch in July 2004 at specified photo point posts. They are numbered from 1 to 17 and are located at strategic locations around the property. These locations were established by placing a metal fence post in each desired location and permanently marked with a metal tag that was inscribed as GPS location. The Wetland Reserve Program was still under development at the time and the exact boundaries were not yet established. After the WRP boundaries were set and the project scope of work was fully known, photo points 17, 7A and 17A were added. Please see Photo Point map (Figure 2) for locations. Photos are taken at 90˚ intervals (4 pictures) at each post. Photos are taken once each season for a total of 4 times per year. The photo points were established to track long-term changes to the environment within the WRP.

Main Stem Scappoose Creek Photo Points

Figure 1: The map of the project site on the main stem of Scappoose Creek shows the property lines of both owners, and the photo point locations.

Main Stem Scappoose Creek

Photo Point # 1: Located at the most downstream edge of Wilson's property, about 75 to 100 feet west of the property line, near the corner. This set of photos is looking west to southwest, along the southern edge of creek.

Before

April 2007

The site was dominated by blackberry and patches of Japanese knotweed. The weeds were cleared in 2007. The planting can be seen in 2011 (on the right hand side). Reed canarygrass continues to be a management challenge.

After

July 2011

Photo Point # 2: Located near the upstream edge of Wilson's property, about 20 yards downstream of the property line. This set of photos is looking south towards the City of Scappoose.

Before

April 2007

The lower 'shelves' were planted heavily with willow. The eroding slope was pulled back with heavy equipment, seeded and covered in coir fabric. The upper levels were planted with a variety of native shrubs and trees.

After

July 2011

Photo Point # 3: Located at the first bend upstream from the downstream property line of LaCombe's. This set is looking north to Northwest from southeastern edge of the creek.

Before

April 2006

High water events flow over the banks of the creek eroding the silty soils in the process. Native trees and shrubs were planted along the creek to help slow down water velocity and stabilize the bank.

After

July 2011

Photo Point # 3: Located at the first bend upstream from the downstream property line of LaCombe's. This set of photos is looking west from the Southern edge of the creek.

Before

April 2006

As these plantings mature, it is hoped that they will help shade out non-native weeds and provide shade for the creek.

After

July 2011

Photo Point # 4: Located at the northern tip of the first bend of the creek, at the upstream border of LaCombe's property. This set of photos is looking south from the southeastern edge of the creek.

Before

April 2006

Fencing livestock from the edges of the stream has allowed vegetation to become reestablished. High water in 2011 caused high mortality in certain species of trees and shrubs.

After

July 2011

Photo Point # 5: Located at the most upstream edge of LaCombe's property bordering Port of St Helens property. This set of photos is looking north along the southern edge of the creek.

Before

April 2006

Fencing livestock from the edges of the stream has allowed vegetation to become reestablished. High water in 2011 caused high mortality in certain species of trees and shrubs.

After

July 2011

High water 2011

This photo is looking north towards the Northwestern corner of Wilson's field, where Photo Point 1 photos are taken.

At the Northern end of Wilson's property, the water has entered the field, filling the old side channels, all the way across the fields from LaCombe's through Wilson's to reenter the creek at the downstream end of the fields.

Looking south over the fields from the North end of Wilson's field back across the side channels towards the property owners homes

From the property on the southern edge of LaCombe's, this photo is looking Northeast following the side channels that run from Lacombe's property through Wilson's property during high water events.

From the southern end of these fields, water tops the creek at a couple low spots and spreads out to fill several old side channel depressions. When the water levels drop in the creek, these side channels hold water and slowly return it back to the stream.

From just south of LaCombe's southern property line, this photo is looking north along the creek with water at full bank.

Hogan Ranch Photo Points

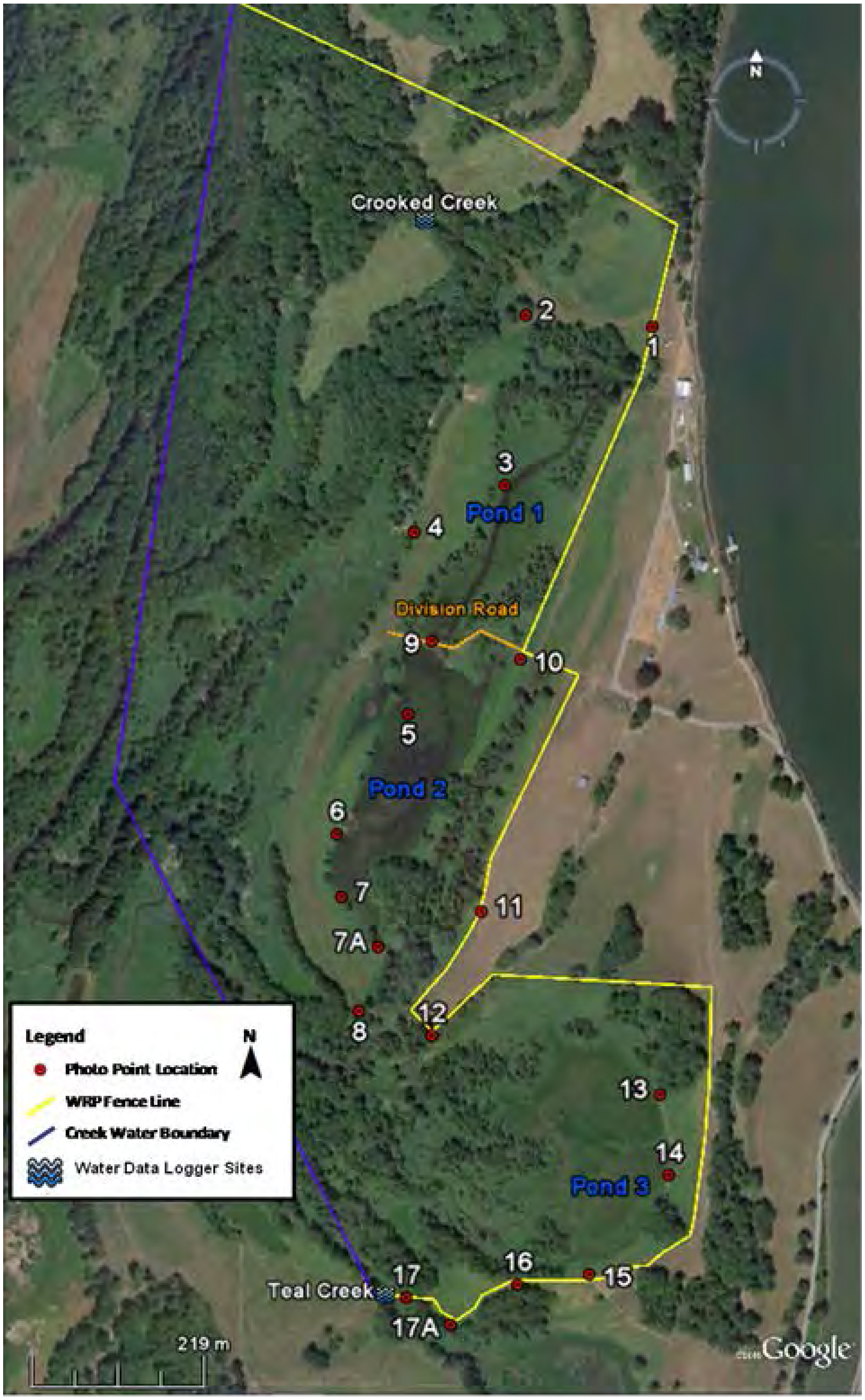


Figure 2: The map of Hogan Ranch shows the Wetland Reserve Program fence line and the established photo points.

Hogan Ranch

Photo Point #2: Located at the North end of the field on the West side of Pond #1, near the control structure. This photo series is looking South along the Western edge of the field towards Teal Creek.

Winter

January 2005

February 2011

The 2005 pictures show the reed canary grass grazed down by livestock and invasive weeds growing along the other side of the fence line. In the 2011 pictures, the invasive weeds have been removed and the grasses are coming up after the summer high water. You can see the trees that were planted in the background across the field.

Late Summer

September 2005

August 2011

Photo Point #4: Located along the Western edge of the field on the West side of Pond #1 in the old fence line. This photos series is looking North along the old fence line towards the State Park lands.

Winter

January 2005

February 2011

The 2005 pictures show the reed canarygrass grazed down by livestock on one side of the fence. In the 2011 pictures the reed canary grass is getting reestablished in the field after the summer high water event. You can see the planted trees in the background across the field (right hand side of photo).

Late Summer

September 2005

August 2011

Photo Point # 7A: Located at the southeast corner of Pond # 2. This photo series is looking North (towards Pond # 1) over the connection point between Pond # 2 and the backwater channel on the East side of Pond # 2.

Winter

January 2005

February 2011

In 2005 a beaver dam had replaced a dislodged pipe between Pond # 2 and the backwater channel that fed into Teal Cr. After the control structure was removed in 2009 and the channel was opened up between Pond # 2 and the back channel, Pond #2 has held water year round.

Late Summer

September 2005

August 2011

Photo Point # 8: Located at the south end of the field at the southern end of Pond # 2, on the roadway that was part of the dike. This photo series is looking North over the field at the Southwestern end of Pond #2.

Winter

January 2005

February 2011

Late Summer

September 2005

August 2011

There was a dike at the southern end of the field that separated Pond # 2 from Teal Creek. That dike was lowered and the elevation dropped to that of the upper field. This has allowed sheet flow to enter Pond #2 from this location during high water events. There was also a failed control structure that was eliminated.

Photo Point #9: Located on Division Road between Ponds #1 and #2. This photo series is looking North over Pond #1.

Winter

January 2005

February 2011

Winter high water levels create a sheet flow connected with Scappoose Bay. Before the control structures were replaced Pond #1 would dry up. It now holds water year round.

Late Summer

September 2005

August 2011

Photo Point #9: Located on Division Road between Ponds #1 and #2. This photo series is looking East along Division Road towards Multnomah Channel

Winter | **Late Summer**


January 2005


September 2005

Division Road separates Pond # 1 & Pond # 2. A water control structures allows the ponds to be regulated as separate bodies of water. High water levels create a sheet flow connected with Scappoose Bay over Division Road. In the past, beaver and nutria tunneled through the dike creating huge holes in the road way. During the replacement of the control structure the roadway was reinforced.


February 2011


August 2011

Photo Point #9: Located on Division Road between Ponds #1 and #2. This photo series is looking South over Pond #2.

Winter

January 2005

February 2011

Winter high water levels create a sheet flow connected with Scappoose Bay. Before the control structures were replaced Pond #2 would dry up except for a small channel in the southern third of the pond. It now holds water year round.

Late Summer

September 2005

August 2011

Photo Point #9: Located on Division Road between Ponds #1 and #2. This photo series is looking West along Division Road towards Scappoose Creek

Winter

January 2005

February 2011

Before the road was reinforced, beaver and nutria tunneled through the dike creating huge holes in the road way. Beaver and nutria are still active in the area and periodically block the control structure. Unless the control structure is routinely maintained, it limits the flow between Pond #1 and #2 during low flow periods

Late Summer

September 2005

August 2011

Photo Point # 10: Photos are taken from the gate fence post at the entry point to Division Rd. They are looking South over the ridge between Pond # 2 (on the Western edge) and the back water area (on the Eastern edge) from the entry point to Division Road.

Winter

January 2005

February 2011

The forest understory in this area was covered with blackberries and had pieces of old fence lines along the ridge. The fencing was removed, and the weeds were cut and treated. The area was replanted with native trees and shrubs.

Late Summer

September 2005

August 2011

Photo Point # 14: Looking North along the Eastern edge of Pond # 3 from the southeastern edge of Pond # 3, towards the main house site.

Winter

January 2005

February 2011

Before the road was reinforced, beaver and nutria tunneled through the dike creating huge holes in the road way. Beaver and nutria are still active in the area and periodically block the control structure. Unless the control structure is routinely maintained, it limits the flow between Pond #1 and #2 during low flow periods

Late Summer

September 2005

August 2011

Photo Point # 14: Located in the field at the southeastern edge of Pond # 3. This photo series is looking East over the field and WRP fence towards Multnomah Channel.

Winter

January 2005

February 2011

The edge around Pond # 3 had been heavily grazed before the WRP fence was constructed. After livestock were excluded, invasive weeds were removed and native plants were planted around the edge and in the understory of existing stands of ash

Late Summer

September 2005

August 2011

Photo Point # 14: Located in the field at the southeastern edge of Pond # 3. This photo series is looking South along the Eastern edge of Pond # 3 towards Santosh Slough.

Winter

January 2005

The varied hydrology of the margin along the edge of the pond that creates the "bowl" fluctuates enough to where it is difficult to establish a plant community.

Late Summer

September 2005

February 2011

August 2011

Photo Point # 14: Located in the field at the southeastern edge of Pond # 3. This photo series is looking West over Pond # 3 towards Teal Creek.

Winter

January 2005

February 2011

After livestock were excluded from the site, a succession of native emergent wetland vegetation has come up at the site. There was more diversity the first few years after exclusion and now the site is dominated by a few species such as wapato. The August 2011 photo shows the reed canarygrass die back at the high water mark.

Late Summer

September 2005

August 2011

Photo Point # 15: Located at the South end of Pond # 3, this photo series is looking north over the pond towards the main house.

Winter

January 2005

February 2011

This photo point was moved to realign with the WRP fence line when it was installed. The photo shows the network of channels within Pond #3 that emerges when the water levels drop in the summer. Some of the channels are evident in the lower water periods in the winter.

Late Summer

September 2005

August 2011

HIGH WATER

The following pictures show high water events.

Photo Point # 17A

Looking North along WRP fence line

April 2011

The swale along the fence at photo point #17 is normally dry. Water was high enough to connect this area to the Boundary pond, just south of the WRP fence line.

Photo Point # 15

Looking North over pond # 3

April 2011

Photo Point # 14: High Water in Pond # 3

Winter Photo Point # 14: High Water in Pond # 3

Looking North
February 2011

Water was high enough to inundate all the WRP fences and into most of the plantings. In the east facing photo, you can see the flagging (above the water) of the trees that were planted along the east edge of Pond # 3. The ash forests also had several feet of water throughout them. The duck blind is missing in the west facing photo.

Looking East over field
February 2011

Looking South
February 2011

Looking West over Pond #3
February 2011

Photo Point # 2: Looking south from the north western end of the field along the west side of Pond # 1, near the control structure.

April 2011

Water from Pond # 1 is covering most of the field between the pond and Crooked Creek. It is connected by the low swale in about the middle of this photo.

Photo Point # 9: These photos were taken by boat from the middle of Division Road.

Winter Photo Point # 14: High Water in Pond # 3

Division Road is the main access point to the fields around Ponds #1 and #2. High water events frequently cover the roadway and connect the ponds with Scappoose Bay as a continuous sheet flow. This year the water was deep enough to cover the fields, the plantings and the plant tubes.

Looking North over the length of Pond #2 towards the state parklands
April 2011

Looking east over division Road (under water) towards Multnomah Channel
April 2011

Looking South over the length of Pond #2 Teal Creek
April 2011

Looking West along Division Rd towards (under water) Crooked Creek

Conclusion

Photo Points show the changes to the restoration projects over time. As the restoration projects proceed, the photos show the different stages (invasive plant removal, construction & revegetation). Some sets show the work that was completed better than others. For example, in the early spring small trees and tubing can be seen as the reed canarygrass hasn't started growing for the season. In late summer the reed canarygrass is tall and the plantings either can't be seen or they blend in with the background.

At Hogan Ranch, high water events covered the fields so plantings were under water when photos were taken, this can happen in winter, spring and/or summer. It will take the planting a few more years to be tall enough to be seen during all seasonal photo shots.
Photo points 15 and 16 were adjusted to line up with the WRP fence after it was constructed so there would not be random fence posts in the fields. These adjustments were within just a few feet of the original post. After construction of the WRP fence was completed and designs were developed for additional restoration work, two additional photo points were added, 7A and 17A, to include areas where work was going to take place.
During construction at Hogan Ranch there were a couple of the changes to the topography that altered the landscape where photo points were originally set up. Some of the photos from different years look like they were taken from a different location. In reality it is the same GPS location but from a different elevation. For example, in Photo Point # 9, the dike was removed in 2009, so the elevation dropped by 10 to 12 feet in 2009. Photo Points 3 and 5 were set up at the edges of the ponds during a dry summer period. After construction in 2009, the water levels have been consistently high enough that these points are only accessible by boat. Several sets of photos were taken by kayak or canoe during high water sheeting events, as most of the WRP area was under water.

References

Dosskey, MG, P Vidon, NP Gurwick, CJ Allan, TP Duval, and R Lowrance. 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. *Journal of the American Water Resources Association* (JAWRA) 46(2):261-277.

D. Torrey Lindo, Stacy L Renfro. 2003. Riparian and Aquatic Ecosystem Monitoring, 4th edition. Photo Pont Monitoring 2003. p 1-7). Portland State University

Pacific Northwest National Laboratory (PNNL). Habitat Restoration Projects in the Lower Columbia River and Estuary (PNNL—15793).Monitoring Protocols for Salmon. June 6, 2006. p 41.

Appendix D. Hogan Ranch and Wilson/LaCombe Species and Survival

Hogan Ranch and Wilson/LaCombe Species List	
Common Name	**Scientific Name**
Black hawthorn	*Crataegus douglasii*
Cascara	*Rhamnus purshiana*
Cluster rose	*Rosa pisocarpa*
Cottonwood	*Populus balsamifera*
Douglas spiraea	*Spiraea douglasii*
Elderberry	*Sambucus sp.*
Indian plum	*Oemleria cerasiformis*
Mixed willow	*Salix sp.*
Ninebark	*Physocarpus capitatus*
Oregon ash	*Fraxinus latifolia*
Ponderosa pine	*Pinus ponderosa*
Red-osier dogwood	*Cornus stolonifera*
Snowberry	*Symphoricarpos albus*
Thimbleberry	*Rubus parviflorus*
Twinberry	*Lonicera involucrata*
Western crabapple	*Malus fusca*
Western serviceberry	*Amelanchier alnifolia*

Hogan Ranch planting survival by species for monitoring years 2008 through 2011. *Note the larger total number of plants in 2009 and 2010 – this can be attributed to the 2009 inter-planting, the larger number of plots evaluated.

Hogan Ranch Planting Survival By Species 2008-2011

	2008				2009				2010				2011			
Species	Total	Dead	Survival	% of total	Total	Dead	Survival	% of total	Total	Dead	Survival	% of total	Total	Dead	Survival	% of total
Black hawthorn	26	1	96%	9%	12	1	92%	2%	3	0	100%	0%	2	0	100%	0%
Cascara	13	4	69%	5%	10	0	100%	2%	19	2	89%	3%	16	16	0%	4%
Cluster rose	12	1	92%	4%	6	0	100%	1%	12	0	100%	2%	0		NA	0%
Cottonwood	9	1	89%	3%	1	0	100%	0%	12	2	83%	2%	7	3	57%	2%
Douglas spiraea	21	0	100%	7%	11	0	100%	2%	18	0	100%	3%	13	3	77%	3%
Elderberry	0		NA	0%	0		NA	0%	4	1	75%	1%	4	4	0%	1%
Mixed willow	100	17	83%	35%	352	32	91%	71%	382	60	84%	58%	169	61	64%	42%
Oregon ash	65	12	82%	23%	81	9	89%	16%	189	41	78%	29%	172	65	62%	42%
Red-osier dogwood	5	3	40%	2%	0		NA	0%	1	0	100%	0%	3	3	0%	1%
Twinberry	11	7	36%	4%	0		NA	0%	0		NA	0%	0		NA	0%
Western crabapple	10	0	100%	4%	8	0	100%	2%	16	0	100%	2%	5	0	100%	1%
Unknown	11	11	0%	4%	17	15	12%	3%	0		NA	0%	14	14	0%	3%
Total	**283**	57	80%		**498**	57	89%		**656**	106	84%		**405**	169	58%	

Wilson/LaCombe planting survival by species for monitoring years 2008 through 2011.

Wilson/LaCombe Planting Survival By Species 2008-2011

Species	2008				2009				2010				2011			
	Total	Dead	Survival	% of total	Total	Dead	Survival	% of total	Total	Dead	Survival	% of total	Total	Dead	Survival	% of total
Cascara	17	0	100%	7%	8	1	88%	4%	13	1	92%	7%	3	0	100%	2%
Cluster rose	5	0	100%	2%	8	0	100%	4%	14	0	100%	7%	7	0	100%	4%
Douglas spiraea	18	0	100%	7%	13	0	100%	7%	14	0	100%	7%	16	0	100%	8%
Indian plum	4	1	75%	2%	3	0	100%	2%	1	0	100%	1%	0		NA	0%
Mixed willows	16	2	88%	6%	6	0	100%	3%	2	0	100%	1%	0		NA	0%
Ninebark	59	11	81%	23%	37	0	100%	19%	25	1	96%	13%	16	5	69%	8%
Oregon ash	20	5	75%	8%	21	1	95%	11%	23	0	100%	12%	15	0	100%	8%
Ponderosa pine	16	4	75%	6%	12	1	92%	6%	13	1	92%	7%	9	3	67%	5%
Red-osier dogwood	41	2	95%	16%	27	1	96%	14%	10	0	100%	5%	5	0	100%	3%
Snowberry	18	0	100%	7%	15	1	93%	8%	18	0	100%	9%	20	0	100%	10%
Thimble berry	7	0	100%	3%	0		NA	0%	1	0	100%	1%	0		NA	0%
Western crabapple	7	0	100%	3%	2	0	100%	1%	8	1	88%	4%	5	0	100%	3%
Western serviceberry	11	2	82%	4%	4	0	100%	2%	5	0	100%	3%	3	1	67%	2%
Unknown	14	14	0%	6%	43	41	5%	22%	1	1	0%	1%	0		NA	0%
Total	**253**	41	84%		**200**	46	77%		**148**	5	97%		**99**	9	91%	

Hogan Ranch & Wilson/LaCombe Restoration Plantings 2011

SW Shrub/Ash Forest

North Willow

East Ash Forest/Shrub

Wilson/LaCombe

Appendix E. Hogan Ranch Ponds Water Quality Data

Hogan Ranch Pond 1

Parameter	pH							DO (O_2 ppm)							Turbidity (NTU)						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	6.7	6.7	6.8	7.1	6.9	6.9	6.9	5.8	6.7	5.3	5.5	7.7	5.6	6.6	204.3	14.3	36.7	16.6	17.1	10.4	10.3
Standard Deviation (±)	0.6	0.5	0.5	0.3	0.5	0.2	0.3	1.5	2.0	1.8	1.5	4.0	2.4	3.1	255.1	7.6	17.6	18.8	13.3	7.4	4.6
Min	6.1	5.9	6.2	6.9	6.0	6.5	6.3	4.2	4.2	2.9	3.8	2.7	1.6	2.4	38.3	5.3	11.1	4.0	2.9	3.8	4.6
Max	7.1	7.2	7.3	7.6	7.7	7.3	7.5	7.2	9.2	7.2	7.1	14.7	8.5	10.8	498.0	24.3	50.0	51.9	42.0	27.7	17.9
Months Sampled	3.0	5.0	4.0	6.0	8.0	9.0	7.0	3.0	5.0	4.0	5.0	8.0	9.0	7.0	3.0	5.0	4.0	6.0	8.0	9.0	7.0

Parameter	Conductivity (µS/cm)							Water Temp °C (Grab Sample)						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	156.6	NA	133.3	153.8	95.8	96.3	80.3	12.5	16.0	21.7	18.5	15.8	13.6	14.6
Standard Deviation (±)	25.3	NA	24.8	57.8	28.2	32.2	32.6	4.2	6.6	4.0	3.6	6.8	5.8	4.9
Min	138.7	NA	99.7	90.2	61.0	46.1	40.6	9.5	5.5	17.6	15.0	5.3	5.8	7.4
Max	174.5	NA	157.3	205.8	141.0	158.5	129.6	15.4	22.0	27.0	22.3	22.1	22.1	20.1
Months Sampled	2.0	0.0	4.0	4.0	8.0	9.0	7.0	2.0	5.0	4.0	4.0	8.0	9.0	7.0

Bacteria	MPN Total/100ml							MPN E. coli/100ml						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	2076.0	1843.0	NA	1679.3	2420.0	1375.4	1562.1	777.5	210.0	NA	13.8	395.0	11.2	5.3
Standard Deviation (±)	485.1	1152.0	NA	1281.1	NA	1020.9	1005.8	484.4	323.5	NA	17.9	508.3	10.4	6.9
Min	1733.0	115.0	NA	200.0	2420.0	276.0	488.4	435.0	6.0	NA	4.1	2.0	2.0	1.0
Max	2419.0	2419.0	NA	2419.0	2420.0	2420.0	2419.6	1120.0	687.0	NA	40.6	980.4	30.5	17.5
Months Sampled	2.0	4.0	0.0	3.0	1.0	7.0	4.0	2.0	4.0	0.0	4.0	5.0	7.0	5.0

Hogan Ranch Pond 2

Parameter	pH							DO (O_2 ppm)							Turbidity (NTU)						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	7.7	6.7	7.0	7.1	6.9	7.0	6.9	9.6	6.4	6.6	5.8	6.9	6.8	7.2	56.0	15.0	32.8	23.3	24.5	10.4	10.6
Standard Deviation (±)	1.3	0.5	0.7	0.1	0.3	0.3	0.2	3.5	1.1	2.6	1.7	2.8	1.9	3.4	43.3	9.0	11.7	21.9	26.7	4.8	7.7
Min	6.3	5.9	6.3	6.9	6.4	6.6	6.4	7.0	4.6	3.2	2.9	2.8	3.3	2.6	27.3	4.0	22.2	6.0	3.0	5.2	5.8
Max	9.5	7.1	8.0	7.3	7.3	7.5	7.1	14.8	7.2	8.9	8.0	11.0	9.6	11.5	119.5	27.5	49.0	55.8	83.3	19.1	27.3
Months Sampled	4.0	5.0	4.0	7.0	8.0	9.0	7.0	4.0	5.0	4.0	7.0	7.0	9.0	7.0	4.0	5.0	4.0	7.0	7.0	9.0	7.0

Parameter	Conductivity (µS/cm)							Water Temp °C (Grab Sample)						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	136.5	NA	123.8	127.1	91.4	90.4	80.7	16.2	15.0	19.6	18.8	16.4	13.7	14.6
Standard Deviation (±)	#DIV/0!	NA	24.8	19.4	19.7	29.6	32.7	5.2	8.0	2.0	3.4	6.5	5.5	5.0
Min	136.5	NA	88.4	97.6	62.9	38.0	40.7	9.0	4.0	17.4	14.9	5.9	5.9	7.4
Max	136.5	NA	141.9	146.5	118.7	143.3	129.0	21.0	25.0	21.0	22.2	24.2	20.9	20.3
Months Sampled	1.0	0.0	4.0	5.0	8.0	9.0	7.0	4.0	5.0	3.0	4.0	8.0	9.0	7.0

Bacteria	MPN Total/100ml							MPN E. coli/100ml						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	1355.5	1499.8	NA	1560.5	2420.0	1448.6	1346.1	97.0	28.5	NA	170.4	121.2	40.8	6.2
Standard Deviation (±)	1504.0	1061.8	NA	1073.1	NA	908.9	895.0	66.5	34.6	NA	240.4	160.5	75.6	6.6
Min	292.0	548.0	NA	200.0	2420.0	70.0	270.3	50.0	1.0	NA	2.0	8.6	1.0	1.0
Max	2419.0	2419.0	NA	2420.0	2420.0	2420.0	2419.6	144.0	74.0	NA	613.0	387.3	224.7	16.0
Months Sampled	2.0	4.0	0.0	4.0	1.0	8.0	7.0	2.0	4.0	0.0	6.0	5.0	8.0	6.0

Hogan Ranch Pond 3

Parameter	pH							DO (O_2 ppm)							Turbidity (NTU)						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	7.3	6.6	6.8	7.2	7.5	6.6	7.2	8.2	8.1	7.3	6.2	10.1	6.7	7.8	14.2	25.4	25.8	10.3	18.3	23.1	15.5
Standard Deviation (±)	0.5	0.4	0.5	0.2	1.3	0.4	0.9	3.7	2.2	2.5	2.4	5.6	4.8	2.6	8.9	26.4	16.7	6.7	10.0	17.0	10.5
Min	6.8	6.0	6.4	6.9	6.5	6.0	6.4	5.7	4.7	5.1	3.8	3.6	1.8	2.8	9.0	9.0	9.6	5.1	4.6	6.1	5.3
Max	7.7	6.9	7.4	7.5	9.3	7.2	9.0	10.8	10.0	10.7	10.8	17.8	15.9	10.4	24.5	72.0	48.3	23.4	33.3	50.7	35.4
Months Sampled	3.0	5.0	4.0	6.0	6.0	8.0	7.0	2.0	5.0	4.0	6.0	6.0	8.0	7.0	3.0	5.0	4.0	6.0	6.0	8.0	7.0

Parameter	Conductivity (µS/cm)							Water Temp °C (Grab Sample)						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	161.1	NA	135.1	114.3	119.5	134.9	85.0	17.3	15.0	20.7	17.9	16.4	12.8	15.0
Standard Deviation (±)	68.3	NA	31.4	65.5	80.4	97.5	26.1	8.6	7.7	2.8	3.5	7.9	5.7	7.3
Min	112.8	NA	102.5	35.6	60.4	37.5	54.1	8.8	6.0	18.2	15.0	5.0	5.9	4.5
Max	209.5	NA	176.0	194.0	280.4	298.5	124.1	26.0	25.5	24.7	22.7	24.6	21.8	26.4
Months Sampled	2.0	0.0	4.0	4.0	6.0	8.0	7.0	3.0	5.0	4.0	4.0	6.0	8.0	7.0

Bacteria	MPN Total/100ml							MPN E. coli/100ml						
Year	2004	2005	2007	2008	2009	2010	2011	2004	2005	2007	2008	2009	2010	2011
Average	2419.0	2419.0	NA	1679.7	1270.8	1367.5	1072.1	1273.0	217.0	NA	282.1	129.0	40.0	12.9
Standard Deviation (±)	0.0	0.0	NA	1281.4	1108.5	1153.5	1073.3	1620.7	243.4	NA	518.1	255.0	44.2	13.3
Min	2419.0	2419.0	NA	200.0	98.0	236.0	110.6	127.0	66.0	NA	9.9	3.1	4.1	2.0
Max	2419.0	2419.0	NA	2420.0	2420.0	2420.0	2419.6	2419.0	579.0	NA	1203.0	648.8	117.8	37.3
Months Sampled	2.0	4.0	0.0	3.0	4.0	6.0	7.0	2.0	4.0	0.0	5.0	6.0	6.0	6.0

Teal and Crooked Creek Water Temperature Data (Hourly Data Loggers)

Hogan Ranch Continuous Data Loggers			Over Entire Deployment Period					
Site	Study Years	Deployment Dates	Max Temp °C	Min Temp °C	Days Over 18 °C	Hours Over 15.6 °C	Hours Over 13.9 °C	Hours Over 25 °C (Lethal)
Teal Creek	2008-2009	7/17/2008-7/17/2009	33.3	0.01	137	3415	3939	344
	2009-2010	7/17/2009-8/19/2010	34.6	-0.4	158	3935	4557	659
Site	Study Years	Deployment Dates	Max Temp °C	Min Temp °C	Days Over 18 °C	Hours Over 15.6 °C	Hours Over 13.9 °C	Hours Over 25 °C (Lethal)
Crooked Creek	2008-2009	2/17/2009-7/17/2009	23.3	3.9	59	1588	1803	0
	2009-2010	7/17/2009-8/19/2010	28.1	0.8	98	5388	6465	113
Hogan Ranch Continuous Data Loggers			**During Critical Salmonid Period Jan 15th -May 15th**					
Site	Study Years	Deployment Dates	Max Temp °C	Min Temp °C	Days Over 18 °C	Hours Over 15.6 °C	Hours Over 13.9 °C	Hours Over 25 °C (Lethal)
Teal Creek	2009	1/15/2009-5/15/2009	23.9	0.6	5	224	521	0
	2010	1/15/2009-5/15/2010	29.7	-0.4	25	303	487	18
Site	Study Years	Deployment Dates	Max Temp °C	Min Temp °C	Days Over 18 °C	Hours Over 15.6 °C	Hours Over 13.9 °C	Hours Over 25 °C (Lethal)
Crooked Creek	2009	2/17/2009-5/15/2009	17.4	3.9	0	94	291	0
	2010	1/15/2009-5/15/2010	19.8	4.5	0	102	304	0

Appendix F. Scappoose Creek Water Quality Data Summary

LACOMBE PROPERTY (SSCA05)
MONTHLY WATER QUALITY DATA SUMMARY

Parameter	pH					DO (O_2 ppm)					Turbidity (NTU)				
Year	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Average	6.7	7.3	7.5	7.1	7.1	8.1	8.9	10.9	11.0	10.6	2.8	5.2	3.0	6.2	7.6
Standard Deviation (±)	0.3	0.3	0.4	0.5	0.3	1.3	1.2	1.3	1.1	0.9	0.7	6.8	1.4	4.5	10.1
Min	6.2	7.0	6.5	6.3	6.7	7.0	7.6	8.6	8.7	9.4	2.1	1.8	1.9	2.9	2.7
Max	7.1	7.8	8.0	8.0	7.7	10.0	10.2	13.1	12.2	12.0	3.8	17.4	6.6	15.6	28.2
Months Sampled	5	5	11	9	6	5	5	11	9	6	5	5	11	9	6

Parameter	Conductivity (µS/cm)					Water Temp °C (Grab Sample)				
Year	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Average	109.1	107.9	84.0	67.4	73.0	17.5	16.9	12.5	10.1	12.4
Standard Deviation (±)	25.1	19.5	20.3	22.0	24.7	3.3	2.4	5.7	4.7	6.4
Min	73.1	84.9	59.3	34.5	32.0	12.7	15.5	3.2	5.4	4.8
Max	135.0	124.5	124.7	103.1	102.6	20.9	20.4	18.4	16.6	22.6
Months Sampled	5	4	11	9	6	5	4	10	9	6

WILSON PROPERTY (SSCA01)
MONTHLY WATER QUALITY DATA SUMMARY

Parameter	pH					DO (O_2 ppm)					Turbidity (NTU)				
Year	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Average	6.8	7.3	7.3	7.0	7.0	7.6	8.2	10.3	10.4	9.3	2.8	5.5	3.5	6.1	7.7
Standard Deviation (±)	0.5	0.1	0.4	0.4	0.2	1.3	1.3	1.9	2.1	1.0	1.2	6.4	1.5	4.5	8.9
Min	5.9	7.2	6.4	6.6	6.8	6.1	7.1	7.0	6.6	8.2	1.8	2.0	1.9	3.2	3.2
Max	7.2	7.4	7.9	7.8	7.4	9.3	9.8	12.8	12.2	11.0	4.7	15.0	6.6	17.4	25.9
Months Sampled	5	4	11	9	6	4	4	11	9	6	5	4	11	9	6

Parameter	Conductivity (µS/cm)					Water Temp °C (Grab Sample)				
Year	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Average	104.3	116.6	87.2	68.0	73.7	18.2	17.2	12.2	10.0	12.6
Standard Deviation (±)	20.9	14.0	23.7	22.4	25.4	3.7	3.0	5.5	4.7	6.2
Min	73.1	100.5	59.3	34.5	31.6	13.4	15.1	3.2	5.3	4.7
Max	126.0	125.5	127.2	104.5	102.4	22.0	20.6	18.4	16.1	21.9
Months Sampled	5	3	11	9	6	5	3	10	9	6

SCAPPOOSE CREEK CONTINUOUS WATER TEMPERATURE DATA							
Over Entire Deployment Period							
Study Years	Deployment Dates	Max Temp °C	Min Temp °C	Days Over 18 °C	Hours Over 15.6 °C	Hours Over 13.9 °C	Hours Over 25 °C (Lethal)
2008-2009	9/11/2008-9/11/2009	21.3	0.01	53	4440	6126	0
2009-2010	9/12/2009-6/30/2010	21.9	1.87	2	1064	1447	0
During Critical Salmonid Period Jan 15th -May 15th							
Study Years	Deployment Dates	Max Temp °C	Min Temp °C	Days Over 18 °C	Hours Over 15.6 °C	Hours Over 13.9 °C	Hours Over 25 °C (Lethal)
2008-2009	1/15/2009-5/15/2009	11.3	5.7	0	0	0	0
2009-2010	1/15/2010-5/15/2010	20	5.3	0	13	24	0