Action Effectiveness Monitoring in the
"Implement Habitat Restoration in the Lower Columbia River and Estuary" Contract

Annual Report

BPA Project Number: 2003-011-00
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1.0 Executive Summary

This report is the annual report documenting Action Effectiveness Monitoring (AEM) efforts implemented by the Lower Columbia River Estuary Partnership (Estuary Partnership) under BPA Project Number 2003-011-00, Contract Number 35012.

In spring 2008, the Estuary Partnership contracted Parametrix, NOAA Fisheries, 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 2008. These AEM sites represent different restoration activities (culvert enhancement to improve fish passage, large wood installation, revegetation, 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 George, to saltwater intrusion in Reach A, near Astoria, Oregon).

Summaries of 2008 AEM Results

- Parametrix analyzed temperature data from 11 loggers deployed in aquatic habitats throughout the Mirror Lake site to characterize summertime temperatures and classify areas suitable for juvenile salmonid rearing and non-native predators (Section 3.0 Temperature AEM at Mirror Lake). In 2008, average daily high temperatures at the Mirror Lake site ranged from 14.2°C to 21.7°C (Figure 5) with warmer temperature likely at the two downstream locations without data. 51% of the site was classified as suitable for juvenile salmonid rearing during summer months whereas 45% was classified as suitable for smallmouth bass, the most likely non-native predator of juvenile salmonids at the site (Figure 12). Juvenile salmon and smallmouth bass likely do not use the same portions of the site. Similar reforestation efforts are proposed in other portions of the site (Figure 13). The overall goal of completed and proposed efforts is to increase the percentage of the site with temperatures suitable for salmonids.

- NOAA Fisheries sampled fishes and macroinvertebrates monthly from April to September 2008 at 3 locations at the Mirror Lake restoration site to describe site usage by fishes, condition and stock of collected juvenile salmonids, and abundance and biomass of macroinvertebrates (Section 4.0 Juvenile Salmonid and Prey AEM at Mirror Lake). Fish species richness ranged from 6 to 16 (Table 12). In May and June, juvenile Chinook and coho were found at sites in Mirror Lake (Lake Site) and downstream of the I-84 culvert (Culvert Site) (Table 14). Between July and September, only 6 fin-clipped Chinook were collected in August at the Culvert Site. At the upstream Young Creek Site, large numbers of unmarked coho (but no Chinook) were captured from May through September. Chinook growth rates for the Culvert Site were among the lowest observed while those for the Lake Site were moderate but not significantly different from other sites (Figure 19). Growth rates between the Lake and Culvert Sites were not significantly different, though salmon at the Lake Site had relatively faster growth rates. Chinook from the Lake Site had significantly higher fish condition factor (CF) than the overall mean for other LCRE samples (Figure 20). For juvenile coho, CF was significantly higher for marked coho (compared to unmarked fish), and differed significantly among sites (Figure 21). Coho from the Lake Site had significantly higher CF than the overall mean for all samples whereas coho from the Culvert Site had significantly lower CF. Juvenile Chinook collected from the Lake and Culvert Sites were identified as Snake River Fall and Upper Columbia summer/fall stocks (Figure 22). Juvenile coho collected at the Young Creek Site were most likely fish spawned in the upstream areas of Young Creek. NOAA Fisheries and CREST are currently processing the 32 individual Chinook salmon stomach contents samples and 98 invertebrate samples, and will described the results in forthcoming reports.

- ACFM collected data at 218 vegetation plots across 259 acres at the Sandy River Delta and Mirror Lake restoration sites (Table 20) and 40 acres at 1 reference site to assess the success of invasive vegetation removal and native vegetation plantings at these restoration sites (Section 5.0 Planting Success AEM at Mirror Lake and Sandy River Delta). At the reference site, ACFM found an average of over 7,700 live, woody plants per hectare, 11% of which are trees (Table 23). At all planted restoration sites, ACFM found a range of 1,200 to 3,200 live, woody plantings per hectare, showing a survival rate of 56% to 90%; trees comprised 37% to 75% of live, woody plantings measured. Duration of weed control before planting, or site preparation, appears to be positively correlated with planting success on all sites. This AEM suggests that continued maintenance is needed at all sites in order to achieve restoration goals. Vegetation management treatments for all sites are outlined in Table 26.

- 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 (Section 6.0 Vegetation and Habitat AEM at Scappoose Bottomlands). Photo-point analyses will be included in the 2009-2010 report. The overall survival rate of plantings along Lower Scappoose Creek was 83% with an average planting density (APD) of 1.3 plants/m^2 (Table 31). On Hogan Ranch, the overall survival was 80% with an APD of 0.27 plants/m^2. Vigor of the surviving plantings was similar between the two sites (Table 31); most plants were of medium vigor and similar proportions of plantings fell into each vigor category. One-year post cattle exclusion, the Hogan Ranch wetlands are showing signs of recovery. Native wapato dominates a large area of Pond 3, providing a food resource for waterfowl and other wildlife. On Ponds #1 and #2, the wetted area is increasing and the vegetation reflects this change. One unintended consequence of the restoration has been an apparent increase in the dominance of reed canary grass on the outer edges of the ponds. AEM has made site managers aware of this potential invasive species issue, and they monitor the situation so that it does not become a long-term issue.

- CREST gathered fish and macroinvertebrate data at Scappoose Bottomlands and habitat (sediment accretion, channel cross-sections, and photo-points), fish, and macroinvertebrate data at the Fort Clatsop restoration and reference sites. Fish and macroinvertebrates were sampled monthly between June and August at Scappoose Bottomlands and March and August at the Fort Clatsop sites and monthly (Section 7.0 Salmon, Salmon Prey, and Habitat Monitoring at Scappoose Bottomlands and Fort Clatsop). For the site at Scappoose Bottomlands sampled consistently between June and April, fish species and abundance varied, and included a large number of goldfish, banded killifish, black crappie, bullhead catfish, and stickleback (Table 36). One coho salmon was collected at this site in November 2008 (Table 36). CREST has archived macroinvertebrate samples from Scappoose Bottomlands and will prioritize samples coinciding with salmon collection future processing and analyses. At the Fort Clatsop restoration site, Chinook, coho, and chum salmon and cutthroat and steelhead trout were observed (Figure 35), and were more abundant and diverse relative to data collected in 2007 prior to restoration actions (Figure 36). At the reference site, Chinook and coho were collected (Figure 37). Prey utilization samples were only collected from juvenile salmonids at the restoration site and showed that salmon diets consisted largely of Chironomids. Macroinvertebrates available as prey peaked in terms of richness and abundance by June and July.

2.0 Background on Estuary Partnership's Action Effectiveness Monitoring

The 2007 Draft Biological Opinion for the Federal Columbia River Power System (Draft 2007 BiOp) highlights the importance of estuarine habitat restoration for anadromous fishes (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 response to the Draft 2007 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 River Estuary Partnership (Johnson et al. 2008). This document provides a framework to evaluate progress towards understanding, conserving, and restoring the estuary to benefit ESA listed salmonid species and outlines a plan for AEM.

The Effectiveness Monitoring Program administered by Lower Columbia River Estuary Partnership (Estuary Partnership) will implement 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 program has invested more than $4 million in habitat restoration in the lower Columbia River estuary (LCRE) since 1999 and contributed to over 30 projects, ranging from riparian revegetation to tidal reconnection.

2.1 Program Goal and Objectives

On-the-ground AEM efforts will 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 will 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:

- Implement AEM as outlined in the Estuary RME plan (Johnson et al. 2008) and following standardized monitoring protocols (e.g., Roegner et al. 2008) where applicable
- Develop long-term datasets for restoration projects and their reference sites
- Increase consistency in monitoring methods and data management and sharing between projects
- Disseminate data and results to facilitate improvements in regional restoration strategies
- Develop 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 Project (BPA 2003-007-00). The Ecosystem Monitoring Project implements monitoring activities to characterize undisturbed emergent wetlands and assess juvenile salmonid usage of those habitats. Several sites monitored by the Ecosystem Monitoring Project are included in the Estuary Partnership's Reference Site Study funded by BPA. Since the Ecosystem Monitoring Project 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.

2.2 Site Selection

In the 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 (Table 1, 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.
- Revegetation 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 in 2008 (Mirror Lake, Sandy River Delta, Scappoose Bottomlands, and Fort Clatsop; highlighted rows in Table 1 and green dots in Figure 1). These AEM sites represent different restoration activities (culvert enhancement to improve fish passage, large wood installation, revegetation, 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 George, 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	Instream	F	Yes
Scappoose Bottomlands	Cattle exclusion; Invasive removal; Native plantings	2004 – Present	Emergent wetland	F	Yes
Alder Creek	Culvert removal	2005 – 2006	Instream	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	A	Yes

Project Name	Restoration Activity	Year(s) When Restoration Occurred	Habitat Type	Reach	Baseline Monitoring
			habitat		
Fort Clatsop	Culvert removal and bridge installation	2005 –Present	Brackish wetland	A	Yes

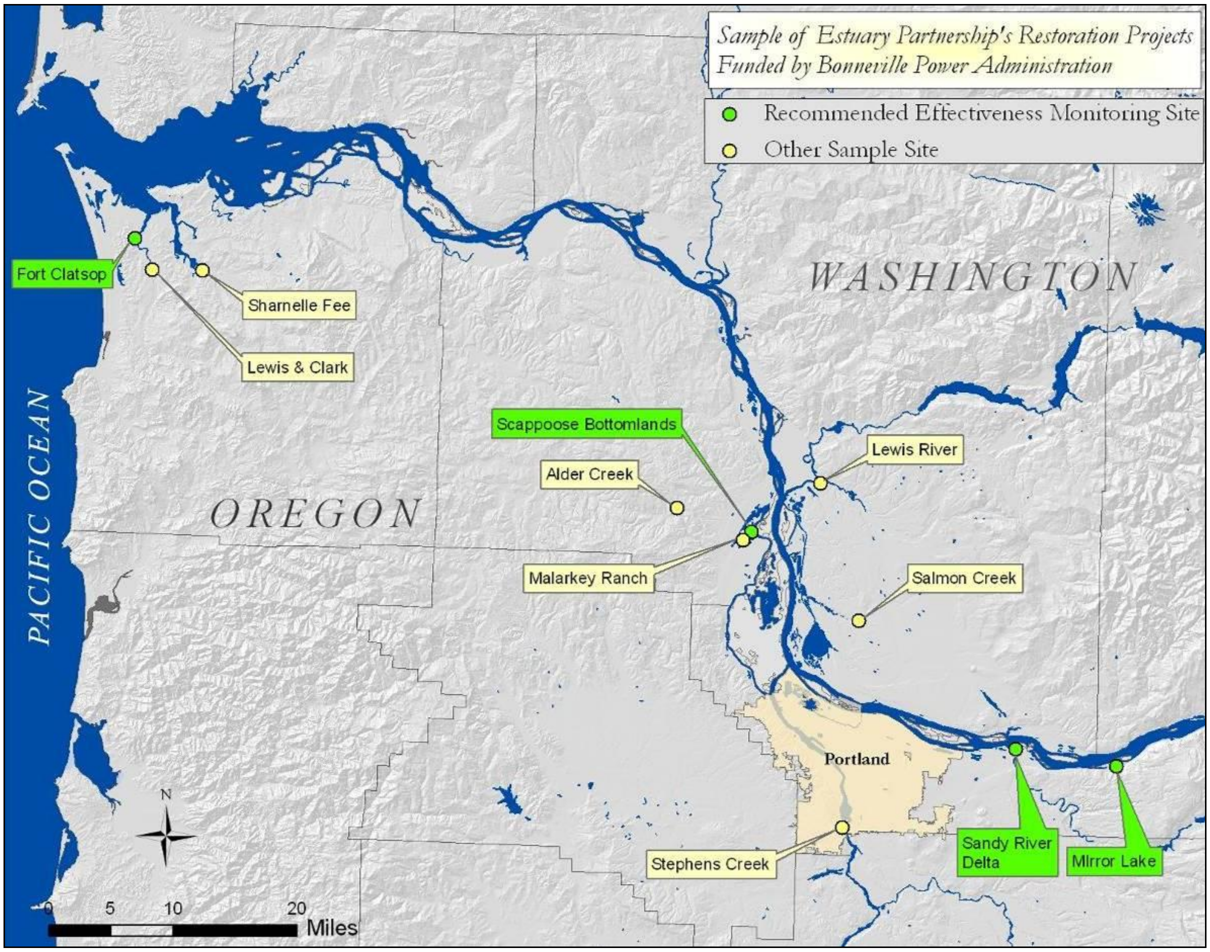


Figure 1: Sample of Estuary Partnership restoration projects funded by BPA presented as potential sites to EOS members. Sites that EOS members recommended for AEM are denoted by the green dots and boxes.

3.0 Temperature AEM at Mirror Lake

Over the past 4 years, several restoration actions have been implemented at the Mirror Lake site. Actions include replacement of a failing culvert with a wooden bridge; reforestation of 45 acres of riparian habitat; installation of 13 instream habitat structures (composed of 65 pieces of large woody debris, LWD); and improvement of fish passage at the site's outlet culvert. In 2008, AEM efforts by Parametrix (Estuary Partnership Contract #07-2008) focused on assessing temperature conditions and juvenile salmonid use of the site. A conceptual model for temperature AEM at Mirror Lake is presented in Appendix 1.

Temperature was identified as a concern at Mirror Lake for three reasons. First, the site is known to support cold-water species, including three species of salmonids protected by the Endangered Species Act: coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha*), and steelhead trout (*O. mykiss*). Second, monitoring during July and August 2005 revealed that temperatures ranged from a night-time minimum of 9°C at the railroad crossings to an afternoon maximum of 29°C at the outlet of Mirror Lake. Third, a comparison of historic (derived from an 1860 General Land Office survey) and current conditions revealed that the vast majority of riparian forests that historically existed at the site are no longer present, drastically reducing shade provided to on-site water bodies.

Specific objectives of this AEM study are to provide data and:

- Quantify the baseline thermal regime of Latourell Creek, Young Creek, Latourell Lake, and Mirror Lake during the low flow period (late July, August, and early September) when temperatures are warmest, and therefore potentially limiting;
- Classify areas suitable for juvenile salmonid rearing and non-native predators during summer months;
- Guide long-term site management and broad-scale planning of restoration/enhancement activities;
- Evaluate juvenile salmonid use of the site prior to passage improvements and LWD installation

3.1 Site Description

The Mirror Lake site is a 390-acre parcel located within Rooster Rock State Park, ~10 miles east of Troutdale in the Columbia River Gorge (Gorge). I-84 forms the site's northern boundary; the Union Pacific Railway rail line forms the southern boundary. About 50% of the land is publicly owned by the Oregon Parks and Recreation Department (OPRD) and is undisturbed forest. The Mirror Lake site is unique in that it provides a large, contiguous tract of historic bottomland hardwood forest within the Columbia River floodplain. The site includes 2 lakes, 2 streams (Young and Latourell Creeks), expansive wetlands, and remnants of its bottomland hardwood forest. Latourell and Young Creeks enter the site as moderate gradient systems with gravel/cobble substrate, but quickly transition to meandering, low gradient streams flanked by extensive wetlands. Both streams support spawning populations of Lower Columbia River coho salmon (StreamNet, 2008; Parametrix, 2004) and provide rearing and/or off-channel habitat for steelhead/rainbow trout and Chinook salmon, likely from Lower Columbia and up-river evolutionarily significant units (ESUs) (StreamNet, 2008; data in Section 4.3). Juvenile rearing is the only salmonid life history stage that occurs at the site during summer months when temperatures are potentially limiting (Table 2). Spawning, migration, egg incubation, and fry emergence occur during fall, winter, and spring months when temperatures are relatively cool and are not a limiting factor. Numerous other species are found on-site (Table 3).

Young Creek, which runs east to west across the site, enters the site through an open-bottom culvert under the Union Pacific railroad tracks ~100 yards downstream of Shepperds Dell Falls. Within the site, the stream's upper segment (~2,800 ft in length) is flanked by 45 acres of non-native Himalayan blackberry (*Rubus discolor*) and reed canary grass (*Phalaris arundinacea*) that was replanted with native species in 2008 by the EP and the Oregon Department of Transportation (ODOT). At the terminus of this upper reach, Young Creek flows beneath a wooden bridge installed by the EP and OPRD in 2005. From the bridge, Young Creek continues west ~5,800 ft to its confluence with Latourell Creek, flowing between I-84 to the north and an upland forest to the south. The lower reach of Young Creek is a wide, low-gradient creek with silty substrate and relatively homogenous habitat. It has few meanders and is flanked by expansive wetlands dominated by reed canary grass and/or wool grass (*Scirpus cyperinus*). About 500 ft of Young Creek (located immediately downstream of the railroad culvert) contains substrate suitable for salmonid spawning while the rest of the stream has silty substrate.

Latourell Creek enters the site through an open-bottom culvert under the Union Pacific railroad tracks ~1 mile downstream of its falls, midway between the east and west extents of the site, and just east of the community of Latourell. Latourell Creek generally is narrower than Young Creek and flows in a deeper channel as it meanders ~4,300 ft north then west from the railroad tracks to its confluence with Young Creek. Above the confluence, the banks are dominated by reed canary grass. Latourell Lake, a four-acre lake located immediately east of Latourell Creek, flows into Latourell Creek ~750 ft downstream of the railroad tracks. Beyond the confluence, Latourell continues west widening and slowing as it approaches Mirror Lake. Vegetation along this marshy area includes wapato (*Sagittaria latifolia*), wool grass, and other native herbaceous species. Latourell Creek flows through Mirror Lake before crossing beneath I-84 via a large twin-box culvert. This culvert constitutes the site's only outlet and hydrologic connection to the Columbia River. The Oregon Department of State Lands (DSL) has designated Latourell Creek as Essential Salmonid Habitat. Within the site, ~200 ft of suitable spawning habitat is located immediately downstream of the railroad crossing. Upstream of the site, ~1 mile of spawning habitat exists.

Latourell and Young Creeks experience peak flows during winter and spring when rainfall is greatest. Portions of their watersheds located upstream of the railroad tracks (the site boundary) are 4.2 and 2.0 square miles for Latourell Creek and Young Creek, respectively. Latourell Creek's total watershed area (including basins for Young Creek and two tributaries that enter below the railroad) is 8.9 square miles. Appendix 2 presents monthly flow estimates for Latourell and Young Creeks.

Table 2: Timing of salmonid use of Latourell and Young Creeks. Juvenile chum and sockeye salmon likely use this area as off-channel habitat during out-migration; however, their presence has not been documented.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Spawning												
Chinook Salmon												
Coho Salmon												
Steelhead/Rainbow												
Incubation												
Chinook Salmon												
Coho Salmon												
Steelhead/Rainbow												
Rearing												
Chinook Salmon												
Coho Salmon												
Steelhead/Rainbow												

	Species/Life Stage Not Present
	Species/Life Stage May Be Present
	Species/Life Stage Greatest Chance of Presence

Table 3: Aquatic species observed *above* and *below* the confluence of Latourell and Young Creeks.[1]

Common Name	Scientific Name	*Above* Confluence	*Below* Confluence
Coho salmon	*Oncorhynchus kisutch*	X	X
Chinook salmon	*O. tshawytscha*	X	X
Steelhead/rainbow trout	*O. mykiss*	X	
Threespine stickleback	*Gasterosteus aculeatus*	X	X
Smallmouth bass	*Micropterus dolomieu*	X	X
Largemouth bass	*M. salmoides*		X
Sculpin	*Cottus spp.*	X	X
Pacific lamprey	*Lampetra tridentata*	X	X
Pumpkinseed	*Lepomis gibbosus*	X	X
Bluegill	*L. macrochirus*		X
Common carp	*Cyprinus carpio*		X
Banded killifish	*Fundulus diaphanus*		X
Yellow bullhead	*Ameiurus natalis*		X
Northern pikeminnow	*Ptychocheilus oregonensis*		X
Chiselmouth	*Acrocheilus alutaceus*		X
Peamouth	*Mylocheilus caurinus*		X
Crayfish	*unknown*	X	X
Red-legged frog	*Rana aurora*	X	
Bullfrog	*R. catesbeiana*	X	X

3.2 Methods

Typically, summer temperature data are collected from June through the end of August. The Mirror Lake site, however, is a backwater area for the Columbia River when Columbia River flows exceed ~180,000 cubic feet per second (Figure 2, Parametrix, 2006). This backwater does not recede until early to mid-July and affects hydrology at all temperature stations except the two stations immediately downstream of the railroad tracks (Figure 3). To reduce complications during fieldwork and data analyses, probes were deployed after the backwater receded from the lower portions of the site.

The project team initially selected 11 locations within the Mirror Lake site where they deployed Vemco™ Minilog TR probes to monitor in-stream temperatures on July 20, 2008. The project team deployed 2 additional probes in Latourell Creek (immediately upstream and downstream of the mouth of Latourell Lake) on August 6, 2008. All probes were set to record at ½-hour intervals and audited using Oregon Department of Environment Quality (ODEQ) protocols (ODEQ, 2001). Table 4 summarizes the probe locations, identification numbers, and deployment ranges. Figure 3 shows the probe locations while Figure 4 provides location photos. The 13 locations were chosen to provide data from the different habitat types distributed throughout the site and a comprehensive summary of the site's thermal profile. This profile provides data that allow for the analysis of temperature increases through the site, the effect of channel types and riparian conditions on stream temperatures, and the effect of the site's two main tributaries (Young Creek and Latourell Lake) on temperatures in Latourell Creek.

[1] Sources: Parametrix 2004; unpublished fish salvage data and field observations by Parametrix staff from 2004 through 2008; data presented in Section 4.3.3 of this report.

Eleven probes were retrieved on September 16, 2008. The probes located at the outlets of Latourell Lake and Mirror Lake could not be located. Due to their close proximity to beaver dams, it is assumed that these probes were removed by beavers.

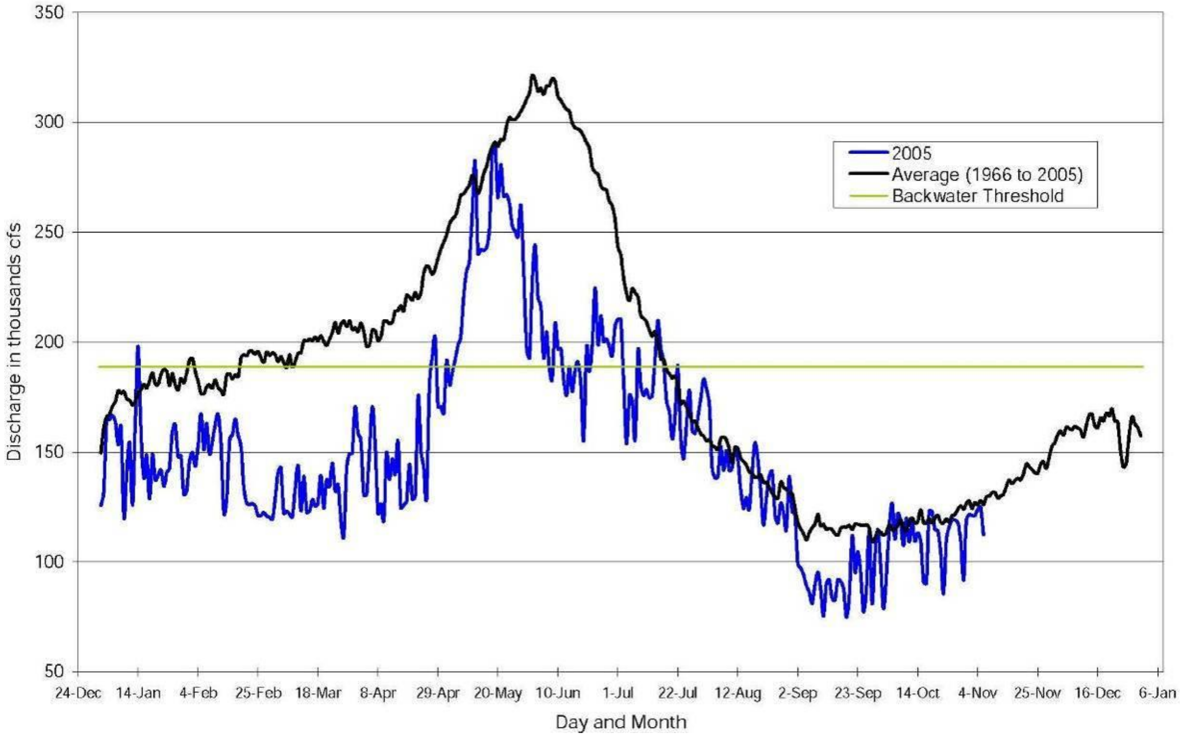
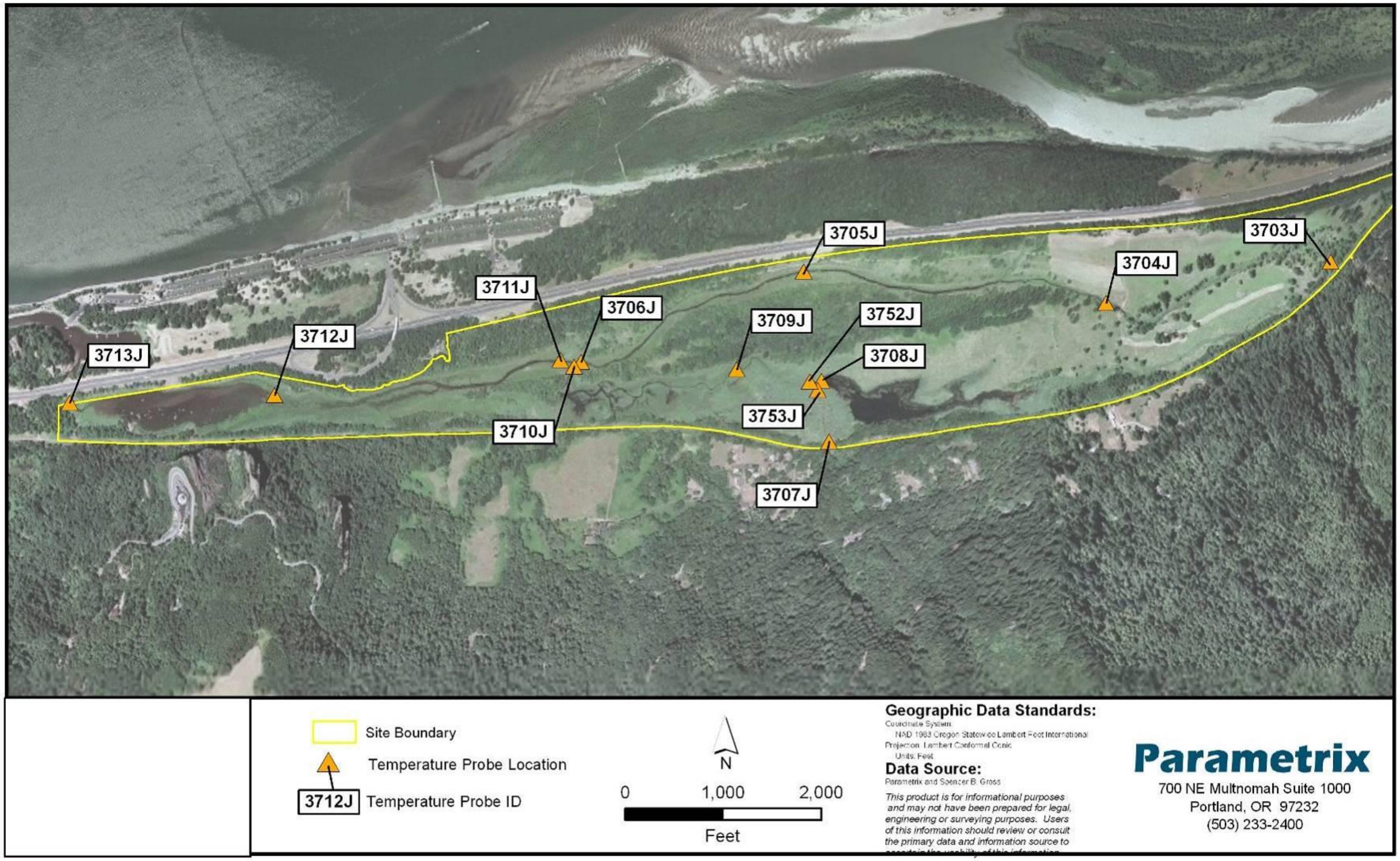


Figure 2: Columbia River average daily flows for 2005 (blue line) and 1996-2005 (black line). Green line denotes the backwater threshold for Columbia River flows inundating the Mirror Lake site.

Table 4: Monitoring station titles, locations, probe ID numbers, and deployment period.

Monitoring Station Title	Location	Probe ID Number	Date Deployed	Date Retrieved
Young Creek – RR	~50 feet downstream of Young Creek's RR crossing; its entry to the site.	3703J	7/20/08	9/16/08
Young Creek – Bridge	~ 50 feet downstream of the Young Creek bridge.	3704J	7/20/08	9/16/08
Young Creek – Middle	Half-way between probes 3704J and 3706J.	3705J	7/20/08	9/16/08
Young Creek – Confluence	~30 feet upstream of Young Creek's confluence with Latourell Creek.	3706J	7/20/08	9/16/08
Latourell Creek – RR	~ 75 feet downstream of Latourell Creek's RR crossing; its entry to the site.	3707J	7/20/08	9/16/08
Latourell Creek – u/s of Latourell Lake	~ 30 feet upstream of Latourell Creek's confluence with Latourell Lake.	3953J	8/6/08	9/16/08
Latourell Lake – Outlet	In Latourell Lake's outlet channel ~10m u/s of its confluence with Latourell Creek.	3708J	7/20/08	Not recovered
Latourell Creek – d/s of Latourell Lake	~ 75 feet downstream of Latourell Creek's confluence with Latourell Lake.	3952J	8/6/08	9/16/08

Monitoring Station Title	Location	Probe ID Number	Date Deployed	Date Retrieved
Latourell Creek – Middle	Approximate downstream terminus of proposed reforestation along Latourell Creek.	3709J	7/20/08	9/16/08
Latourell Creek – Confluence	~ 30 feet upstream of Latourell Creek's confluence with Young Creek.	3710J	7/20/08	9/16/08
Latourell Creek – d/s of Confluence	~ 75 feet downstream of Latourell Creek's confluence with Young Creek.	3711J	7/20/08	9/16/08
Mirror Lake – Inlet	Where Latourell Creek flows into Mirror Lake.	3712J	7/20/08	9/16/08
Mirror Lake – Outlet	~ 25 feet upstream of the I-84 culvert.	3713J	7/20/08	Not recovered



Analysis by C. Hainey; Analysis Date: Nov-2008; Plot Date: November 11, 2008; File Name: Figure9_MirrorLakeRestorationProject_TempProbe.mxd

Figure 3: Temperature monitoring locations at the Mirror Lake site. Refer to Table 4 for location names.

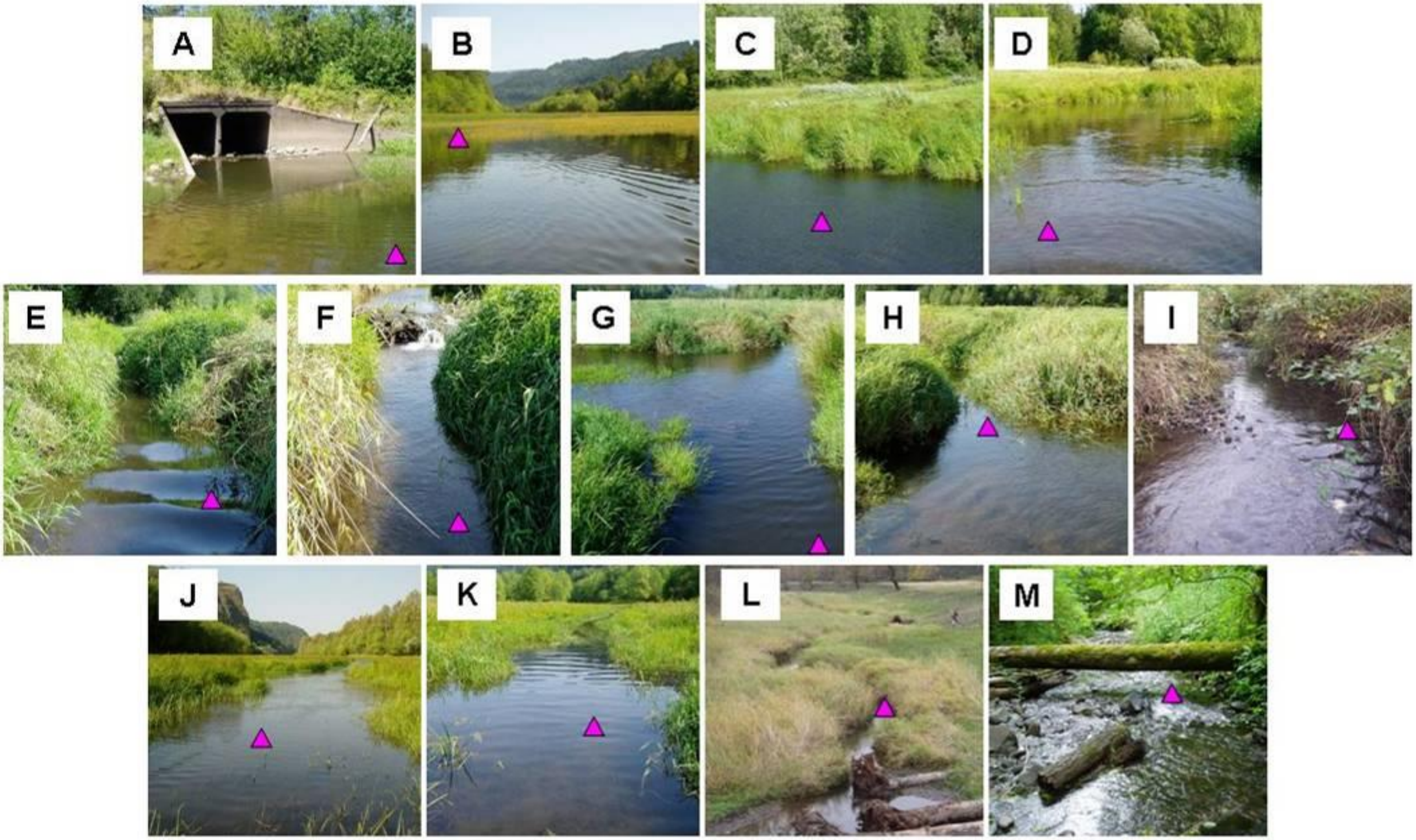


Figure 4: Photos of temperature monitoring locations at the Mirror Lake site. A) Upstream end of I84 culvert. Mirror Lake - Outlet (#3713J). B) Inlet of Mirror Lake (facing upstream). Mirror Lake – Inlet (#3712J). C) Latourell Creek – d/s of Confluence (#3711J). D) Latourell Creek – u/s of Confluence (#3710J). Photo taken facing d/s (north). E) Latourell Creek – Middle (#3709J). Photo taken facing u/s (east). F) Latourell Creek – d/s of Latourell Lake (#3952J). Photo taken facing u/s (east). G) Latourell Lake - Outlet (#3708J). Photo taken facing d/s (west). H) Latourell Creek – u/s of Latourell Lake (#3953J). Photo taken facing u/s (south). I) Latourell Creek – RR (#3707J). Photo taken facing u/s (south). J) Young Creek – Confluence (#3706J). Photo taken facing d/s (west). K) Young Creek – Middle (#3705J). Photo taken facing u/s (east). L) Young Creek – Bridge (#3704J). Photo taken facing d/s (west). M) Young Creek – RR (#3703J). Photo taken facing d/s (north).

3.3 Data Analyses

Analyses focus on water temperatures relative to juvenile rearing as this is the only salmonid life history stage that occurs on-site during summer months when temperatures potentially are limiting (Table 2). The following thresholds for juvenile salmonids were culled from the literature and used to interpret results:

- Bjornn and Reiser (1991) report 10-13°C as the preferred temperature range for juvenile steelhead rearing, and 12–14°C as the preferred range for juvenile Chinook and coho salmon rearing. This analysis uses 14°C as its threshold value since coho salmon are the primary species present on-site during summer months.
- ODEQ reports 18°C in their 2003 Temperature Criteria as the maximum temperature for salmon and trout rearing and migration.
- Bjornn and Reiser (1991) report that most juvenile salmonids are at risk of mortality when temperatures exceed 23-25°C.

Table 5 outlines the habitat classification categories developed based on these thresholds. These classifications account only for temperature as an indicator of habitat quality.

Based on available habitat, water temperature, fish sampling, field observations, and scientific literature, smallmouth bass are the non-native, piscivorous species most likely to inhabit the site and pose a threat to juvenile salmonids. This conclusion was drawn for the following reasons:

- Smallmouth bass are the non-native piscivorous species present at the site that are most tolerant of cool-water temperatures;
- Smallmouth bass are the only non-native piscivore that has been observed upstream of the Young Creek/Latourell Creek confluence; and,
- A recent report cites smallmouth bass as one of three major non-native predators of juvenile salmon (ISAB, 2008); the two other species (walleye [*Sander vitreus*] and channel catfish [*Ictalurus punctatus*]), have not been observed at the site.

Moyle (2002) reports that smallmouth bass, “rarely establish where water temperatures do not exceed 19°C in summer for extended periods.” Moyle (2002) also reports that in California, smallmouth bass populations typically occur in areas where summer water temperatures are 21–22°C while a temperature range of 27–31°C is selected in a laboratory setting. Based on this research, Parametrix developed the habitat classification zones for smallmouth bass outlined in Table 6. Again, this system accounts only for temperature as an indicator of habitat quality.

Table 5: Temperature-based habitat classification for juvenile salmonids.

Classification	Definition
Ideal Rearing Habitat	Stream reaches where average maximum daily temperatures are between 10°C and 14°C.
Functional Rearing Habitat	Stream reaches where average maximum daily temperatures are between 14°C and 18°C.
Poor Rearing Habitat	Stream reaches where average maximum daily temperatures are between 18°C and 23°C.
Unusable (Lethal) Rearing Habitat	Stream reaches where average maximum daily temperatures exceed 23°C.

Table 6: Temperature-based habitat classification for smallmouth bass.

Classification	Definition
Poor Smallmouth Habitat	Stream reaches where average maximum daily temperatures do not exceed 19°C.
Functional Smallmouth Habitat	Stream reaches where average maximum daily temperatures are between 19°C and 21°C.
Ideal Smallmouth Habitat	Stream reaches where average maximum daily temperatures are between 21°C and 31°C.

3.4 Results and Discussion

Table 7 summarizes temperature results.

Table 7: Summary of temperature data (°C) collected from July 21 – September 15, 2008.

Station	Avg Daily Low Temp	Avg Daily High Temp	Avg Diurnal Fluctuation	Avg Hours < 14°C	Avg Hours > 18°C	Avg Hours > 23°C
Young Creek – RR	12.0	14.2	2.2	18.7	0.0	0.0
Young Creek – Bridge	12.3	14.9	2.6	15.8	0.1	0.0
Young Creek – Middle	12.4	19.3	6.9	10.1	4.4	0.2
Young Creek – Confluence	13.0	22.6	9.6	6.0	8.9	2.3
Latourell Creek – RR	11.9	15.1	3.2	14.4	0.8	0.0
Latourell Creek – u/s of Latourell Lake	12.3	15.4	3.1	13.1	1.1	0.0
Latourell Lake – Outlet	NA	NA	NA	NA	NA	NA
Latourell Creek – d/s of Latourell Lake	12.5	15.8	3.3	12.1	1.2	0.0
Latourell Creek – Middle	12.2	16.0	3.8	11.9	0.9	0.0
Latourell Creek – Confluence	12.7	17.6	4.9	8.6	2.4	0.0
Latourell Creek – d/s of Confluence	12.9	19.2	6.3	6.9	4.4	0.2
Mirror Lake – Inlet	15.7	21.7	6.0	1.5	13.0	2.6
Mirror Lake – Outlet	NA	NA	NA	NA	NA	NA

3.4.1 Average Daily High and Low Temperatures

Average daily high temperatures at the Mirror Lake site ranged from 14.2°C to 21.7°C (Figure 5). However, based on previous monitoring and temperature audits, the 2 locations where temperature probes were not recovered (Latourell Lake – Outlet and Mirror Lake –Outlet) would have had warmer temperatures. In 2005, the average daily high temperature at the outlet of Mirror Lake was 26.4°C

(Parametrix, 2006). Indeed, an audit at the outlet of Latourell Lake at 3:50 pm on July 20, 2008 recorded a temperature of 32.4°C. Average daily high temperatures appear to be affected by 2 primary factors:

1. Distance upstream from the outlet of the site (the I-84 culvert): Average daily high temperatures are inversely related to distance upstream from the I-84 culvert;
2. Channel/habitat type: Average daily high temperatures are higher in the two lakes and in portions of each creek where the channel is wide, shallow, and less defined.

Temperatures within Latourell and Young Creeks are relatively cool where each creek enters the site (average daily high temperatures of 15.1°C and 14.2°C, respectively); however, by the time Latourell Creek enters Mirror Lake, its average daily high temperature has increased 6.6°C, from 15.1°C at the railroad to 21.7°C at the Mirror Lake – Inlet monitoring station. The average daily high temperature at its mouth (the I-84 culvert) likely is one to two degrees higher (Parametrix, 2006). Most warming occurs in reaches where the channel is wider, shallower, and less defined and flows are lower (see Section 3.4.5).

Average daily low temperatures exhibit similar patterns, except the difference between stations is less pronounced (less than 0.6°C). The exception to this is the Mirror Lake – Inlet station, where the average low temperature increases 2.8°C from the previous station. This discrepancy is likely related to water residence time. At the upper stations, the channels are relatively narrow and water flows through (and is replaced) relatively quickly. In contrast, in the site's lakes, residence time is longer so a large portion of the water heated during the day remains through the night, thus helping maintain elevated temperatures.

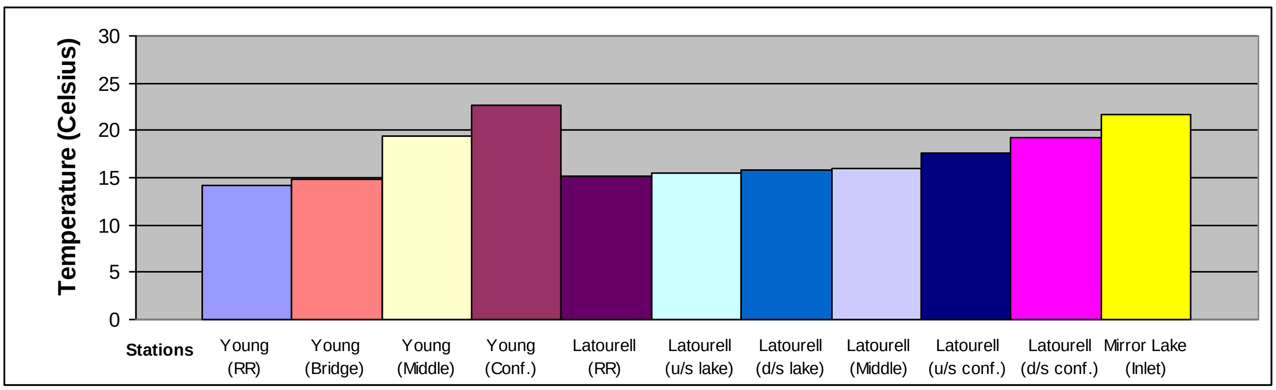


Figure 5: Average daily high temperatures for Mirror Lake monitoring locations.

3.4.2 Average Diurnal Fluctuations

Average diurnal fluctuations were calculated as the difference between the average daily minimum and maximum temperatures at each monitoring station. The largest diurnal fluctuations were noted at the following monitoring stations: Young Creek – Confluence (9.6°C), Young Creek – Middle (6.9°C), and Latourell – d/s of Confluence (6.3°C) (Figure 6). These results are predictable in that the middle and lower portions of Young Creek are wide, shallow, and flow through expansive wetlands. Consequently, they have significant surface area, lower flows, and are susceptible to rapid daytime warming; however, at night, their moderate detention time allows most of the warmer water to move out of the system as it is replaced by water from cooler, upstream reaches. This pattern facilitates significant cooling through the night, and therefore a larger diurnal fluctuation. The Latourell – d/s of Confluence station's large diurnal fluctuations primarily are generated by inflow (and resultant temperature influences) from Young Creek.

The two monitoring stations with the lowest diurnal fluctuations are Young Creek's upper-most stations, which have average diurnal fluctuations of 2.2°C and 2.6°C. Diurnal fluctuations at these stations likely are the lowest because their upstream reaches flow through relatively narrow channels flanked by forested habitats. This combination provides for limited warming during daylight hours, and therefore lower diurnal fluctuations. This condition should be maintained, if not improved, as the recently replanted riparian areas mature.

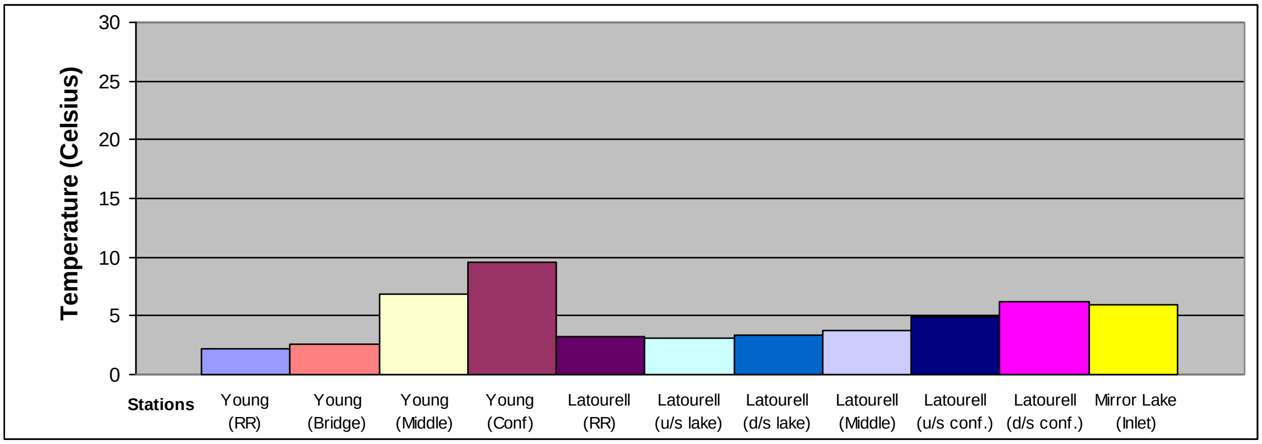


Figure 6: Average diurnal temperature fluctuations at Mirror Lake monitoring locations.

3.4.3 Hours Per Day with Temperatures below 14°C

Bjornn and Reiser (1991) report 12-14°C as the preferred temperature range for juvenile coho and Chinook salmon, with the preferred temperature range for steelhead trout being slightly lower (10-13°C). Throughout most of the site, average maximum daily temperatures are well above this range; consequently, as an additional indicator of habitat quality, Parametrix calculated the number of hours per day temperatures are within this preferred range, i.e., below 14°C (Figure 7). Temperatures were below 14°C for an average of at least 8 hours daily. In most of the cooler reaches, temperatures are below 14°C for an average of twelve to eighteen hours per day. With the likely exception of the Mirror Lake – Outlet and Latourell Lake – Outlet monitoring stations, temperatures typically fall below 14°C throughout the entire site. This theoretically allows juvenile salmon to move and feed throughout the site on a daily basis.

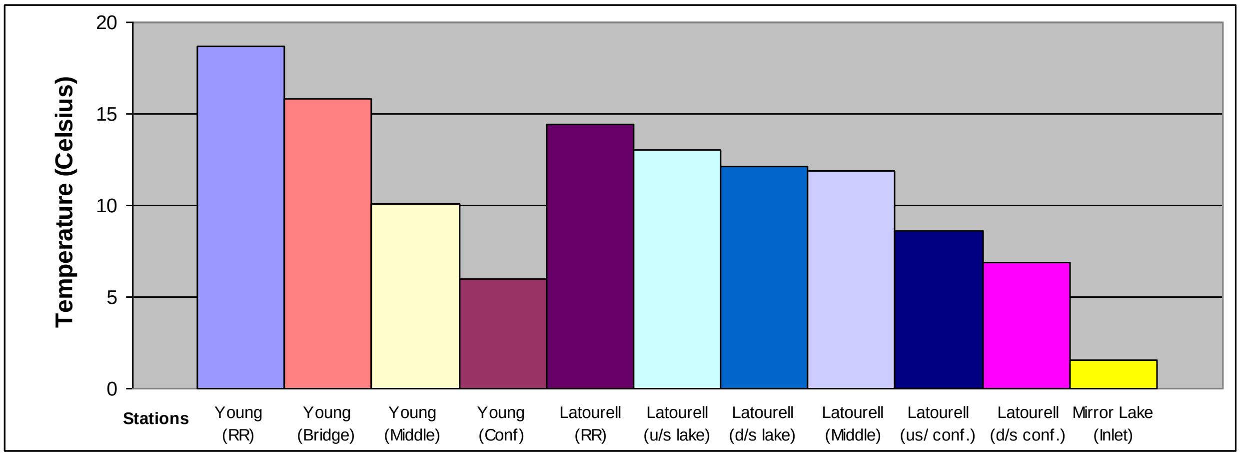


Figure 7: Hours per day with temperatures below 14°C at Mirror Lake monitoring locations.

3.4.4 Hours Per Day with Temperatures Above 18°C

ODEQ and NMFS report 18°C in their 2003 Temperature Criteria as the maximum temperature for salmon and trout rearing and migration (ODEQ, 2003). Average daily high temperatures exceeded this threshold in many monitoring locations; consequently, Parametrix estimated the duration of thermal stress by calculating the average number of hours per day temperatures exceeded 18°C (Figure 8).

The site-wide pattern mimicked those for average daily maximum temperature and average diurnal fluctuation. On average, the upstream portion of Young Creek and the entirety of Latourell Creek above its confluence exceeded 18°C less than 3 hours. All but one of these upper reaches exceeded the 18°C threshold for less than 1.5 hours daily. Temperatures at the Mirror Lake – Inlet station exceeded the 18°C threshold an average of 13.5 hours per day. This duration likely would have been exceeded at the Latourell Lake – Outlet and Mirror Lake – Outlet stations.

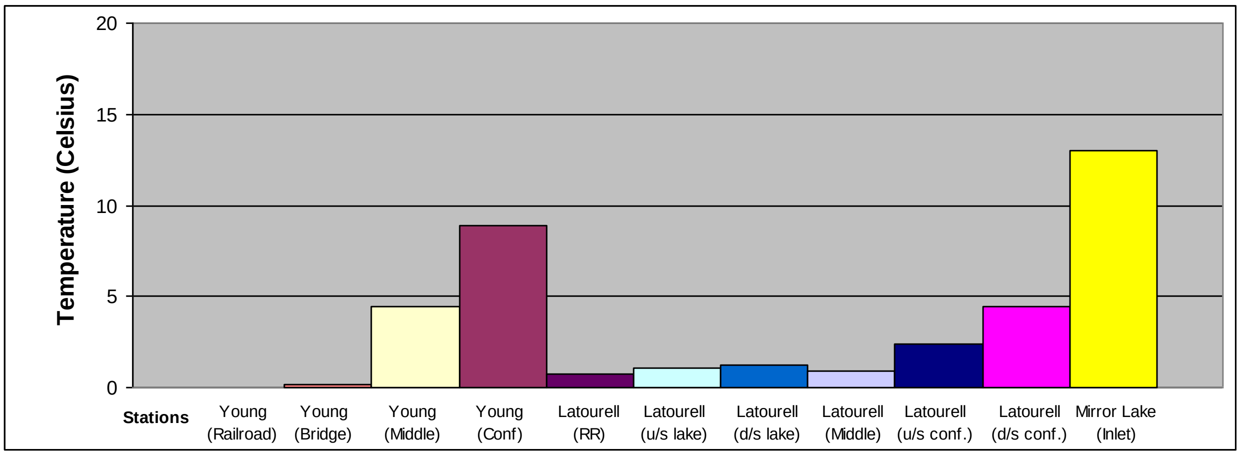


Figure 8: Hours per day with temperatures above 18°C at Mirror Lake monitoring locations.

3.4.5 Temperature Increase between Monitoring Stations

Table 8 and Figure 9 outline the temperature increases that occur between monitoring stations. Figure 10 presents the temperature increase per 1,000 linear feet of stream.[1] Together, these analyses identify the stream reaches where the greatest total warming and fastest rate of warming occur.

The reaches with the greatest length, least restricted channel, and lowest flows[2], e.g., Young (Middle to Confluence), exhibit the greatest total increase in temperature. Similarly, Young Creek's two lower reaches, which have the least restricted channels and lowest flows, i.e., greater surface area and longer residence times, exhibited the highest rates of temperature increase. The exceptions to this are the short reaches on Latourell Creek that have significantly higher temperatures than Latourell Creek. Although their flows are much lower, their inflow results in measurable warming of the mainstem. The warming that occurs in these reaches is the result of these tributaries and is not attributable to solar radiation and ambient air temperatures, which cause warming in other portions of Latourell Creek. Consequently, a direct comparison of thermal loading rates in these reaches with other reaches is not valid.

[1] This analysis assumes that temperature increases are linear and uniform between each monitoring station.
[2] At their confluence, summer low flows in Young Creek are estimated to be approximately one-half of those in Latourell Creek (Appendix 2).

As Latourell Creek flows from the railroad and into Mirror Lake, the stream's average maximum daily temperature increased 6.6°C. About 30% (2.0°C) of this increase can be attributed to its tributaries. In particular, Young Creek warms the mainstem by an average of 1.6°C. The remaining 4.6°C increase is a result of thermal loading within the site. This loading likely is caused by two factors:

1. The site's wide, shallow, low-gradient channels, which are flanked by expansive wetlands. This natural characteristic increases water retention time and surface area, which increase the effect of atmospheric conditions on surface water temperatures.
2. The majority of the site's riparian areas has been cleared of woody species and is now dominated by invasive species that provide little shading. This also increases the effect of atmospheric conditions (particularly solar radiation) on surface water temperatures.

Restoration has been proposed and/or implemented in several reaches where riparian deforestation is the primary factor contributing to thermal loading. These reaches, which together result in ~3.5°C of temperature increase to Latourell and Young Creeks, are noted in Table 7. Future monitoring in these reaches and comparison with the baseline data presented in this report will help determine the effectiveness of those restoration efforts.

Table 8: Summary of temperature increases between monitoring stations.

Stream Reach	Temp Increase (°C)	Approximate Reach Length (ft)	Temp Increase per 1,000 ft (°C)	Reforestation Proposed and/or Implemented
Young (RR to Bridge)	0.7	3,000	0.2	Yes
Young (Bridge to Middle)	4.4	3,200	1.4	Yes
Young (Middle to Confluence)	3.3	2,550	1.3	No
Latourell (RR to u/s Latourell Lake)	0.3	750	0.4	Yes
Latourell (u/s to d/s Latourell Lake)	0.4	100	4.1[1]	NA[2]
Latourell (d/s Latourell Lake to Middle)	0.2	1,000	0.2	Yes
Latourell (Middle to u/s of Conf.)	1.6	2,300	0.7	Yes
Latourell (u/s Conf. to d/s Conf.)	1.6	200	7.9[1]	NA[2]
Latourell (d/s Conf. to ML Inlet)	2.5	3,000	0.8	No
Latourell (ML Inlet to ML Outlet)	NA	2,150	NA	No
Totals	6.6[3]	18,250	--	--

Notes:

[1] Temperature increases in these reaches are due primarily to thermal loading from tributaries (Young Creek and Latourell Lake). These temperature increases represent the effect of the tributaries and therefore are not directly comparable to the rates of increase in other reaches.

[2] Not applicable. Reforestation is proposed; however, temperature increases in these short reaches are due to thermal loading from tributaries and therefore would not be affected by the proposed restoration.

[3] Because Young Creek and Latourell Lake are tributaries to Latourell Creek, their thermal loading is captured at monitoring stations located downstream of their entry into the Latourell Creek system. Consequently, temperature increases in these tributaries are not added to Latourell Creek's total value.

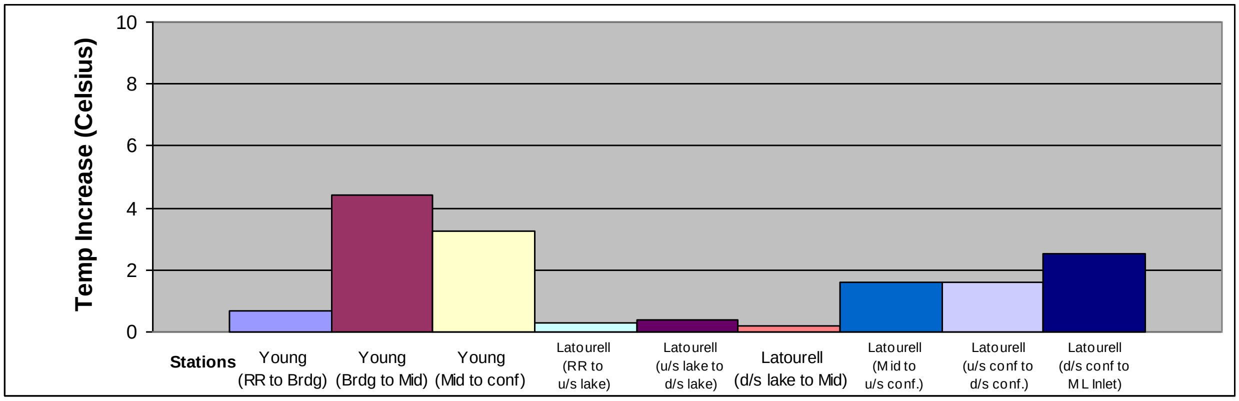


Figure 9: Temperature increase between monitoring stations calculated as the increase in average maximum daily temperatures.

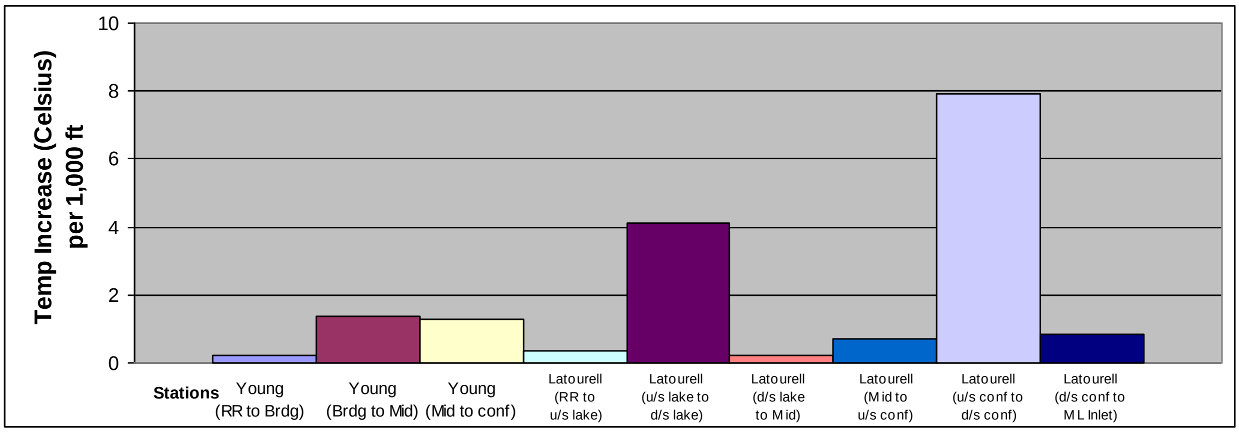


Figure 10: Temperature increase between stations calculated as the increase in average maximum daily temperatures per 1,000 ft.

3.4.6 Habitat Classification

Habitat quality was classified for juvenile salmonids and smallmouth bass based on temperature increases between stations and thermal criteria, outlined in Section 3.3 A-B, Table 9). Appendix 3 contains supporting calculations.

51% of the site was classified as "functional" for juvenile salmonid rearing during summer months whereas 45% was classified as "functional" or "ideal" for smallmouth bass (Figure 12). These areas do not overlap. Temperatures in Latourell Creek are suitable for juvenile salmonids down to its confluence with Young Creek. Temperatures in lower Young Creek approach lethal levels. Downstream of the confluence, Latourell Creek warms significantly, with an average daily maximum temperature increasing from 17.6°C upstream of its confluence to 21.7°C at Mirror Lake. Although this temperature range is not lethal to salmonids, it is less preferable than cooler temperatures. As the stream flows through Mirror Lake, temperatures there are also likely unsuitable for salmonids during summer months. Smallmouth bass likely are most prevalent in the lower 0.50-mile of Young Creek (downstream of the Young Creek – Middle station) and lower Latourell Creek (downstream of its confluence with Young Creek).

Table 9: Summary of habitat classification results.

Habitat Classification	Temperature Range	Source	Linear Feet of Stream	% of On-site Stream Length
Juvenile Salmonids				
Ideal	10-14°C	Bjornn and Reiser (1991)	0	0
Functional	14-18°C	ODEQ (2003); Bjornn and Reiser (1991)	9,150	51
Poor	18-23°C	ODEQ (2003); Bjornn and Reiser (1991)	6,700	37
Unusable	>23°C	Bjornn and Reiser (1991)	2,150	12
Smallmouth Bass				
Ideal	21-31°C	Moyle (2002)	4,425	24
Functional	19-21°C	Moyle (2002)	3,725	21
Poor	<19°C	Moyle (2002)	9,850	55

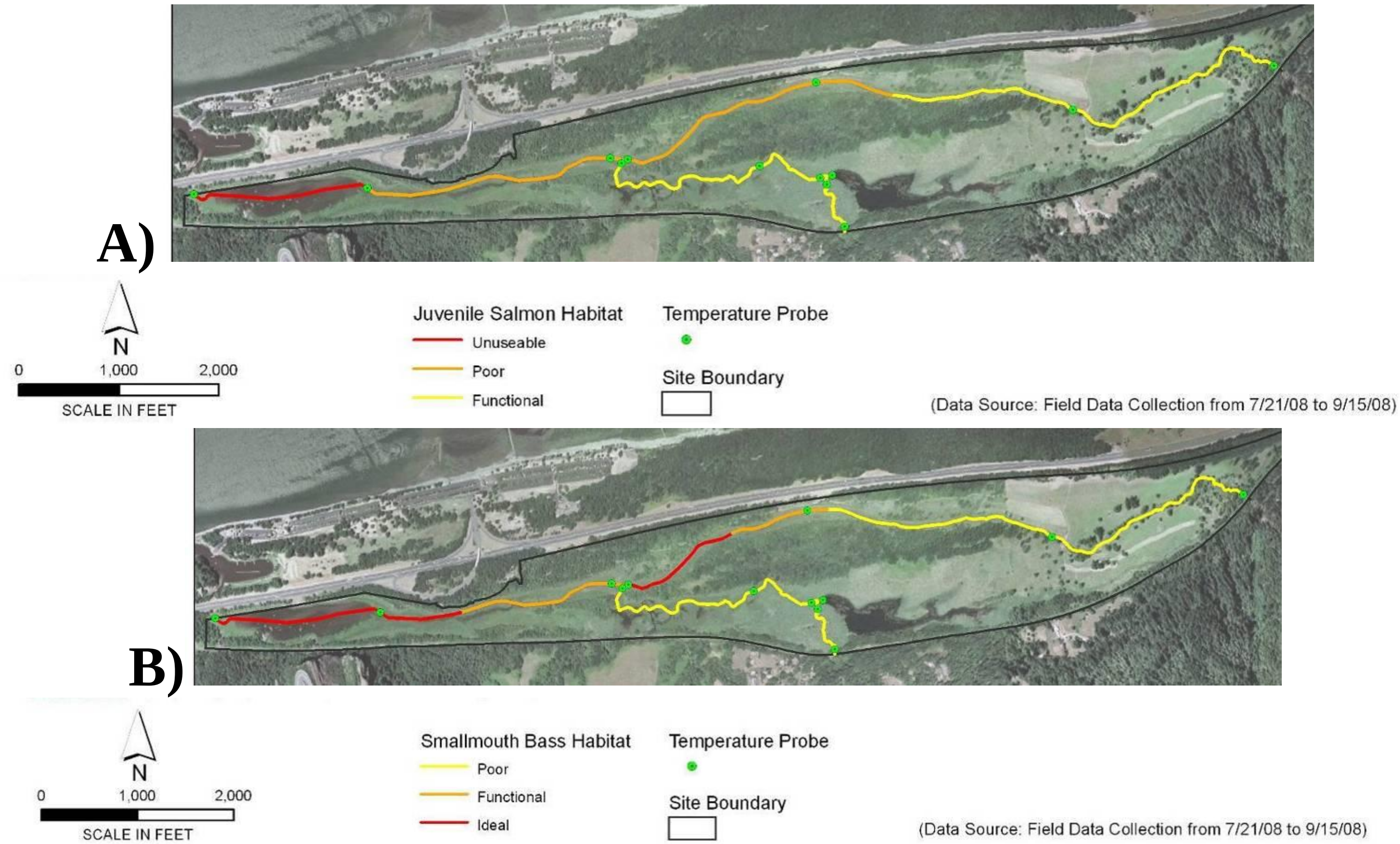


Figure 11: Juvenile salmon habitat classification (A) vs. smallmouth bass habitat classification (B).

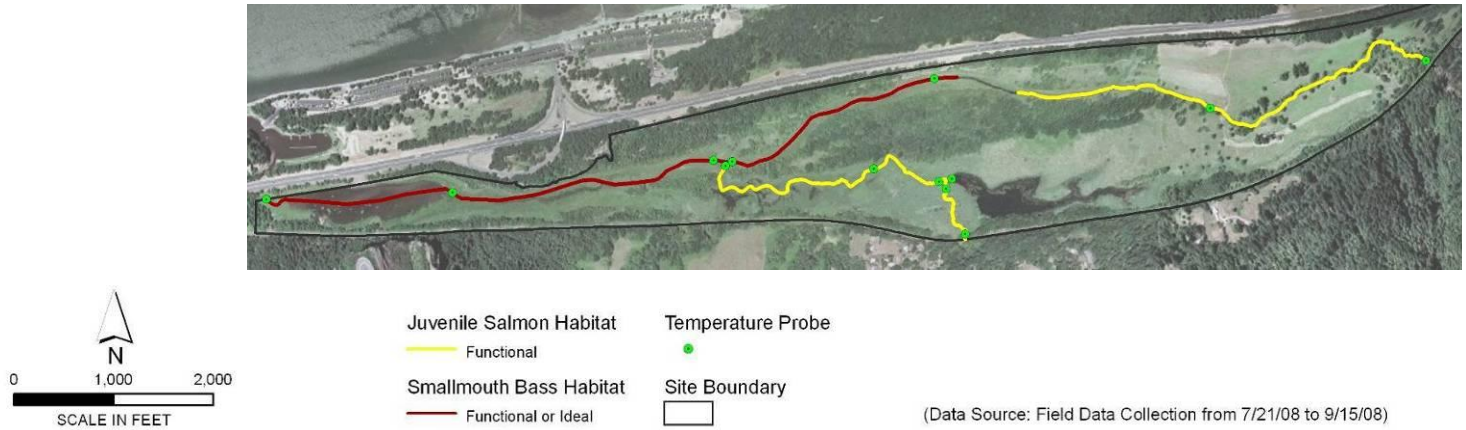


Figure 12: Functional and ideal habitat for juvenile salmon and smallmouth bass.

3.5 Additional Data Collection and Analyses

This analysis of surface water temperatures at the Mirror Lake site was based on best available data. To obtain a better understanding of the site's thermal profile, the following information could be collected and/or analyses performed:

- Additional data collection and analyses could be performed[1]. Completion of ODOT's 2005 temperature study would provide additional baseline data and address inter-annual variability.
- A more detailed comparison of precipitation and temperatures in 2008 vs. historic conditions could be done (Appendix 4).
- A weather station could be installed to determine if data at local weather stations are representative of site conditions and used to inform the historic analysis.
- Daily temperature and precipitation data from nearby weather stations could be downloaded and compared with surface water temperatures to assess their relationships with stream temperatures.
- Flow data could be collected to relate flow with surface water temperatures, precipitation data from nearby weather stations, and/or precipitation from the on-site weather station (if installed).

3.6 Conclusions

Figure 13 provides a summary of the study's results, showing average daily high and low temperatures for each monitoring station. Instream temperatures increase relatively quickly at the site. For example, average daily high temperatures in Young Creek increase from 14.2°C at the railroad tracks to 22.6°C at its confluence with Latourell Creek, a distance of only 1.7 miles. Generally, the sites with the highest temperatures also had the largest diurnal fluctuations.

The site's rapid increase in temperature can be attributed to two primary factors: channel form and riparian condition. The first is one of the site's natural characteristics, i.e., the lower portions of both Latourell and Young Creeks have channels that naturally are wide, shallow, and flanked by expansive wetlands. This channel-type increases surface area and decreases velocities, a combination that results in higher summer temperatures. The second characteristic of the site however, is an artifact of historic land use. The site was cleared and farmed for ~100 years. Although all farming and grazing ceased in the early 1990's, the site's riparian forests have not regenerated due to increase in invasive species. The lack of structure in the riparian community negatively affects instream temperatures.

Low-flow (summer) temperatures are suitable for juvenile salmonids in ~51% of the site, while 45% is suitable for smallmouth bass, the most likely non-native species to prey on juvenile salmonids at the site (Table 9 and Figure 12). Juvenile salmon and smallmouth bass likely do not use the same portions of the site.

Due to the importance of the site to both Lower Columbia and upriver salmon populations, the Estuary Partnership, ODOT, and OPRD have funded several restoration efforts over the past four years. One effort included the reforestation of 45 acres of riparian forest to provide shade to Young Creek and reduce its artificially high rates of temperature increase (Figure 13). Similar reforestation efforts are proposed in other portions of the site (Figure 13). The overall goal of these efforts (both completed and proposed) is to increase the percentage of the site that has temperatures suitable for use by salmonids. These efforts will become increasingly important as other impacts anticipated in the future, e.g., global warming and increased beaver activity, begin to affect temperatures at the site. The Estuary Partnership has funded replication of this study in 2009. They also plan to implement the study at 10-year intervals as the reforested areas mature over the next 20 to 30 years.

[1] The temperature analysis detailed in this report will be repeated in 2009 to obtain an additional (and final) year of baseline data. Future (post-restoration) studies are planned at a frequency of 5-10 years.

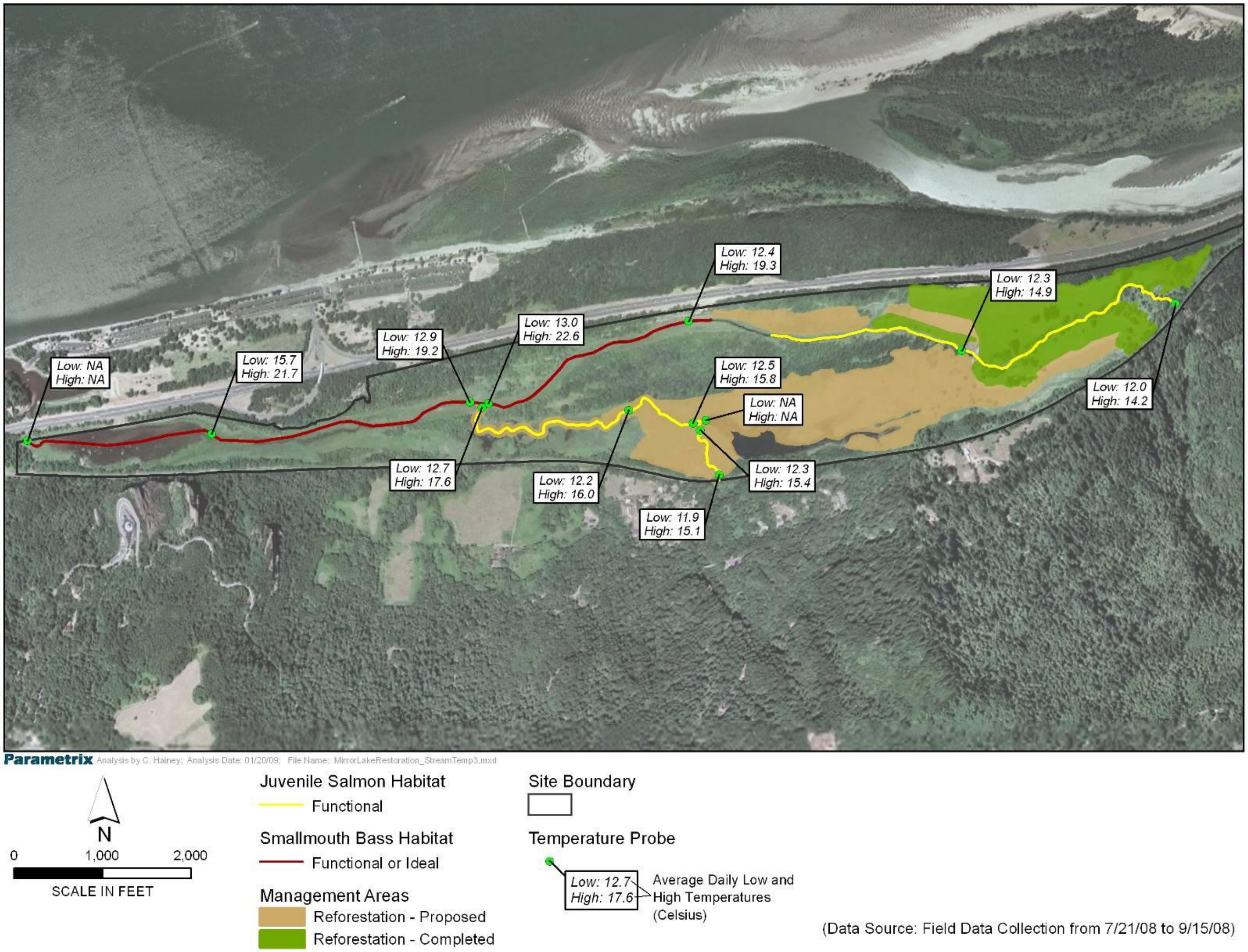


Figure 13: Summary of temperature data, habitat classifications, and reforestation areas for Mirror Lake.

4.0 Juvenile Salmonid and Prey AEM at Mirror Lake

See Section 3.1 for a description of the Mirror Lake site and restoration activities. In 2008, NOAA Fisheries investigated prey availability, fish assemblages, and juvenile salmon usage of the Mirror Lake site (Estuary Partnership Contract #02-2008). They focused on the following five work elements:

1) A survey of prey availability and habitat use by salmon and other fishes at site (Mirror Lake)
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 (Mirror Lake and Fort Clatsop)
4) Analyses of biochemical measures of growth and condition (e.g., whole body lipid content for salmon collected at Mirror Lake and Fort Clatsop).
5) Compilation of data and annual report preparation.

4.1 Fish Sampling Locations

Figure 14 shows the four areas of focused fish sampling at the Mirror Lake site and Table 10 contains the coordinates of those sampling locations. Site #1 (Lake) is on the open water part of the lake near the I-84 culvert (Figure 14, Figure 15A). 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 the Latourell Creek basin, which includes Young Creek. Its water level varies seasonally depending on the elevation of a beaver dam at its outlet and backwater from the Columbia River that inundates the site during spring runoff.

Site #2 (Young Creek) is on Young Creek and is approximately 2 miles upstream of Site #1 (Lake) (Figure 14, Figure 15B). The creek varies from about 1.5 meters wide at low water levels to about 5 meters at high water. The riparian area is dominated by reed canary grass to the edge of the creek bed and immediate 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, provide shade, and cover for stream inhabitants. Prior to August 2008 when restoration activities aimed at introducing large wood back into Young Creek were completed, very little large woody debris existed at this site and grasses provided the only available cover.

Site #3 (Latourell Creek) is on Latourell Creek and is ~1.5 miles upstream of Site #1. This site is accessed from the hamlet of Latourell on the Crown Point Highway by wading down Latourell Creek and entering the site by crossing beneath the railroad. Once in the site, Latourell Creek maintains moderate gradient for ~100 meters before its elevation flattens in a portion of the creek that is flanked by a 3 – 4 acre off-channel lake. Latourell Creek is dominated by grasses along the banks and immediate upland areas of the lake at the sampling site. Bottom sediment consisted of gravel in the moderate gradient areas and consolidated mud after the gradient flattens (Figure 14, Figure 15C).

Site #4 (Culvert) is located immediately below the I-84 culvert and adjacent areas opposite the boat launch and associated docks (Figure 14, Figure 15D,E). The area immediately below the culvert had very little to no vegetation associated with the banks or bottom. The banks were steep, and rocky, areas consisting of pebbles to small boulders. Bottom sediment was the same. The adjacent areas were dominated by grasses, with a steep bank (1.5 meter) that dropped off quickly. Bottom sediments were composed of very soft mud.

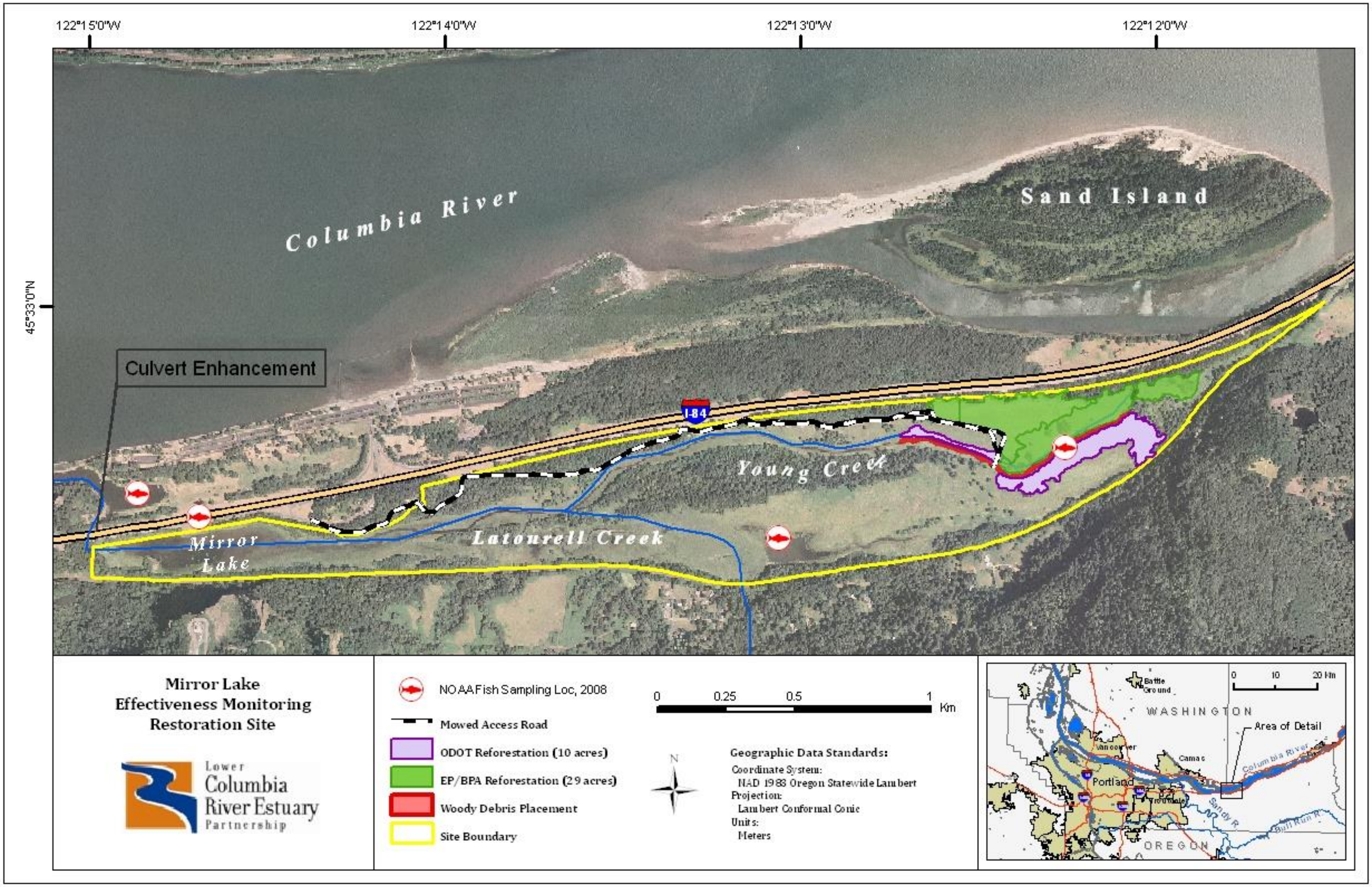


Figure 14: Fish sampling sites and approximate locations of restoration actions at Mirror Lake.

Table 10: Coordinates for fish monitoring sites at Mirror Lake.

Site Name	Latitude	Longitude
Site #1 (Lake)	45° 32.562'N	122° 14.703'W
Site #2 (Young Creek)	45° 32.735'N	122° 12.275'W
Site #3 (Latourell Creek)	45° 32.544'N	122° 13.072'W
Site #4 (Culvert)	45° 32.606'N	122° 14.878'W

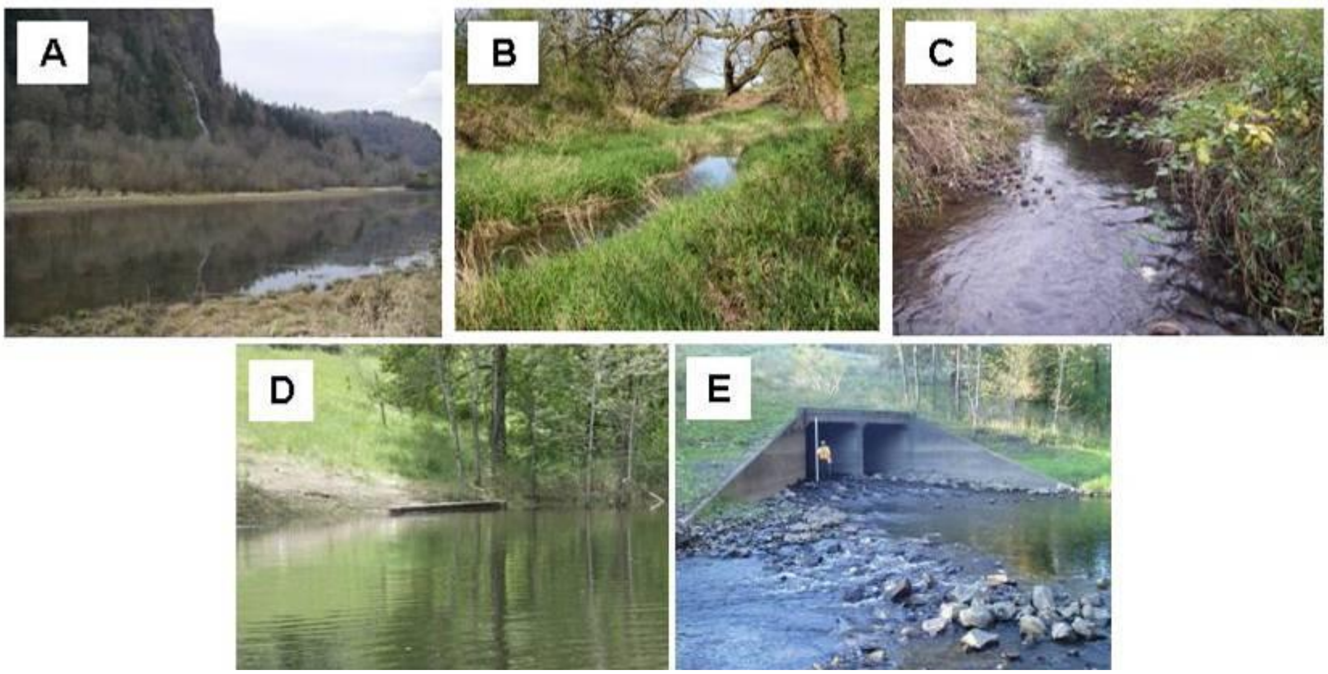


Figure 15: Photos of fish sampling sites at the Mirror Lake project area. A) Site #1 (Lake); B) Site #2 (Young Creek); C) Site #3 (Latourell Creek); D) Site #4 (Culvert) at high water; and E) Site #4 (Culvert) at low water.

4.2 Methods

4.2.1 Fish Sampling

Fish were collected from April 2008 through September 2008. Due to variation in topography, accessibility, and water levels among the monitoring sites, several gear types were used for sampling. Sites #1(Lake) and #2 (Young Creek) were sampled from April to September. Due to access issues, only one sampling, in April, was conducted at Site #3 (Latourell Creek). Site #4 (Culvert) was sampled from May to September as its replacement and to examine salmon presence on both sides of the culvert.

Fish were collected using a Puget Sound beach seine (PSBS) (37 x 2.4 m, 10 mm mesh size), a baby beach seine (BBS) (10 x 1.5 m, 5 mm mesh size), or a modified block net (MBN) where the middle portion of 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 BBS were deployed on foot in shallow water where efficient boat deployment was not permissible. MBN was used to sample fish in small stream channels where fishing with PSBS and BBS 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 and weighted and checked for adipose fin clips to distinguish between marked or unmarked fish. At each sampling event, NOAA Fisheries recorded the coordinates of sampling locations, time of sampling, water temperature, weather, habitat conditions, and vegetation.

4.2.2 Otolith Analyses

Otoliths of fish ranging in size from 52-95 mm (fork length), collected from Mirror Lake Sites #1 (Lake) and #4 (Culvert) and Ecosystem Monitoring Project sites (Table 11) were extracted and processed for microstructural analysis of recent growth. Specifically, sagittal otoliths were embedded in Crystal Bond© and polished in a transverse plane using 30-3μm lapping film. Using Image Pro Plus© (version 5.1), with a mediacybernetics (evolutionMP color) digital camera operating at a magnification of 20 x, NOAA-Fisheries determined 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 otolith were used). Average daily growth (DG, mm/day) was determined using the following Fraser-Lee equation:

$$La = d + \frac{Lc - d}{Oc} Oa$$

$$DG = \frac{Lc - La}{a}$$

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. An ANOVA was used to determine whether average daily growth rates differed among sites. Data were normally distributed according to the Shapiro-Wilks test.

Table 11: Otolith sample sizes per site. Samples collected from Mirror Lake are highlighted in gray.

Site	# of Otoliths
Campbell Slough (Ridgefield), 2007	14
Campbell Slough (Ridgefield), 2008	10
Beacon Slough	9
Franz Lake	12
Pierce Island	5
Sand Island	8
Mirror Lake #1 (Lake)	9
Mirror Lake #4 (Culvert)	11
Confluence Oregon	13
Confluence Washington	15

4.2.3 Prey Sampling

For the invertebrate prey sampling, the objective was to collect aquatic and terrestrial invertebrate samples and 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.

In 2008, NOAA Fisheries implemented the following 4 types of invertebrate collections at the monitoring locations at Mirror Lake:

1) Open water column Neuston tows (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 10 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 (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 at least 5 m. The samples were then processed and preserved in the same manner as the open water tows.
3) Terrestrial sweep netting (3 collections at each site at each sampling time). Sweep netting collects terrestrial invertebrates that are associated with riparian vegetation and may be prey for fish in these habitats. For these samples, insects were collected using a sweep net along a transect of a recorded distance of at least 5 m along the river margin where vegetation was present. Transects were parallel to the bank and approximately 3 m from the water's edge. The net was swept through the vegetation for the length of the transect and for ~0.5 m on either side once thoroughly. Insects were transferred from the net into labeled plastic bags or jars containing some ethanol to both kill the inverts and trap them in the bag or jar. Additional ethanol was when added to preserve the samples.
4) Benthic core sampling (5 cores per sampling time). This sampling technique collects macroinvertebrates living in bottom sediments. Benthic sampling was done with a hand-held coring device made of PVC tubing ~5-cm in diameter, which was inserted 10 cm into the sediment. The macrofauna were retained on a 0.5-mm sieve, washed, transferred to labeled jars and preserved in ethanol.

4.3 Results

4.3.1 Water Level and Its Effect on Fishing

At all sites, water level increased from April through June and declined thereafter. Figure 16 shows the water depth measured below Bonneville Dam on the Columbia River during this period. During spring runoff (April through July), water levels at the Mirror Lake sites coincided with Columbia River water levels. After early to mid July, water levels at the site were more constant and influenced by the elevation of the beaver dam at the I-84 culvert and flows in Latourell and Young Creeks. The rise and fall of water levels prohibited effective sampling of the Mirror Lake sites as described below.

Site #1 (Lake): This site was successfully fished in April. However, higher water levels in May and June prohibited fishing because the site was submerged and nearby trees and shrubs interfered with successful sampling. From July through September, water levels receded while the growth of aquatic vegetation increased. Low water levels in the culvert (Figure 4) and the increased vegetation cover made site access difficult and prohibited the use of the PSBS. The BBS was used then to sample the site from July through September. The presence of aquatic vegetation also interfered with the effective retrieval of the BBS because it lifted the lead line off the bottom, allowing fish to escape.

Site #2 (Young Creek). This site is approximately two miles upstream of Site #1 (Lake), and followed a similar trend in water levels. The water level was so high in June that NOAA Fisheries could not use the MBN to fish this site and instead used one set of the PSBS (Figure 17).

Site #3 (Latourell). This site was only sampled once in April. No water level information is available.

Site #4 (Culvert). This site is connected to Site #1 (Lake) by the I-84 culvert, and had similar water level trends. At mid to higher water, NOAA Fisheries sampled the area immediately below the culvert and two adjacent areas. At low water, NOAA Fisheries noted that the bottom substrate was comprised of very soft mud, which prevents successful beach seining. In the month of September, the MBN was used to fish the channel below the culvert.

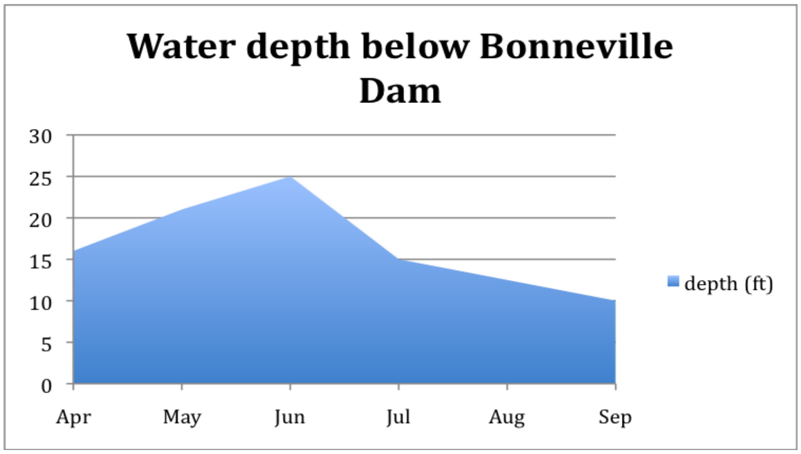


Figure 16: Water depth (ft) below Bonneville Dam (data from USGS).

Figure 17: Fishing with modified block net at lower water vs. relatively higher water levels at Site #2 (Young Creek).

4.3.2 Water Temperature

Inter-site differences in water temperature were observed (Figure 18). These differences were likely associated with habitat conditions and time of sampling at a particular site. Typically, NOAA Fisheries sampled Site #1 (Lake) in the morning, Site #2 (Young Creek) in the mid-morning through mid afternoon, and Site #4 (Culvert) later in the afternoon. At Site # 1 (Lake), water temperature increased from April through September (9°C to 22.5°C). At Sites #2 (Young Creek) and #4 (Culvert), water temperature increased from May through August and declined slightly in September. Overall, Site #2

(Young Creek) had the lowest surface water temperature due primarily to its upstream-most location in the basin, overhanging vegetation, and channel morphology.

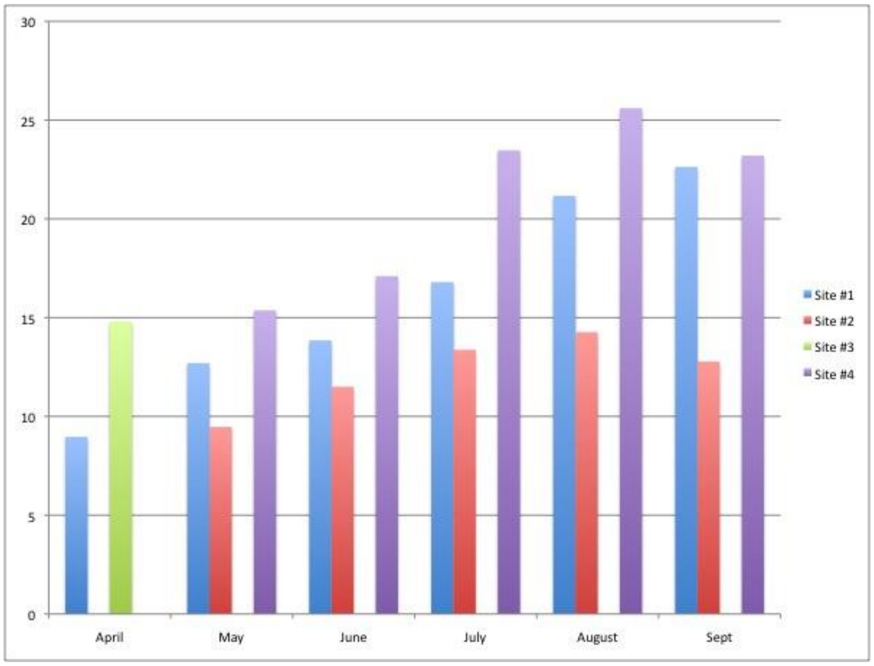


Figure 18: Water temperature (°C) at Mirror Lake Sites #1 (Lake), #2 (Young Creek), #3 (Latourell Creek) and #4 (Culvert) at the time of fish collection. Temperature data are not available in April for Sites #2 and #4.

4.3.3 Fish Species Composition

All four Mirror Lake sampling sites were utilized by fish (Table 12). However, the number and type of fish present varied with time and site (Table 12). Site #3 (Latourell Creek) had the lowest total number of species captured (n = 3), but only one sampling event. Of the sites sampled for multiple months, the total number of species captured was lowest at Site #2 (Young Creek), where 6 different species were collected. At Sites #1 (Lake) and #4 (Culvert), 14 and 16 species, respectively, were collected. These two sites had similar species composition, which may have been influenced by the culvert connecting the sites, their proximity to the mainstream Columbia River, and similar temperature conditions.

Table 13 shows the percentage of each species caught at each site by month of capture. The percentages of species collected varied somewhat for Sites #1 (Lake) and #4 (Culvert) as counts of killifish, stickleback, bass and other species fluctuated between sampling events. At Site #2 (Young Creek), juvenile coho salmon and stickleback were consistently collected (though at varying levels) while sculpin, lamprey, and rainbow trout were detected infrequently. The efficiency of sampling methods, particularly at Site #2 (modified block net utilizing a smaller “chase” net), likely affected the detection and number of non-salmonid species caught. While this method (MBN) appeared efficient for capturing juvenile salmonids, smaller species or slender species (such as lampreys and benthic species) are probably more capable of eluding the chase net as it herds fish downstream into the block net. For instance, 1 lamprey was collected in August using the MBN technique. During salvage efforts for site restoration activities, higher number of lampreys were collected using a backpack electro-shocker (C. Collins, personal communication). Based on these observations, the data presented here provide a relative estimate of non-salmonid species and their numbers at these sites. Additional sampling methods to describe non-salmonid species composition in more detail.

Table 12: Summary table showing number of successful fishing events made by site, month, and gear type (PSBS = Puget Sound Beach Seine, BBS = Baby Beach Seine, MBN = Modified Block Bet). Table includes a list of all species collected at each site.

Site	Month	Gear	Number of Events	Number of Species Caught	Species Caught (Total Number)
Site #1 (Lake)	April	PSBS	3	3	Chinook, coho, three spine stickleback, banded killifish, bluegill, scuplin, pumpkinseed, yellow bullhead, small mouth bass, peamouth, chiselmouth, carp, northern pikeminnow, carp, steelhead/rainbow trout (15)
	May	PSBS	2	4	
	June	PSBS	2	8	
	July	PSBS	3	5	
	Aug	BBS	3	8	
	September	BBS	3	4	
Site #2 (Young Creek)	April	BBS	3	2	coho, three spine stickleback, sculpin, chiselmouth, steelhead/rainbow trout, lamprey (6)
	May	MBN	3	2	
	June	PSBS	1	0	
	July	MBN	3	4	
	Aug	MBN	3	5	
	September	MBN	3	5	
Site #3 (Latourell Creek)	April	BBS	3	3	Pumpkinseed, yellow bullhead, small mouth bass (3)
Site #4 (Culvert)	May	PSBS	3	9	Chinook, coho, three spine stickleback, banded killifish, bluegill, sculpin, pumpkinseed, yellow bullhead, small mouth bass, peamouth, chiselmouth, carp, northern pikeminnow, sucker, shad, yellow perch (16)
	June	PSBS	1	5	
	July	PSBS	3	11	
	Aug	PSBS	2	10	
	September	MBN	1	3	

Table 13: Total number of each species captured as a percentage of the total number of all fish captured.

			Percent Total Catch													
Site	**Month**	**Total Catch**	Chinook	Coho	Banded killifish	Three spine Stickleback	Pumpkinseed	Small mouth bass	Peamouth	Chiselmouth	Yellow perch	Northern pikeminnow	Carp	Sculpin	Bluegill	Others
Site #1 (Lake)	April	37			2.70	94.59									2.70	
	May	26	92.31	3.85		3.85										
	June	81	6.17	11.11	14.81	62.96		1.23		1.23				1.23		1.23 Banded Killifish
	July	337			11.57	16.32	6.53		20.77				44.81			
	August	194			12.89	32.47	15.46		2.06	2.06		8.29	26.29		0.52	
	September	177				11.86	78.53	6.21				3.39				
Site #2 (Young Creek)	April	4				75.00								25.00		
	May	88		89.77		10.23										
	June	0														
	July	576		91.49		3.30								4.86		0.35 rainbow trout
	August	799		74.09		24.41								1.13		0.13 lamprey
	September	707		88.68		8.63				0.99				1.27		0.42 rainbow trout
Site #3 (Latourell Creek)	April	36					91.67	5.56						0.00		2.78 yellow bullhead
Site #4 (Culvert)	May	593	11.13	55.31	16.86	0.34	3.71		2.36	9.78				0.34	0.17	
	June	429	0.47			0.23		0.23	29.14	69.93						
	July	143			2.10	0.70	2.80	0.70			2.10	14.69	6.29		11.89	18.88 sucker; 39.86 shad
	August	302	1.99		5.30	11.26	56.62	8.94		7.95	0.33	5.63	1.32	0.66		
	September	59				6.78	88.14	5.08								

4.3.4 Salmon Usage of Mirror Lake Sites

Juvenile salmonids were collected at all sites sampled monthly (i.e., Sites #1, #2, and #4; Table 13 and Table 14). Site #3 (Latourell Creek) was sampled in April only, because access to the site was difficult, and no salmon were collected at that time. However, adult coho spawners and juvenile coho have been observed in this stream section in recent years (C. Collins, personal communication), so salmon may be utilizing the site. The April only sampling may have missed any yearling coho that had already outmigrated, while young-of-the-year coho may not yet have emerged from their spawning redds. Further sampling in Latourell Creek would be needed to characterize salmonid use of this site.

Both juvenile Chinook and juvenile coho were found at Sites #1 (Lake) and #4 (Culvert). Chinook salmon were most abundant at both sites in May, with the largest number of fish collected at Site #4 on the downstream end of the culvert (Table 14). A large number of juvenile coho salmon (over 300 fish) were also collected at Site #4 in May; about 73% of these were marked coho from hatchery releases. Only a few coho salmon were collected at Site #1 (Lake). After June, salmon were not collected at either Site #1 (Lake) or Site #4 (Culvert) until August when some Chinook (n = 6) with fin clips were caught at Site #4 (Culvert). No salmon were collected in September at Sites #1 and #4.

At Site #2 (Young Creek), large numbers of unmarked coho were captured from May through September, but no Chinook were captured at any time, although juvenile Chinook were captured downstream at Sites #1 and #4. As noted above, at Sites #1 and #4, Chinook abundance was highest in the month of May, and the numbers decreased in the month of June. While successful sampling was not possible in June at Site #2 due to extremely high water levels, it is doubtful whether fish caught at Sites #1 and #4 originated from the upstream sections of Mirror Lake (Sites #2 and #3). If Chinook caught at Sites #1 and #4 originated from upstream, Chinook should have been caught at Site #2 in the month of April or May. Preliminary results of the genetic analysis of the juvenile Chinook collected from Mirror Lake Sites #1 and #4 (see below) indicate that the fish are from Snake River Fall and Upper Columbia summer/fall stocks. This would be consistent with their being migrants from the Columbia River, although the resolution provided by these genetics analyses may not be sufficient to discriminate between fish from a local population and fish from related stocks from other parts of the Columbia Gorge or Middle to Upper Columbia. While our understanding of how outmigrating fall Chinook salmon use off-channel tidal freshwater habitats, it is well-established that they use such habitats in the estuary for feeding as they acclimate to saltwater (Bottom et al., 2005; Fresh et al., 2005). To date, studies suggest that salmon from several upriver stocks may be feeding and rearing for extended periods at tidal freshwater sites in the Lower Columbia as well (LCREP, 2007; Freisen et al., 2005). Chinook collected at this site were likely outmigrants from other populations.

The juvenile coho collected at Site #2, on the other hand, were most likely fish spawned in the upstream areas of Young Creek, particularly since only one coho was captured in May, and only 4 in June in the lake portion of the study area (Mirror Lake #1). The origin of the coho collected at Sites #1 (Lake) and #4 (Culvert) are less certain. Some of the unmarked coho may have moved downstream from Site #2, although many of the fish found at Sites #1 and #4 were substantially larger than those collected at any time at Site #2. In addition, the large number of marked, hatchery coho collected at Site #4 (Culvert) in May would have come from outside the Mirror Lake system. It would be useful in future sampling to collect genetic samples from the juvenile coho to help determine their stock of origin, although it might be difficult to assign the fish to individual populations accurately at this point.

It is possible that low water temperature may have prompted juvenile coho to stay to feed and rear at Site #2 (Young Creek). Temperature and habitat were suitable, and these fish appeared to consist primarily of offspring of coho that had spawned at the site. In addition, the presence of juvenile coho at the Young Creek site for an extended period is consistent with observations of coho rearing behavior in other studies.

Juvenile coho have a more varied residence time than other salmonids, and many juvenile coho found in streams from California to British Columbia can spend a year in streams before migrating downstream to saltwater (Quin, 2005). They prefer a lower gradient stream system than Chinook (Nickelson, 1998), and tended to remain further upstream than other salmonids. They are found in higher abundance than Chinook in smaller streams. High dissolved oxygen levels and plentiful stream cover are important factors to fry survival, and these were available at the Young Creek site.

It is also possible that the high water temperatures that developed at Site #1 (Lake) discouraged juvenile coho form completing their outmigration to the Columbia. Juvenile coho, like most salmonids, require cool water for survival and growth, and are susceptible to warmer summer water temperatures (Madej et al., 2006). There is evidence from other studies that high downstream temperatures may restrict juvenile coho migration to saltwater, contributing to longer-term residence times in some stream systems (Madej et al., 2006) by forming a thermal restriction in the system. Eaton et al. (1995) estimated that the maximum temperature tolerance for coho is 23.4°C (Eaton et al., 1995) based on data mostly from larger streams and rivers and including adult coho salmon. In smaller tributaries it has been estimated that temperatures greater than a range of 16.8°C to 18.1°C become intolerable for rearing juveniles (Welch et al., 2001). Temperatures at Site #1 were in the 16-18°C range in early July, and above 20°C in August and September, so were likely too high to be suitable for rearing coho. This study suggests that temperatures above acceptable thresholds may preclude the presence of coho salmon in the lower regions of Mirror Lake, reducing the value of the area as rearing habitat in the summer months.

Table 14: Summary table for Chinook and coho salmon by Mirror Lake site and month.

		Chinook				Coho			
Site	Month	Number Caught	Number Measured	Length (mm)	Mean Weight (g)	Number Caught	Number Measured	Length (mm)	Mean Weight (g)
Site #1 (Lake)	April	0				0			
	May	24	4 20	86.25±11.27 78.31±41.89[m]	7.58±2.86 10.79±12.35[m]	1	1	114.00	16.70
	June	5	5	54.80±5.31[m]	2.18±0.79[m]	4	4	77.38±18.33	6.43±4.59
	July	0				0	0		
	Aug	0				0	0		
	September	0				0	0		
Site #2 (Young Creek)	April	0				0	0		
	May	0				79	79	45.66±21.94	1.91±3.95
	June	0				0	0		
	July	0				527	90	80.60±8.87	6.15±2.14
	Aug	0				592	75	85.05±11.55	7.48±3.46
	September	0				627	75	82.66±13.29	6.58±2.32
Site #3 (Latourell Creek)	April	0				0	0		
Site #4 (Culvert)	May	66	31	51.06±7.94	1.55±0.80	328	15 43	133.46±9.49 135.93±12.70[m]	23.36±5.06 25.15±6.95[m]
	June	2	2	60.0±7.07	2.50±1.27	0			
	July					0			
	Aug	6	6	89.50±14.07[m]	7.27±3.60[m]	0			
	September	0				0			

[m] represent mean length and weight of marked (fin-clipped) fish

4.3.5 Juvenile Chinook Salmon for Genetics, Diet, Growth, and Lipid Analyses

A subset of juvenile Chinook salmon collected at Sites #1 (Lake) and #4 (Culvert) were necropsied to collect stomach content samples for prey analyses, otoliths for growth rates, and whole body samples for genetics, lipid, and growth rate analysis. The samples collected are listed in Table 15. Similar samples were also collected by CREST from juvenile Chinook salmon at two sites near the Fort Clatsop restoration site on the Lewis and Clark River. Preliminary data on the genetics and otolith samples are presented below. Analyses of whole body samples for lipid content are in progress, and data will be available in early 2009. Genetics data were not collected for coho salmon because reliable stock identification methods for these species are not yet available, and because our permits did not authorize this type of sampling for these species.

Table 15: Samples collected from juvenile salmon at Mirror Lake in 2008. All sample types used individual fish samples for analyses except for the bile samples, which were composite samples.

Collection Date	Site Name	Number of Fish	% Hatchery (Marked)	Sample Type				
				Genetics	Otolith	Bile	Stomach Taxonomy	Body Lipid & Chemistry
5/13/08	Mirror Lake #1	13	85	13	13	1	13	13
5/15/08	Mirror Lake #4	14	7	14	14	1	14	14
6/10/08	Mirror Lake #1	5	0	5	5	0	5	5
8/5/08	Mirror Lake #4	2	100	2	2	0	0	2

4.3.6 Otolith Analyses for Growth Rate

Based on our ANOVA's, Chinook growth rates varied significantly among the Ecosystem Monitoring and Effectiveness Monitoring sites where data are available, for each of the time intervals measured (7, 14, and 21 days; Figure 19 and Table 16). Growth rates of fish collected at Mirror Lake #4 were among the lowest observed at our monitoring sites. Based on a Bonferroni test (within each time interval), NOAA Fisheries determined that Chinook from Mirror Lake #4 (Culvert) had significantly lower growth rates for the last 7 days of growth than fish from Ridgefield (sampled in 2007), one of our reference Ecosystem Monitoring sites in the Ridgefield Wildlife Refuge where growth rates were among the highest measured; the pattern was similar for other time periods but differences were not statistically significant. Growth rates in juvenile Chinook from Mirror Lake #1 (Lake) were in the middle range of growth rates observed at the sampling sites, and not significantly different from growth rates at any of the other sites. Growth rates at the 2 Mirror Lake sites were not significantly different from each other, though salmon at Site #1 (Lake) had faster growth rates than salmon collected from Site #4 (Culvert).

Table 16: ANOVA results comparing Chinook recent (last 7, 14, and 21 days) daily growth rates among 7 LCRE sites.

Source	df	Mean-Square	F-ratio	P
Last 7 days	9	0.038	3.46	0.0009
Error	96	0.010		
Last 14 days	9	0.037	3.26	0.001
Error	96	0.011		
Last 21 days	9	0.035	2.86	0.004
Error	96	0.01		

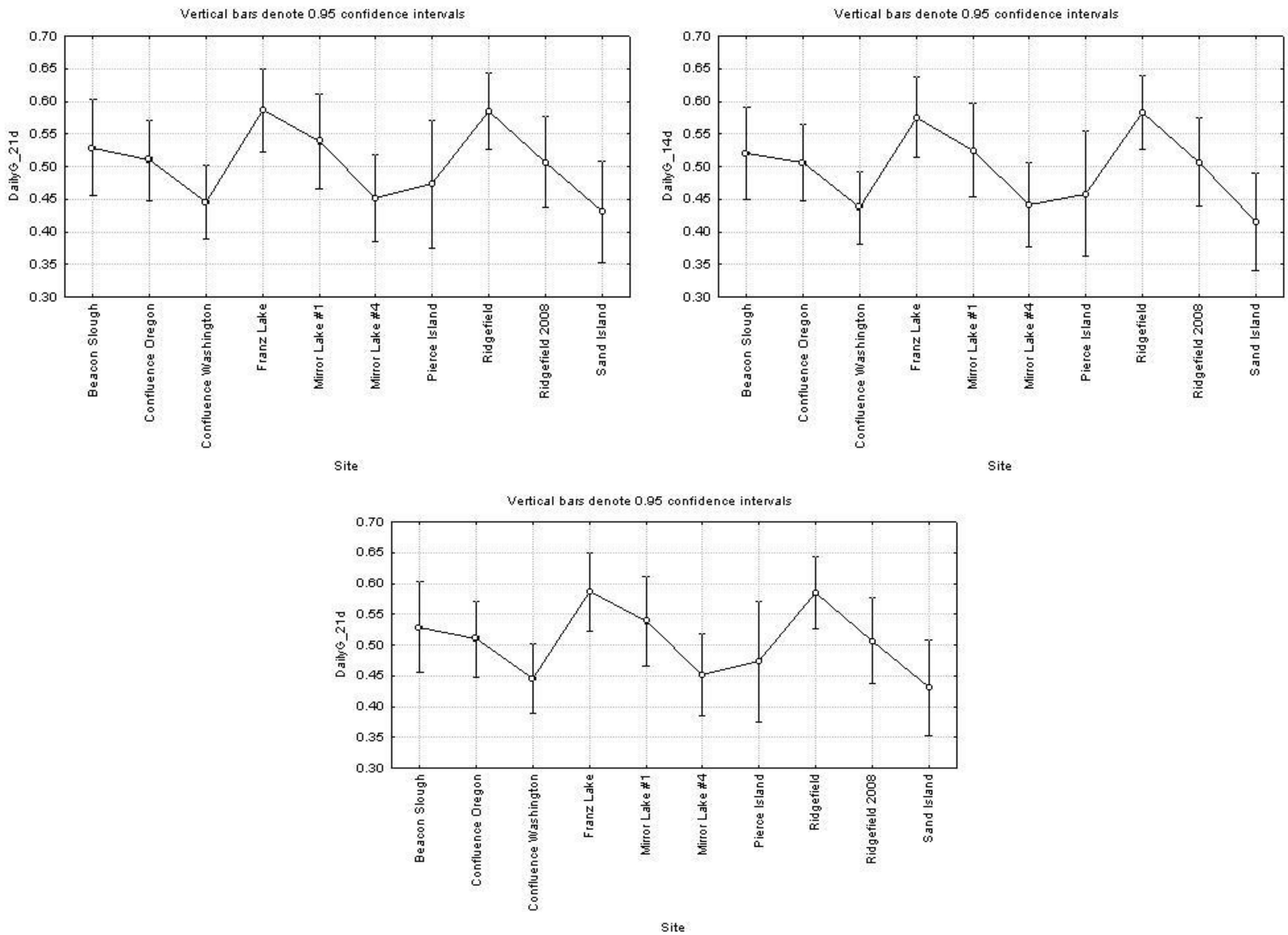


Figure 19: Box plots of the average daily growth rates for three intervals of recent growth (7, 14, and 21 days) for juvenile Chinook salmon collected in the LCRE.

4.3.7 Salmonid Size and Condition

In addition to differences in growth rate, as estimated from otolith analysis, significant differences were found in fish condition factor (CF) among juvenile Chinook and coho collected from the Mirror Lake sites and other Ecosystem Monitoring sites in the LCRE. A 2-way ANOVA examining differences among sites and between marked and unmarked Chinook indicated that there was no significant differences in condition among marked, presumably hatchery fish and unmarked, presumably wild fish, but that the CF did differ significantly among sites (Table 17, Table 18, Figure 20, and Figure 21).

T-test results for model parameter estimated indicated that CF was significantly higher ($p= 0.0011$) than the overall mean for all samples in juvenile Chinook from Mirror Lake #1 (Lake). Condition factor in fish from Mirror Lake #4 (Culvert) did not differ significantly from the overall mean ($p = 0.5824$). Condition factor was also higher in fish from the Confluence at Oregon, the Confluence at Washington, and Ridgefield ($0.0004 \leq p \leq 0.0265$) and lower in fish from Franz Lake ($p = 0.0102$) and Pierce Island ($p < 0.0001$).

Among juvenile coho, the 2-way ANOVA of CF examining differences among sites and between marked and unmarked coho indicated that marked coho had a significantly higher CF ($p = 0.0202$, Table 18) than unmarked, presumably wild fish. Condition factor also differed significantly among sites (Figure 21). T-test results for model parameters estimated (Table 18) indicated that CF was significantly higher ($p \leq 0.0109$) than the overall mean for all samples in fish from Mirror Lake #1 (Lake portion), whereas condition factors in fish from Mirror Lake #4 (Culvert) were significantly lower ($p \leq 0.0401$) from the overall mean. At Mirror Lake #2 (Young Creek) CF was not significantly different from the other sites.

Table 17: 2-way ANOVA effects test results comparing fish condition of marked and unmarked juvenile Chinook salmon among 8 LCRE sites.

Source	df	Sum of Squares	F-ratio	P
Marked vs. Unmarked	1	0.003	0.433	0.511
Site	8	0.393	7.88	0.0001

Table 18: 2-way ANOVA effects test results comparing fish condition of marked and unmarked juvenile coho salmon among 10 LCRE sites.

Source	df	Sum of Squares	F-ratio	P
Marked vs. Unmarked	1	0.112	5.43	0.0202
Site	9	0.549	2.95	0.0020

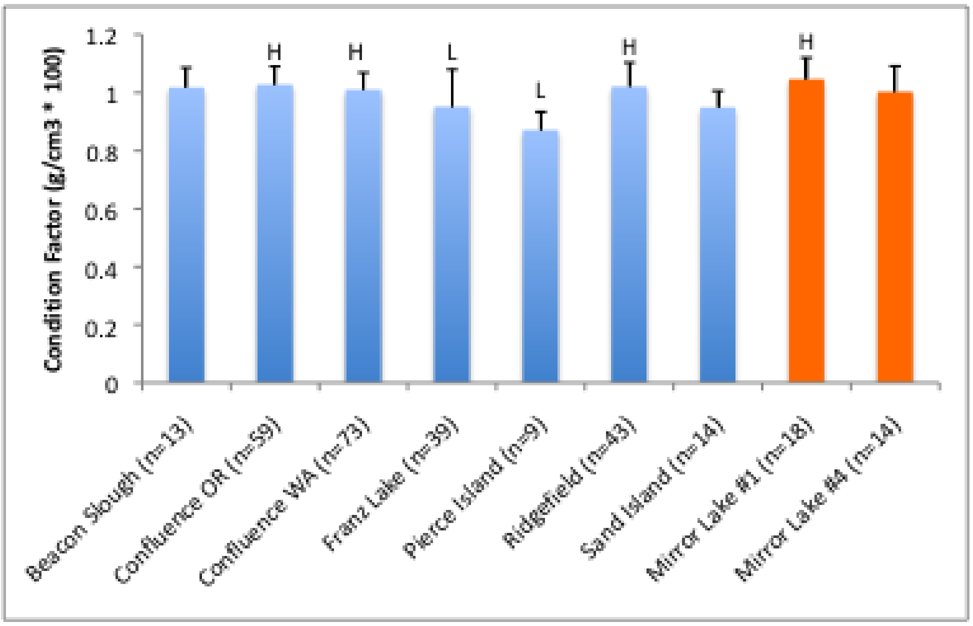


Figure 20: Mean condition factor of juvenile Chinook salmon from Mirror Lake Sites #1 (Lake) and #4 (Culvert), compared to Ecosystem Monitoring sites in the LCRE. Error bars represent standard deviation from the mean. H = value in higher than overall mean for all fish sampled; L = value is significantly lower than overall mean for all fish sampled; 2-way ANOVA, adjusting for proportion of marked (hatchery) vs. unmarked (presumably wild fish, $p < 0.05$).

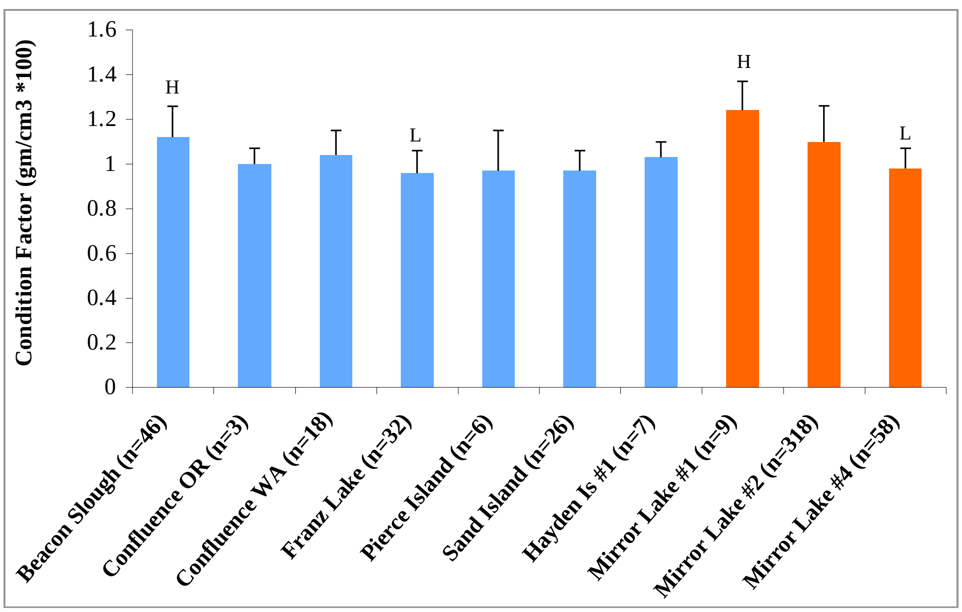


Figure 21: Mean condition factor of juvenile coho salmon from Mirror Lake Sites #1 (Lake), #2 (Young Creek) and #4 (Culvert), compared to Ecosystem Monitoring sites in the LCRE. Error bars represent standard deviation from the mean. H = value in higher than overall mean for all fish sampled; L = value is significantly lower than overall mean for all fish sampled; 2-way ANOVA, adjusting for proportion of marked (hatchery) vs. unmarked (presumably wild fish, $p < 0.05$).

4.3.8 Genetic Stock Identification of Juvenile Chinook Salmon

Fin clips for genetic analyses were collected from juvenile Chinook salmon at Mirror Lake #1 and #4 sites, and by CREST from juvenile salmon at two sites near Fort Clatsop on the Lewis and Clark River. Analyses have been completed for a subset of the samples collected from Mirror Lake. These preliminary results (Figure 22) show that at Mirror Lake #1 (Lake), over 70% of juvenile Chinook were from the Upper Columbia River summer/fall stock, while the remainder were Snake River fall Chinook. At Mirror Lake #4 (Culvert) about 40% of the fish were from the Spring Creek fall group, which originate in the Columbia Gorge and Hood River area, and another 35% were Upper Columbia River Summer/Fall Chinook. The remainder of fish was Deschutes River fall and Snake River fall Chinook. Of the juvenile Chinook collected from Mirror Lake that were analyzed for genetics, only one fish was a marked hatchery fish, and it was from the Spring Creek fall group. Remaining samples from the Mirror Lake sites are currently being analyzed, with samples from the Lewis and Clark River sites to follow. These data will be included in a later report from NOAA Fisheries.

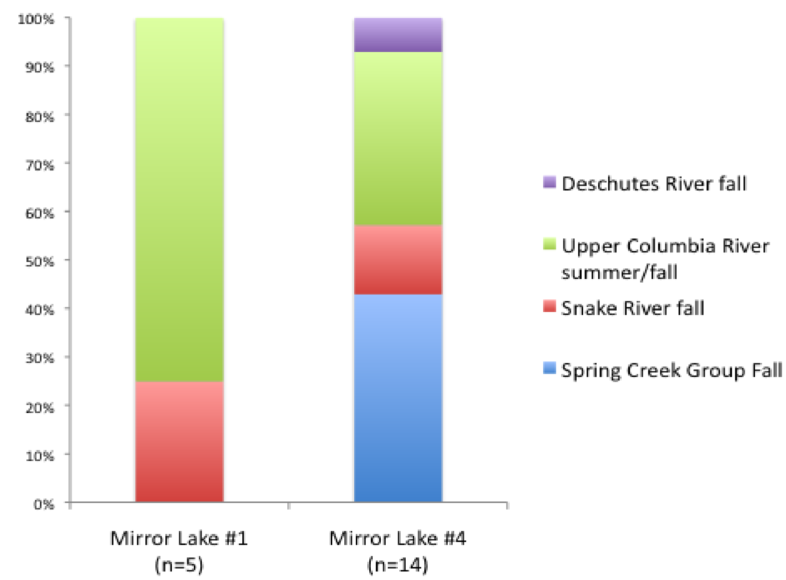


Figure 22: Percentages of juvenile Chinook salmon collected at 2 Mirror Lake sites by genetic stock, as determined by microsatellite analysis.

4.3.9 Prey Availability and Diet Analyses for Juvenile Chinook Salmon

Table 10 lists the numbers of prey samples collected from each site at each sampling event. As of August 2008, NOAA Fisheries collected 98 invertebrate samples and 32 individual Chinook salmon stomach contents samples from the Mirror Lake site for taxonomic analyses. Preliminary observations indicate Chironomidae larvae and pupae and Cladocerans will dominate open water collections while Odonata larvae and Trichoptera larvae will dominate emergent vegetation collections. Chironomidae adults and other Diptera adults dominate the terrestrial sweep collections. Sample processing is being conducted by CREST staff and will be documented in forthcoming reports.

Table 19: Summary table showing number of prey samples collected at each site for each month of sampling (as of 8/26/2008).

	Open Water Neuston Tows					Emergent Vegetation Neuston Tows					Terrestrial Swipe Nets					Benthic Cores					Total Samples
Site	May	June	July	Aug	Total	May	June	July	Aug	Total	May	June	July	Aug	Total	May	June	July	Aug	Total	
Mirror Lake #1	2	3	3	3	11	3	3	3	3	12	3		3	3	9			5	5	10	42
Mirror Lake #2					0	3	3	3	3	12			3	3	6	5		5	5	15	33
Mirror Lake #4	3	1		2	6	2	1			3	2			2	4			5	5	10	23
Grand Total	5	4	3	5	17	8	7	6	6	27	5	0	6	8	19	5	0	15	15	35	98

4.4 Conclusions

Overall, NOAA Fisheries found a substantial number of coho using Site #1 located on Young Creek. These coho appear to be mainly wild fish produced within the Latourell Creek basin. Relatively few Chinook salmon were collected at the sites above and below the I-84 Culvert (Sites #2 and #4, respectively) and were mostly Upper Columbia and Snake River stocks likely entering the area from the mainstem Columbia River. The growth rate and condition of Chinook and coho were comparable to those from other sites located in the Gorge.

Monitoring at the Mirror Lake restoration site provides some baseline data for fish use of the site prior to the enhancement of fish passage at the I-84 culvert and additions of large wood structure in Young Creek. Parametrix implemented both of these restoration actions with funding from the Estuary Partnership in August 2008. In 2008-2009, NOAA Fisheries will continue to monitor the Mirror Lake restoration site for prey availability, fish assemblages, and juvenile salmon usage. Preliminary prey data will be available in forthcoming reports. Further monitoring at this site will aim to provide information on the usage of the large wood structures by coho and relative abundances of salmonids below and above the I-84 culvert. Since 2008 was a relatively high water year inundating the lower fishing sites in May and June, efforts in different years and under different flow conditions for the mainstem Columbia River may be able to provide more information on the use of the site by upriver ESUs during migrations in May and June.

5.0 Planting Success AEM at Mirror Lake and Sandy River Delta

In August and September 2008, Ash Creek Forest Management (ACFM) staff established and sampled 218 vegetation plots across 299 acres at the Sandy River Delta and Mirror Lake restoration sites (Table 20) and one reference site at the confluence of the Sandy and Columbia Rivers in east Multnomah County, Oregon (Estuary Partnership Contract #06-2009). The goal of restoration at Sandy River Delta is to establish native Columbia River floodplain forest and scrub habitats. The goal of restoration at Mirror Lake is to establish a self-sustaining riparian forest, i.e., one that has natural recruitment and is composed of native woody species. Vegetation monitoring and analyses rendered in this report are intended to gauge current stocking levels, estimate responses of critical weeds to treatments, identify impediments to successful plant establishment, and recommend future courses of treatments that will ensure the overall success of the project. A conceptual model for planting AEM at Sandy River Delta and Mirror Lake is presented in Appendix 1.

5.1 Restoration Sites and Monitoring Locations

For a description of the Mirror Lake site, refer to Section 3.1 in this report. The Sandy River Delta is an island at the confluence of the Sandy and Columbia Rivers. At both sites, restoration actions were implemented to control competing noxious and non-native vegetation (e.g., Himalayan blackberry and reed canary grass) and to recover native Columbia River floodplain forest and scrub plant communities with associated ecosystem function. Resulting native plant cover is expected to contribute to improved riparian function through large wood recruitment in aquatic habitats, increased shading of aquatic habitats, increased quantity, quality, and diversity of allochthonous input, and erosion control. Anticipated effects on terrestrial resources include reduced edge, greater extent of hardwood forest cover and greater habitat diversity.

At the Sandy River Delta site, Ash Creek Forest Management staff monitored 4 restoration locations, covering a total area of 230 acres. These 4 locations included: 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 USACE's 155 acres "Sundial Island North" (Table 20, Figure 23). Staff also monitored one 29-acre restoration site at Rooster Rock State Park, "Mirror Lake."

ACFM also established and sampled a reference site representing target conditions for restoration activities (Figure 23). The reference site, located riverward from the Sandy Drainage Dike at the confluence of the western Sandy River outlet, is approximately 40 acres of relatively undisturbed ash-cottonwood forest located within a 70-acre forested area. The site typifies ash-cottonwood floodplain forest of the lower Columbia River, remnants of which exist on islands and elsewhere on the Columbia floodplain from Bonneville Dam downstream to near the town of Rainier, Oregon, at which point marine influences increase dramatically. Mixed-age cottonwood and ash comprise the great majority of canopy trees within the sampled area, with the oldest stems estimated in excess of 100 years.

Table 20: Restoration locations and number of acres restored at the Sandy River Delta (SRD) and Mirror Lake (ML) sites.

Restoration Location	Larger Restoration Site	Restoration Funder(s)	Number of Acres Restored	Year(s) of Initial Planting
Sundial Island North	SRD	USACE	155	2007
Southwest Quad	SRD	EP and BPA	40	2005, 2008
South Bank/North Slough	SRD	EP	20	2005
North Bank Sandy Channel	SRD	EP	15	2006
Mirror Lake	ML	EP	28	2008

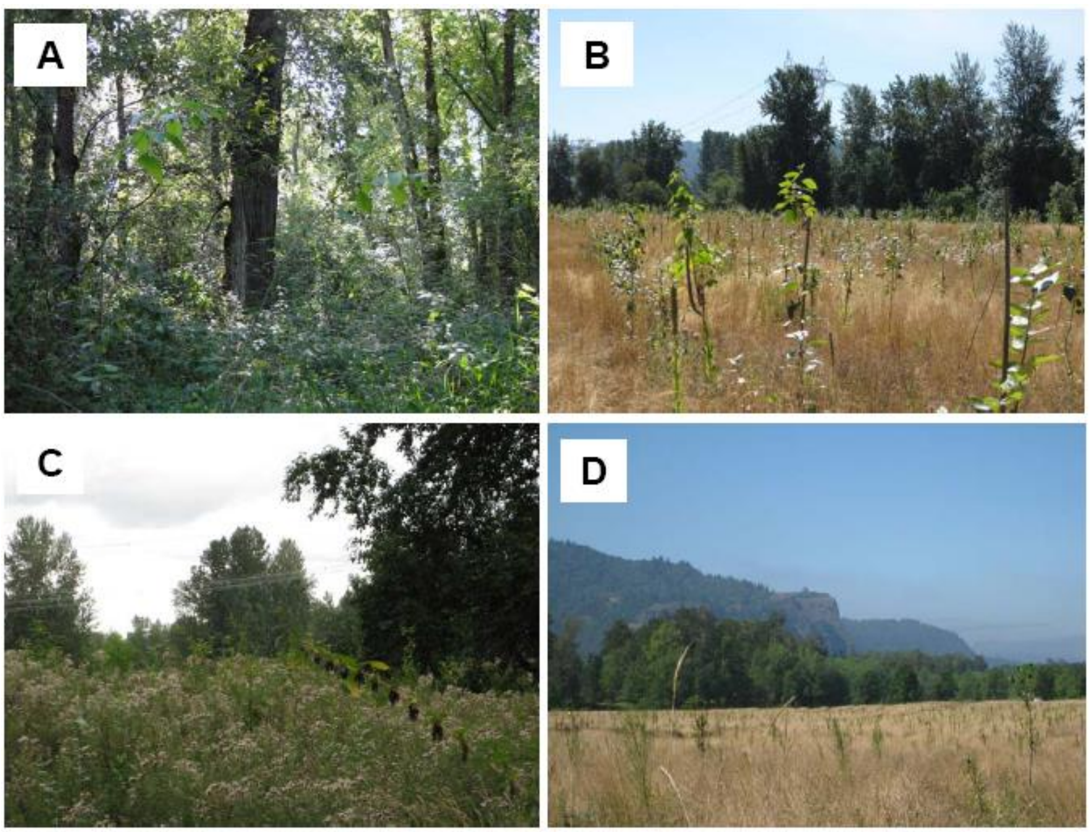


Figure 23: Photos of some AEM locations at SRD and ML, August 2008. A) Cottonwood, ash and native understory vegetation at the reference site for SRD. B) Cottonwood, ash, and snowberry plantings on Sundial Island North. C) Canada thistle invasion on Sundial Island North. D) Cottonwood and ash plantings at Mirror Lake with native grass cover.

5.2 Physical Characteristics at the Monitoring Locations

Many similarities and differences in site conditions and restoration approaches exist between sites at Sandy River Delta and Mirror Lake. All restoration locations and the reference site are within ten miles of one-another on the Oregon side of the Columbia River and are within the active Columbia River floodplain on alluvial soils (predominantly Rafton, Sauvie, and Faloma silt loams). These soils, although described as poorly drained, are relatively coarse with a large fraction of sand and moderate to very high rates of water transmission. Despite saturation in winter and spring under flood conditions, these soils can become severely dry late in the growing season, posing significant challenges to establishment of young planted trees and shrubs. Portions of all restoration sites contain soils that are nearly pure sand. These areas support very poor vegetation growth and resist establishment of woody vegetation.

All sites are exposed to weather extremes at the mouth of the Columbia River Gorge, including cold, dry east winds in winter and hot, dry east winds in summer and early fall. Winter winds are often accompanied by freezing rain, sleet, and snow; ice and snow sometimes accumulate to a thickness able to cause severe tree crown damage. Flooding may occur in winter as well as in late spring following snowmelt. This bi-modal flood regime, with flooding occurring well into the growing season, creates growing conditions that are unlike anywhere else in western Oregon. Harsh conditions have yielded communities of plants that are relatively simple, but also unique to the Columbia River floodplain, including a small number of endemics, such as *Coreopsis atkinsoniana* and *Salix fluviatilis*. Species with wider distributions occurring in the Columbia floodplain nevertheless exhibit characteristics that distinguish them from populations elsewhere, such as markedly later budbreak in *Fraxinus latifolia*, and later seed dispersal in *Populus balsamifera spp. trichocarpa.* These distinctions, perhaps developed in response to late spring floods, point out the strong selective forces at work within this floodplain, and the need to preserve and promote plants of local genetic origin.

Wildlife at the restoration sites present challenges to restoration success. In particular, blacktail deer and voles are present to varying degrees at all sites, and have damaged or killed plantings by browsing, antler rubbing, and girdling. Elk, however, are present in large numbers only at Mirror Lake, where they are browsing, antler-rubbing and trampling planted trees and shrubs in high-traffic areas.

The proportion of pre-existing tree cover varies significantly among sites. Overall, the Southwest Quad and the 20-Acre South Bank North Slough sites have the lowest proportion of pre-existing canopy, and the 15-acre Sandy River Riparian site has the highest. In areas with heavy tree cover, restoration focus shifts to eliminating understory weeds – primarily Himalayan blackberry – and establishing native shrubs. Forested areas present a variety of challenges to restoration operations. Trees, down logs and other habitat components prevent or curtail the use of many mowing and farming implements; these obstacles also make laying out consistent plant rows difficult or impossible.

5.3 Comparison of Pre-planting Preparation and Plant Installation by Site

Pre-planting treatment varied greatly among the five restoration sites, both in duration of site preparation and the number and types of treatments applied (Table 21). These differences reflected differing conditions on sites, funding constraints, expanding knowledge of area restoration techniques, weather, access, and desires of funding partners. For instance, site constraints limited the use of soil cultivation techniques and row layout at the 15-acre North Bank Sandy Channel site, and funders wished to minimize the use of herbicides. Funding was available for a short window; hence, a limited number of site preparation treatments was compressed into a three-month period prior to planting.

Restoration sites also differed in installed plant density and species (Table 22). Crews planted exclusively shrubs in areas beneath power lines, and predominantly trees elsewhere. Outside of power line corridors, the same set of floodplain-adapted species were generally planted on each of the sites, with a few exceptions (Table 22). Planters generally placed trees and shrubs based on hydrologic, light, or other site conditions. For instance, spiraea was planted mostly in low, wet areas, red elderberry was planted predominantly in uplands with partial shade, and Pacific ninebark was placed near streams with beaver activity.

Table 21: Preparation treatments applied to restoration and AEM locations at the SRD and ML.

Larger Restoration Site	Monitoring Location	Year(s) of Site Prep.	Treatment Types and Number Applied to Site					
			Goat Grazing	Site-Prep Mowing	Pre-cultivation Herbicide Application	Plowing	Discing	Post-cultivation Herbicide Application
SRD	Sundial Island North	1.5	1	1	1	1	3	1
SRD	SW Quad	2		1	1		2	2
SRD	South Bank/North Slough	1.5		1	1		2	1
SRD	North Bank Sandy Channel	0.25		1	1			
ML	ML	2.25		1	1		3	3

Table 22: Woody species installed at SRD and ML Site.

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
*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

5.4 Methods

ACFM followed the vegetation success monitoring protocol in Roegner et al. (2008), except on the narrow site at the 15-acre North Bank Sandy River, where they established plots along a changing azimuth to capture interior and edge restored habitat. At all sites, transects and plots were spaced according to site size to ensure sampling of entire restoration area. GPS points were taken at each baseline endpoint, at transects-baseline intersections and at each plot (error range typically 14 – 28 feet). Baseline endpoints and transects along the baseline were also marked with PVC stake, flagged and labeled with a pink marking whisker. One-third of total plots per site were randomly chosen and marked with PVC and a pink marking whisker. GPS point locations were hand recorded as backup.

At each plot, woody vegetation was recorded as live or dead, natural or planted; plant vigor and, if suppressed, suppression by weedy vegetation were noted. In many instances, it was necessary to use a machete to access plots, where the woody plants were recorded as suppressed or not suppressed based on the conditions before the plot was altered by surveyors. Notes were made about plot and vegetation conditions (such as herbivory, animal activity, herbicide damage, etc.). Herbaceous vegetation was classified using Daubenmeir cover class on a 4 m radius (except as noted, where a 1 m^2 was used). Herbaceous vegetation was identified to species when possible, but to work within time constraints, sometimes to genus. Where plot center landed on a boundary, the plot was transformed into a 5.66 m radius semicircle (noted in data).

For all of the sites except Mirror Lake, the number of plants installed per hectare is simply the total number of plants initially installed at the site divided by the number of hectares. Percent survival is the number of plants per hectare surviving based on data collected on 4-m radius plots. At Mirror Lake, initial planting density varied significantly, with the heaviest planting occurring in narrow bands along the immediate stream banks, largely out of the sampled area. As a result, simply dividing the number of installed plants over the planted acreage does not yield an accurate baseline for assessing survival. To account for this, additional data was collected to determine initial planting density and survival within the sampled area. Since plantings were installed at regular spacing within mechanically-defined rows, the survey crew randomly selected 20, 15.4-meter segments of planted row throughout the sample area and counted the number of surviving, dead, and missing plants in each segment. The baseline is the total of all three conditions, and percent survival is the proportion of surviving plants to the total.

Surveyors noted specific habitat features for plots falling within existing forested areas or exhibiting other atypical conditions. In forested areas, surveyors measured and recorded diameter at 1.5m height of all trees within each plot (see Roegner et al. 2008). Where the middle of the woody plant (shrub or tree trunk) was not within a 4 m-radius plot, it was not included in the survey. Densiometer readings were taken in each cardinal direction about 2 m from plot center and averaged, per Roegner et al. (2008). (Please note: densiometer values represent the amount of area overhead not occupied by canopy cover). Photos were taken at most transect points along the baseline and were taken with care to capture landscapes or trees that would be easily located for future reference. Azimuth, type of camera and zoom were noted in photo log.

5.5 Results

At the reference site, ACFM found an average of over 7,700 live, woody plants per hectare, 11% of which are trees (Table 23). At all planted restoration sites, ACFM found a range of 1,200 to 3,200 live, woody plantings per hectare, showing a survival rate of 56% to 90%; trees comprised 37% to 75% of live, woody plantings measured. When naturally occurring (non-planted) trees and reference shrubs are included, the total of live, woody native plants on all restoration sites ranged from 1,700 to 3,300 per hectare. Duration of weed control before planting, or site preparation, appears to be positively correlated with planting success on all sites.

Table 24 shows that vegetation composition has shifted dramatically in response to site preparation, planting, seeding, and maintenance treatments. The two predominant weeds, *Rubus discolor* and *Phalaris arundinacea*, which covered nearly all of the project sites prior to restoration activities, are significantly reduced in coverage on most sites. Both species, however, persist throughout all of the restoration sites and were present on a majority of sample plots.

Table 25 shows vigor of native plants averaged across all of the sites and the effect competing vegetation on vigor of installed woody plants sampled. 'Low vigor' describes a plant which is severely suppressed or damaged. 'Medium vigor' indicates the plant shows normal stress expected in early outplantings (discoloration of leaves, herbivory, etc). 'High vigor' is applied to plants that are in excellent condition and growing vigorously relative to species growth potential. Of all installed plants sampled, 87% show 'Medium vigor,' 6% are 'Low,' and 7% are 'High.' Of all installed plants sampled, 25% are suppressed by weeds, and 75% are 'free to grow.'

Table 23: Plant survival and stocking by location.

	AEM Locations					
	Sundial Island North	**SW Quad**	**South Bank/North Slough**	**North Bank Sandy Channel**	**Mirror Lake**	**Reference Site**
Acres restored	155	40	20	15	29	
Monitoring plots per site	50	30	20	50	38	30
Plants installed per hectare	2,010	3,840	2,150	4,610	3,444	
Live, installed plants per hectare in 2008 sampling season	1,228	3,240	1,540	2,588	3,100	
Percent planting survival	**61%**	**84%**	**72%**	**56%**	**90%**	
Total live, woody plants per hectare	1,784	3,367	1,660	2,860	3,417	7,753
Percent trees of total live, woody plants	**75%**	**37%**	**75%**	**64%**	**51%**	**11%**

Table 24: Response of Himalayan blackberry (*Rubus discolor*, RUDI) and reed canary grass (*Phalaris arundinacea*, PHAR) to restoration activities by location. Pre-treatment cover of RUDI and PHAR were estimated from aerial photographs.

		AEM Locations				
Weed	**Weed Cover and Presence**	**Sundial Island North**	**SW Quad**	**South Bank/North Slough**	**North Bank Sandy Channel**	**Mirror Lake**
RUDI	Percent pre-treatment cover	60	50	60	75	50

Weed	Weed Cover and Presence	AEM Locations: Sundial Island North	SW Quad	South Bank/North Slough	North Bank Sandy Channel	Mirror Lake
	Percent cover in 2008	11	3	8	10	3
	Percent change in cover	-49	-47	-52	-65	-47
	Percent of plots with RUDI	90	53	90	78	68
PHAR	Percent pre-treatment cover	15	40	15	5	40
	Percent cover in 2008	6	1	6	9	7
	Percent change in cover	-9	-39	-9	4	-33
	Percent of plots with PHAR	35	83	50	56	68

Table 25: Plant vigor and suppression averaged across AEM locations at SRD and ML.

	Low Vigor	Medium Vigor	High Vigor	Suppressed by Weeds	Not Suppressed by Weeds
Total live, installed trees and shrubs on restoration sites	97	1,459	124	386	1,155
Ratio per rating (%)	6	87	7	25	75

5.6 Discussion

Significant reductions in coverage of two critical weed species – reed canary grass and Himalayan blackberry – are evident in the data from all of the sites. The only exception is an increase in *Phalaris* at the 15-acre North Bank Sandy Channel site; this increase may be due to reduced use of herbicide and reduction in blackberry cover, allowing reed canary grass to expand into areas previously dominated by blackberry. Although much reduced in coverage, both of these species are present throughout the sites, posing an ongoing threat to restoration plantings.

Unfortunately, other weeds, including typical pests such as teasel, thistles and poison hemlock, as well as several other species of non-native grasses and forbs have increased (Figure 23C). These weeds have sprung up to fill voids left by removal of more competitive canary grass and blackberry. Fortunately, while they can compete with native plantings, these weeds generally pose less of a threat to the establishment of native trees and shrubs and are expected to mostly fade out as tree and shrub canopies fill in. Native grass seeding was effective in reducing the invasion of these early seral weeds, especially where coupled with longer site preparation and the use of broadleaf-selective herbicides, as at Southwest Quad and Mirror Lake (Figure 23D).

Plant survival varies significantly between sites, and survival rates appear to be correlated with the number of site-preparation treatments and the overall duration of site preparation prior to woody plant installation (Figure 24). Site-preparation treatments including mowing, spraying and cultivation reduce vegetation competition and nearly eliminate populations of voles. Possible explanations for increased survival on sites with more and longer site preparation include reduced competition for water and light, and reduced damage by voles.

Another possible explanation for increased survival on better prepared sites is reduced mechanical and chemical damage. Treatments to control severe weed competition are often necessary to maintain restoration sites. When rampant weeds obscure native planting rows, plantings are sometimes inadvertently cut or sprayed during maintenance operations. When extensive site preparation has occurred subsequent maintenance treatments are less frequent, and weeds less rampant thus effectively reducing the exposure of new plantings to possible damage.

Systematic layout of plantings greatly facilitates finding native plantings during maintenance treatments. Installing plants in rows allows efficient use of mowing, cultivating, and spraying equipment, and allows hand crews to locate and clear or spray around individual plants. On all sites except the North Bank Sandy Channel, crews installed plantings in mechanically defined rows. Difficulty locating plants, as well as reduced site preparation and limited equipment access, may have contributed to lower survival on this site.

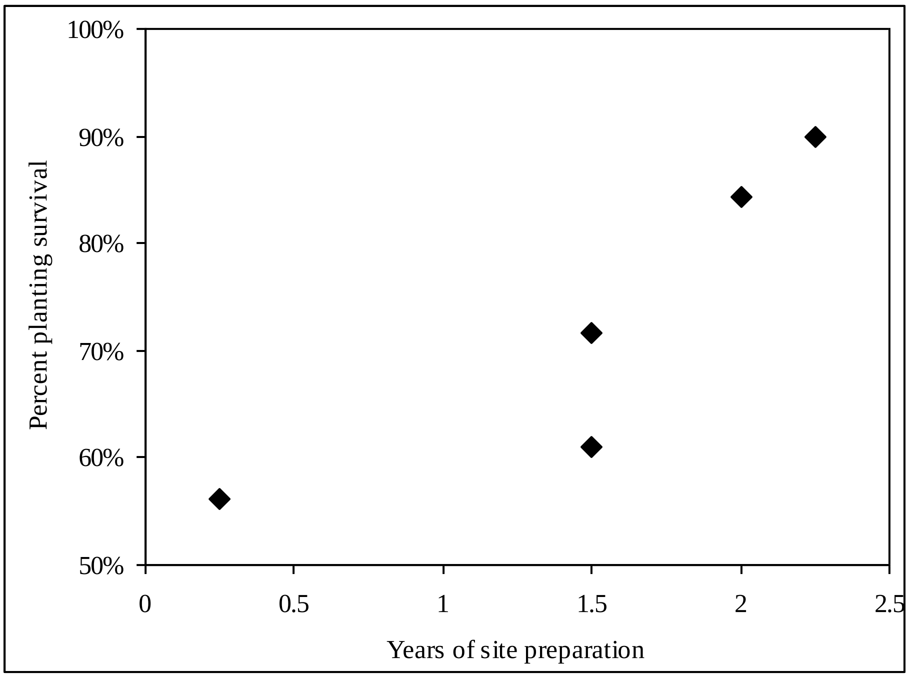


Figure 24: Percent survival of plantings by year(s) of site preparation.

5.7 Recommendations

Continued maintenance is needed at all of the sites sampled in order to achieve the goal of restoring Columbia River floodplain forest and scrub. Inter-planting to increase stocking on Sundial Island North and South Bank North Slough will help ensure long-term occupancy of the entire site with native trees and shrubs. Additional vegetation management treatments are indicated for all of the sites, as shown in Table 26.

We recommend the following change to the vegetation success protocol in Roegner et al. (2008):

Total number of live, installed plants (T) is divided by number of plots sampled (n) to get average of live, installed plants per plot (Tp). Total per plot is then multiplied by 200 (because a 4-m radius plot is 1/200th ha) to estimate total number of live, installed plants per hectare (Th). This total is then divided by number of plants originally installed per hectare (i) to get survival rate of installed woody plants.

T / n = Tp

Tp * 200 = Th

Th / i = % survival.

We also developed a system for monitoring long, narrow, or otherwise irregularly-shaped restoration sites, such as the long North Bank Sandy Channel site. Since establishing a baseline was impractical on this site as called for in the Roegner protocol, ACFM took plots at regular intervals along an irregular, zig-zagging transect, thereby capturing edge and interior site conditions. Further review of this approach, and recommendations for further adaptation, may facilitate future monitoring of this and other narrow restoration sites.

Field trials could provide valuable information for future restoration projects, saving money and increasing project success. Field investigations could include herbicide effectiveness and hazards to native plantings, the effectiveness of various native grass seeding mixtures, cost/benefit analysis of various plant spacing and configurations, and effectiveness of native shrub seeding for understory establishment.

Table 26: Recommended 2009 maintenance treatments for Sandy River Delta and Mirror Lake.

		Restoration Location				
Recommended Treatment	**Treatment Date**	**Sundial Island North (USACE)**	**SW Quad (BPA)**	**South Bank/North Slough (EP)**	**North Bank Sandy Channel (EP)**	**Mirror Lake (EP, ODOT)**
Inter-planting	2/1/2009	X; Done		X; est. $10,000		X; Done
Spring moisture cons. Spot spray	3/1/2009	X; Done		X; est. $4,000		X; Done
Mow	8/1/2009	X; Planned	X; est. $8,000			X; Planned
Spot-spray blackberry	9/1/2009	X; Planned	X; est. $6,000	X; est. $3,000	X	X; Planned

5.8 Conclusions

Analysis of data from the reference site demonstrates that natural forests along the lower Columbia River contain heavy cover of Oregon ash and black cottonwood as well as dense thickets of native shrubs, averaging over 7,000 woody stems per hectare. In order to restore Columbia River floodplain forests, comprehensive site preparation, dense woody plantings, and consistent maintenance are critical to overcome entrenched competitive invasive weeds such as reed canary grass and Himalayan blackberry, which now cover thousands of floodplain acres. Seeded native grasses occupy space created by removal of invasive weeds, and help to prevent or delay weed re-invasions as native plants become established. The value of native grass seeding is especially apparent on the Southwest Quad and Mirror Lake sites, where native grasses have largely occupied the herb layer and reduced influx of thistles and other early seral weeds.

Overstory trees alone are unable to prevent incursions of certain non-native weeds, as apparent in the dense Himalayan blackberry thickets, which carpet the forest floor beneath remnant, canopied areas on Sundial Island. Only multi-layered canopies, including a well-developed and dense shrub layer, seem able to minimize blackberry invasion, such as on portions of the Reference Site and the North Bank Sandy Channel. Monitoring demonstrates that elements of both overstory and understory layers are developing on all of the sampled restoration sites. However, competitive invasive weeds are still present throughout those areas sampled. Ongoing maintenance to control weeds, especially Himalayan blackberry, is needed to ensure successful, long-term restoration of these sites. Most of the stocked vegetation are trees, with little or no shrub understory. When canopy trees are fully established and crowns have closed, seeding and planting of native shrubs to establish full understory cover will complete the process of restoring these habitats.

6.0 Vegetation and Habitat AEM at Scappoose Bottomlands

The purpose of these action effectiveness assessments is to build upon previously conducted baseline studies (Oregon Riparian Assessment Framework, 2004) in order to understand how cattle exclusion and riparian revegetation 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 can monitor baseline 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. Conceptual models for planting and cattle exclusion at Scappoose Bottomlands are presented in Appendix 1.

In 2008, SBWC implemented the following work elements for their action effectiveness:

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

6.1 Site and Restoration Description

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 Creek. 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.

Over 90% of the lands surrounding the Scappoose Bay Bottomlands are used as pasturelands for livestock. As such, riparian areas have been 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 canary grass and blackberry. Little regeneration of native ash and willow has occurred, and beaver are taking down mature trees. Cattle heavily graze on unprotected wetland plants in late summer, reducing the diversity of native wetland vegetation.

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.

Restoration activities at Lower Scappoose Creek and Hogan Ranch have been made possible by partnerships between the landowners, Scappoose Bay Watershed Council (SBWC), Oregon Watershed Enhancement Board (OWEB), Natural Resources Conservation Service (NRCS), Ducks Unlimited (DU), and the Lower Columbia River Estuary Partnership (Estuary Partnership). Riparian fencing was installed along Scappoose Creek in 2007 and 2008 and at Hogan Ranch in 2005 with supplemental fencing in 2007. Significant weed management and riparian planting was conducted in 2007 and 2008 at both sites. Overall, habitat was conserved on 173 ac at Hogan's Ranch, when volunteers installed 10,000 ft of fencing to exclude cattle from waterways, removed 5 ac of invasive species like Himalayan blackberry and Canadian thistle, and repopulated areas with native fauna like ash and dogwood. While this work has not caused significant modifications of site hydrology on either site, Ducks Unlimited has replaced water control structures on two of the wetlands on the Hogan Ranch site, Allowing water to be held longer through the summer encouraging native aquatic vegetation & discouraging invasive reed canary grass, while providing water fowl habitat. Without the water control structures the water levels would drop in spring allowing reed canary grass to out-compete native vegetation. Water levels are adjusted by pulling boards in the water control structures.

The Lower Scappoose Creek project site is located on two private properties (Wilson and LaCombe properties) along Scappoose Creek. This area consists of low alluvial rolling plains that form the floodplains along Scappoose Creek (Scappoose Bay Watershed Assessment, 2000). This section of Scappoose Creek is low gradient, dominated by fine sediments, and tidally influenced year round. The surrounding area is subject to sheet flows during high water events in winter. Areas adjacent to the stream are used for pasture and hay crops, and have little to no tree canopy.

The Hogan Ranch site is north of the city of Scappoose, and bordered by Scappoose Creek on the east and Multnomah Channel on the west. The property's legal description is T4N, R1W, S20, 29, 31 (Lev, 2004). This area has low alluvial rolling plains with numerous ponds, creeks and sloughs (Scappoose Bay Watershed Assessment, 2000). For this action effectiveness monitoring effort, all 3 major ponds (referred to as Ponds #1, #2, and # 3) are being evaluated. Pond #3 lies on the eastern edge of the property and is tidally influence year round whereas Ponds #1 and #2 experience sheet flows and tidal influence at higher water levels. This area consists of seasonal and perennial wetlands and ash forests.

6.2 Methods

6.2.1 Protocols

The SBWC combined applicable methods from Methods for Evaluating Wetland Condition (EPA, 2002), Field & Laboratory Methods for General Ecology (Brower Zar von Ende, 1998), and Oregon Riparian Assessment Framework (ORAF, 2004) to formulate the original monitoring protocols for Lower Scappoose Creek. Since this area is tidally influenced and considered a freshwater estuary, the site and monitoring activities fall outside the scope of the above methodologies. By integrating methods from each text, SBWC developed appropriate and workable methods for this area in 2007. In 2008, the "Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary" (Roegner et al., 2008) were released. The SBWC established methods are comparable with these newly released protocols.

6.2.2 Habitat Classification

SBWC classified wetlands in the Lower Scappoose Creek area with the Cowardin wetland classification system (EPA, 2002). These habitats were then ranked by the degree of hydrologic alteration following Fennessy, EPA, 2002).

6.2.3 Photo Points

SBWC established 5 photo points on April 11, 2007 at the Lower Scappoose Creek site (Figure 25) and 15 photo points on July 28, 2004, with 2 more added in 2008 at the Hogan Ranch site (Figure 26). GPS coordinates were collected and archived for these photo point locations. Photos were taken at 90° intervals (4 pictures) at each location and once each season for a total of 4 times per year. SBWC established the photo point locations to track long-term environmental changes at this restoration site.

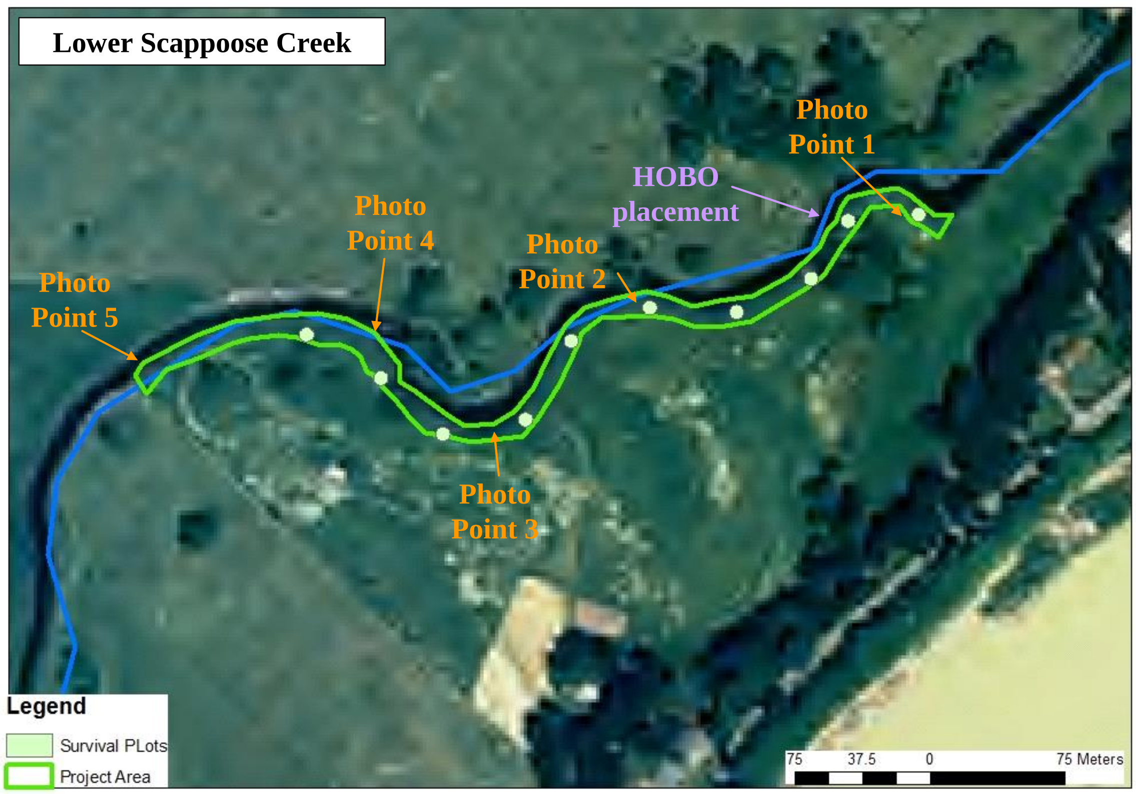


Figure 25: Photo-point, HOBO logger location, and planting survival monitoring plots along Lower Scappoose Creek.

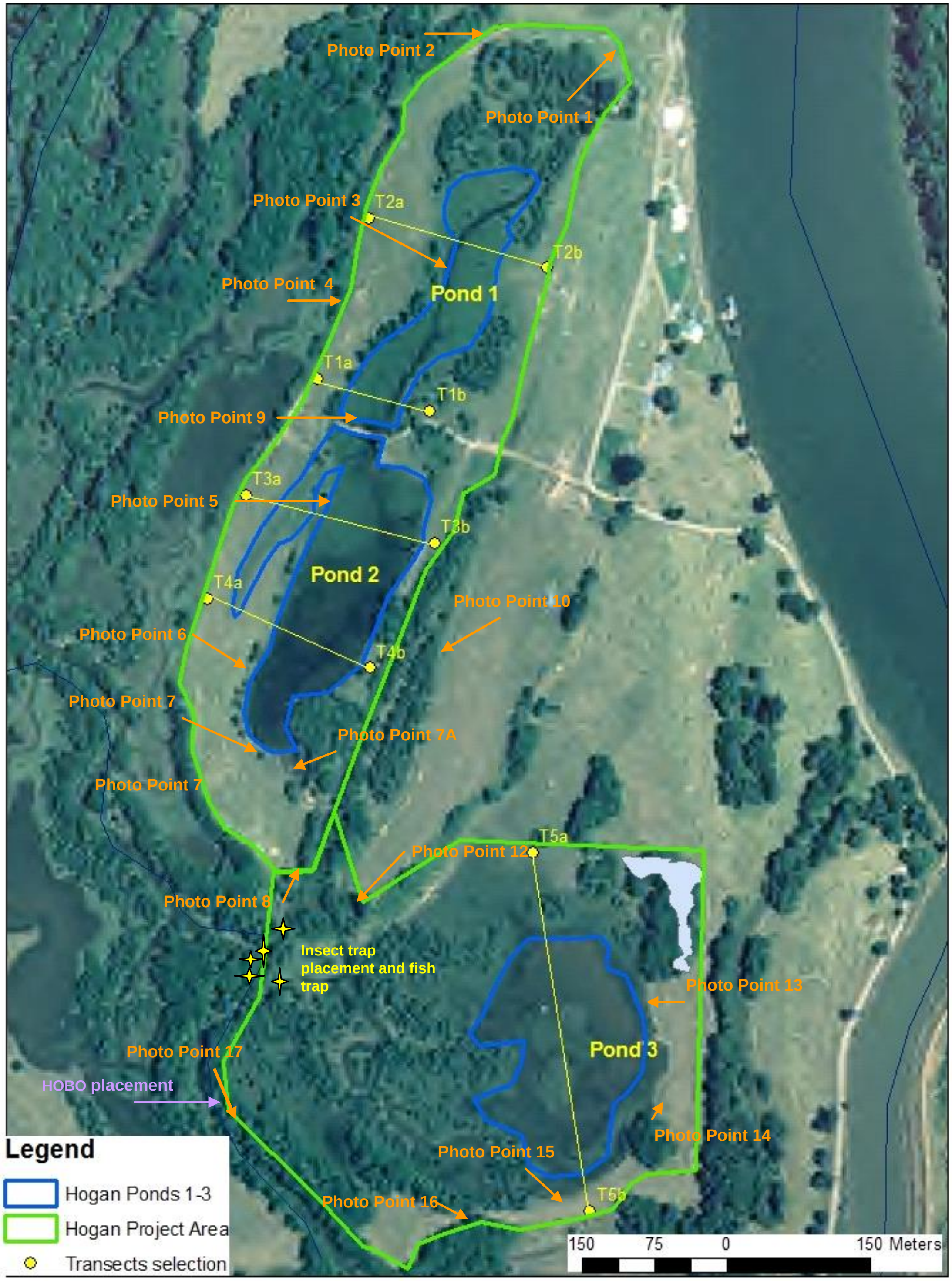


Figure 26: Locations of photo-point, vegetation transects, insect traps, fish sampling, and HOBO logger at Hogan Ranch.

6.2.4 Water Quality and Depth Monitoring

Water samples were collected monthly from Scappoose Creek at the downstream corner of the Wilson property (GIS # SSCA01) and the upstream corner of the LaCombe property (GIS # SSCA05). These samples were tested for dissolved oxygen (using a Hach Dissolved Oxygen Titration Kit), turbidity (Hach Turbidity Meter), pH (Orion pH meter), and conductivity (YSI 30 Conductivity Meter). In 2007, SBWC tested water samples collected from Lower Scappoose Creek and Hogan Ranch for nitrogen and phosphorus. Since this testing detected little (if any) of these nutrients, SBWC were advised by the Oregon Department of Environmental Quality (ODEQ) to discontinue this sampling. During sampling, air temperature was measured with a NIST Thermometer. SBWC installed a HOBO temperature and pressure sensor was installed to provide temperature and water level data at 60-minute intervals at the two sites. SBWC installed a HOBO between Photo-points #1 and # 3 on Scappoose Creek (Figure 25) and another HOBO near Photo-point # 17 at Hogan Ranch (Figure 26).

6.2.5 Success of Vegetation Plantings

SBWC staff assessed the survival and vigor of plantings in riparian areas along Lower Scappoose Creek and marshy wetlands at Hogan Ranch. Both sites were fenced to exclude livestock and then planted with native woody plants in winter 2008. At each site, SBWC staff followed the planting protocol outlined in Roegner et al. (2008) as closely as possible. The riparian site at Lower Scappoose Creek has a narrow planting strip (4-5 m; Figure 25), making it unfeasible to implement the baseline and perpendicular transects called for in the monitoring protocol. Instead, they placed plots systematically from a random start in a path parallel to the creek. Plots were located every 50 m along the length of the planted area (Figure 25), starting at 48 m from the property line. The start point was chosen with a random number table. SBWC staff assessed planting survival and vigor at 10 8-m diameter plots at this site, following the guidelines in Roegner et al. (2008).

At the second site, Hogan Ranch Pond #3, the planted area was wide, but irregularly shaped. SBWC staff implemented the baseline and transect sampling design for this area, but needed to modify transect widths and locations along the baseline to conform to the planted area. Plantings at Hogan Ranch include ash forest, willow, and shrub communities. SBWC staff placed a baseline through each of the communities and constructed transects and plots systematically from a random start as much as was feasible. In total, they assessed planting survival and vigor at 54 plots on this site (Figure 27), following the Roegner et al. (2008) recommendations.

Total planting survival was calculated as the total number of living plants divided by the total number of installed plants. Vigor was assessed qualitatively in the field. Average planting density (APD) was the average of the density of plantings in each plot (plants/m^2).

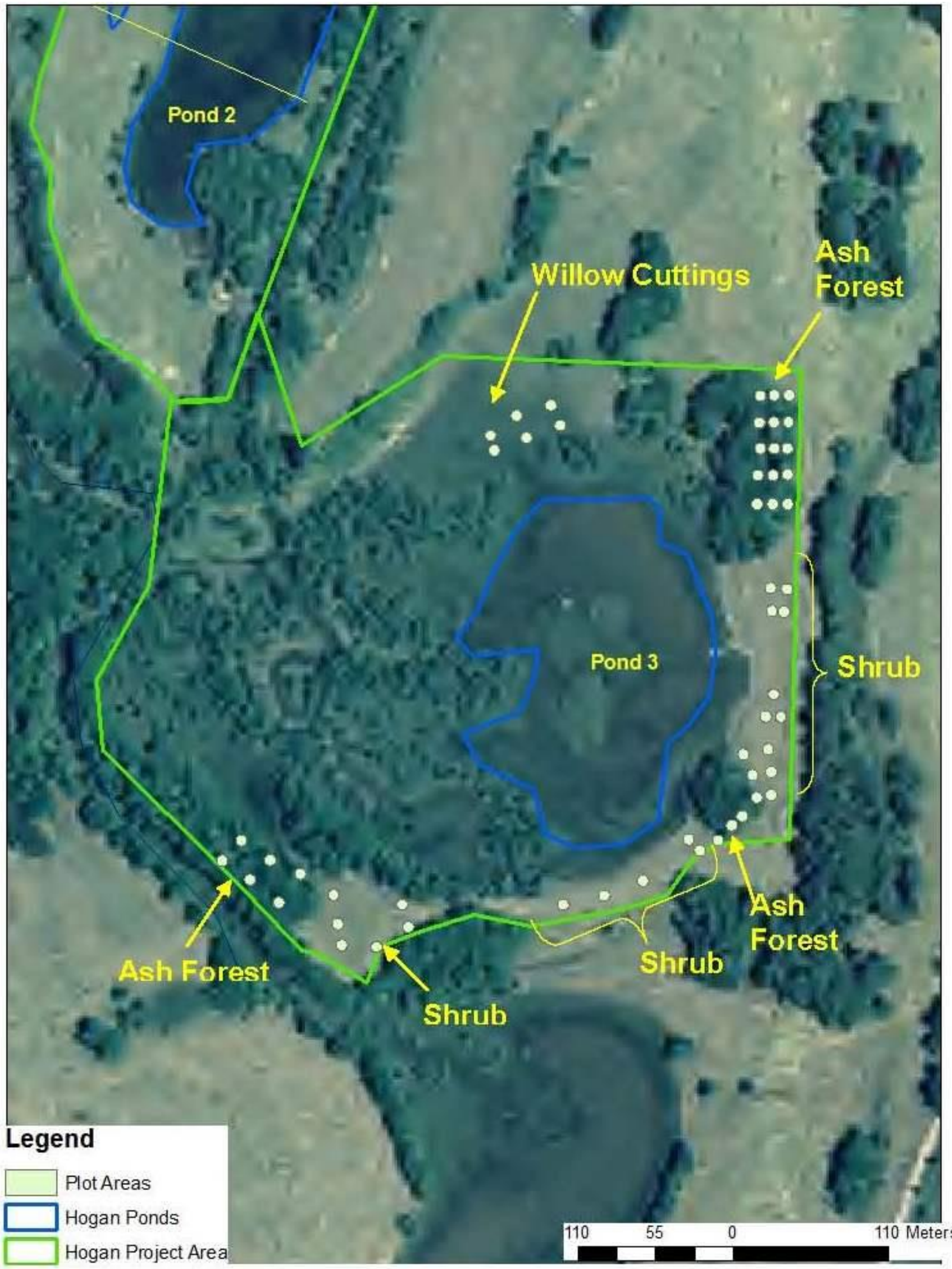


Figure 27: Location of plots for monitoring vegetation survival on Hogan Ranch Pond #3.

6.2.6 Vegetation Community Monitoring at Hogan Ranch

The composition of the vegetation communities at Hogan Ranch were examined to describe changes in community following ecological restoration activities in 3 tidal freshwater ponds. SBWC staff assessed vegetation communities along transects running across the ponds (Figure 26). On each transect, they identified the communities based on changes in vegetation. The simple basin topography of each pond leads to clear bands of vegetation ringing a central depression, as vegetation communities differ along the hydrologic gradient to the center of the pond. From high to low elevations, the vegetation transitions from a mix of upland and facultative pasture grasses ("FACU grass and forbs"), to a band of facultative wetland grass with a sparse willow over story ("FACW grasses/forested fringe), to an obligate wetland marsh edge community ("Marshy shore"), to the submerged and floating vegetation in the wetted area of the pond ("Wetted area"). This pattern was consistent on both sides of the pond. Transects intersect each of the outer rings of vegetation twice. These communities were recorded separately in the field, but then combined for the purposes of data analysis when no significant differences were found between pond sides.

Within each identified community, we randomly placed an appropriate number of 50 cm x 100 cm plots within a band extending 2 m on both sides of the transect line. Number of plots per community were proportional to the area of the community along transect. The width of each community along transects was recorded in 2004 and 2008. When deep water and/or mud made central areas of the ponds inaccessible, staff estimated the community composition and width of inaccessible area visually from pond edges. In each plot, they recorded the estimated percent cover of every rooted species. When estimated cover was less than 1%, they recorded it as 0.5% (vs. classifying it as "trace"). Species with total cover less than 1% were recorded as "trace" in the final data table.

In 2004 (3 years prior to restoration), 5 transects were established and permanently marked. Subsequent monitoring in 2005 (two years before restoration efforts) and 2008 (one year after construction phase) used the same transects. Plot locations differ between years because they were placed with random tosses at each sampling time. The number of plots in each community also varied between years as community widths changed in response hydrology (Table 27).

Data were analyzed by calculating the total cover for each species in each community at each pond. In addition, the USDA PLANTS database was used to categorize each species' native status and wetland indicator status when possible so that changes in native species richness and wetland status across the three years could be assessed. Additionally, they compared the widths of the communities along the transects, both to explain observed changes in vegetation and to document hydrologic changes associated with restoration on Ponds #1 and #2.

Table 27: Sampling effort associated with each vegetation community at the Hogan Ranch ponds.

		Number of Plots		
Pond	**Community**	**2004**	**2005**	**2008**
1	FACU grasses and forbs	5	5	8
	FACW grasses/ forested fringe	4	4	6
	Marshy shore	7	5	4
	Wetted area	0	1	6
2	FACU grasses and forbs	6	5	7
	FACW grasses/ forested fringe	2	2	1
	Marshy shore	3	2	5
	Wetted area	5	1	7
3	FACU grasses and forbs	0	3	1
	FACW grasses/ forested fringe	3	1	3
	Marshy shore	4	1	2
	Wetted area	2	0	1

6.3 Results

6.3.1 Habitat Classification

Using the Cowardin hierarchy of habitat types for palustrine systems, the Lower Scappoose Creek properties are classified as "seasonally flooded" with tidal influence in the stream channel. The immediately surrounding fields, or meadows, are "irregularly flooded" during rain events and/or when inundated by high water levels in Lower Scappoose Creek (EPA 2002). Fennessy (EPA 2002) uses a scale of 1 (relatively low impact) to 24 (relatively high impact) to assess the degree of hydrologic alterations at wetland sites based on the amount and type of human disturbance; type of usage; and type of vegetation. Following cattle exclusion and native vegetation plantings, the score for this section of Lower Scappoose Creek has improved from 11 to 9. Here, Lower Scappoose Creek has functional hydrology, but remains affected by past grazing activities and current grazing on adjacent properties. The replanted riparian buffer will take several years to become established. Grazing has impacted the native plant communities by increasing the occurrence of invasive weeds, decreasing regeneration of native species, compacting the soil, and eroding stream banks.

Likewise, for the Hogan Ranch wetlands, Pond #1 is classified as "seasonally flooded" following the Cowardin hierarchy. The forested and emergent wetlands and surrounding fields, or meadows, are "irregularly flooded" during rain events and/or when inundated by high water levels in nearby stream channels. In the dry season, water levels are largely controlled by a water control structure at the Northwest corner, but the site is still affected by tidal influences, river levels in the Multnomah Channel, and subsurface hydrology. Prior to the installation of this control structure, Pond #1 tended to dry up by late summer. This is the first year (2008) since the control structures have been replaced and the there is still a wetted area with in the pond. Pond # 2 lies to the south of Pond # 1. This pond is affected by the same influences as Pond # 1 and a second water control structure located between the two ponds. Pond # 2 is overall deeper and larger than Pond #1 and holds a fair quantity of water year round. Thus, this pond is classified as half-seasonal wetland and half permanently flooded, making it Type 2 in the Cowardin hierarchy.

Pond # 3 is a subtidal, emergent wetland pond that is classified as "semi-permanently flooded." The immediately surrounding fields (meadows) are "irregularly flooded" during rain events and/or when river levels inundate them. (EPA, 2002).

Based on the Wardrop & Brooks scale of hydrologic alterations, Ponds #1 and #2 receive a ranking of 10 (denoting intermediate alterations) whereas Pond # 3 a ranking of 1 (denoting low impact). All three ponds have functional hydrology, but past intense grazing has occurred around Ponds #1 and #2. Emergent wetland species in Pond # 3 are rebounding and growing following cattle exclusion. Vegetation growth is discussed in Section 6.3.6. Grazing has negatively impacted the native plant communities, compacted the soil, and eroded the stream banks. Since cattle have been excluded from this area, the emergent plant communities are showing a fast positive response. Simultaneously, the invasive species reed canary grass is becoming more prevalent now at the site without control by grazing or other means. Since the expansion of invasive species like reed canary grass is of concern, SBWC is observing invasive species at the site and considering their management in long-term restoration strategies.

6.3.2 Photo Points

The SBWC is compiling photos points collected in 2008 and previous years to assess environmental changes at these sites relative to surrounding lands outside the project area. In 2008, high water levels from spring to summer prevented collection of photo points for all seasons. Figure 28 provides an example of a photo point series for one location along Lower Scappoose Creek in January and June 2008.

A more detail assessment of the long-term photo point data will be presented in the 2008-2009 report on effectiveness monitoring activities from SBWC.

Figure 28: Photo point example showing seasonal changes between January and June 2008 at one location (photo point #1) along Lower Scappoose Creek.

6.3.3 Monthly Water Quality and Depth Monitoring

For Lower Scappoose Creek, trends in monthly water quality conditions varied by sampling time and parameter (Table 28). Overall, throughout the sampling period in 2008 relative to 2007, values for water temperature and conductivity were lower whereas values for pH and dissolved oxygen were higher (Table 28). In 2007, water depths increased from early to late summer. In 2008, the opposite occurred as estimated water depths decreased from early to late summer and had wider ranges in values.

For Hogan Ranch, values for water quality parameters measured monthly varied by sampling time and for some parameters by pond (Table 29; Figure 29). For water temperature, the lowest temperatures were observed in August for 2007 data vs. June for 2008 data (Figure 29A). In both years, temperatures were generally comparable between ponds throughout the sampling period though a wider range of temperatures was observed in 2008 (Figure 29A).

For dissolved oxygen, values in Ponds #1 and #2 decreased over the sampling period in 2007 but peaked in August 2007 in Pond #3 (Figure 29B). In 2008, dissolved oxygen values were less variable and peaked in July. Again, Pond #3 had the highest dissolved oxygen values in August 2008. Note the June 2008 dissolved oxygen reading is considered an outlier because sample collection and testing were not completed on the same day, making this observation inconsistent with the others.

Turbidity in 2007 varied between ponds and sampling date. Turbidity in Pond #1 increased over the sampling period from 11.1 NTUs in June to 50.0 NTUs in August whereas it peaked in July in Pond #3 at 48.3 NTUs and then dropped to 9.6 NTUs in August (Figure 29C). Pond #2 had relatively consistently turbidity values ranging from 23.2 – 33.0 NTUs with the lowest observation taken in July. In contrast with the 2007 data, the 2008 turbidity observations increased at all ponds over the summer sampling period. In June and July 2008, turbidity values were less than 13 NTUs at all three ponds when water levels were high (Table 29; Figure 29C). These 2008 turbidity values were consistently lower than 2007 values taken prior to cattle exclusion and replacement of the water control structures. Currently, the ponds hold more water, allowing increased plant growth and water filtration. This plant growth helps stabilizes the fine sediment within the ponds that can be easily disturbed. Turbidity levels rose sharply after the water levels dropped in late July and August 2008 (Figure 29C).

Conductivity values increased over the summer sampling period in both 2007 and 2008 (Figure 29D).Values spiked in Ponds #1 and #3 in August 2008.

For pH observations in 2007, values peaked in June (Figure 29E). Values in Ponds #1 and #2 then increased from July to August whereas Pond #3 decreased consistently from June to August. For all ponds, pH values in the July and August were less than 6.7. Compared to 2007, pH observations in 2008 were less variable between the ponds and sampling period and did not drop below 6.9 all season.

In 2008, SBWC collaborated with the City of Scappoose to complete monthly bacteria counts in the Hogan Ranch ponds; no data are available for 2007 (Figure 29F-G). The results suggest that tests with a higher colony capacity are needed for this sampling because colony counts were above the limits of the tests. The August tests are the first tests to be completed with the new limitations (maximum 2,419 colonies). They came back showing an increase in coliform counts with lower water levels in Ponds # 2 and # 3. There is a difference in sedimentation load and vegetation density. This may account for some of the bacteria level differences. Even with the livestock excluded from the area, bacteria counts increase as water levels drop and became stagnant.

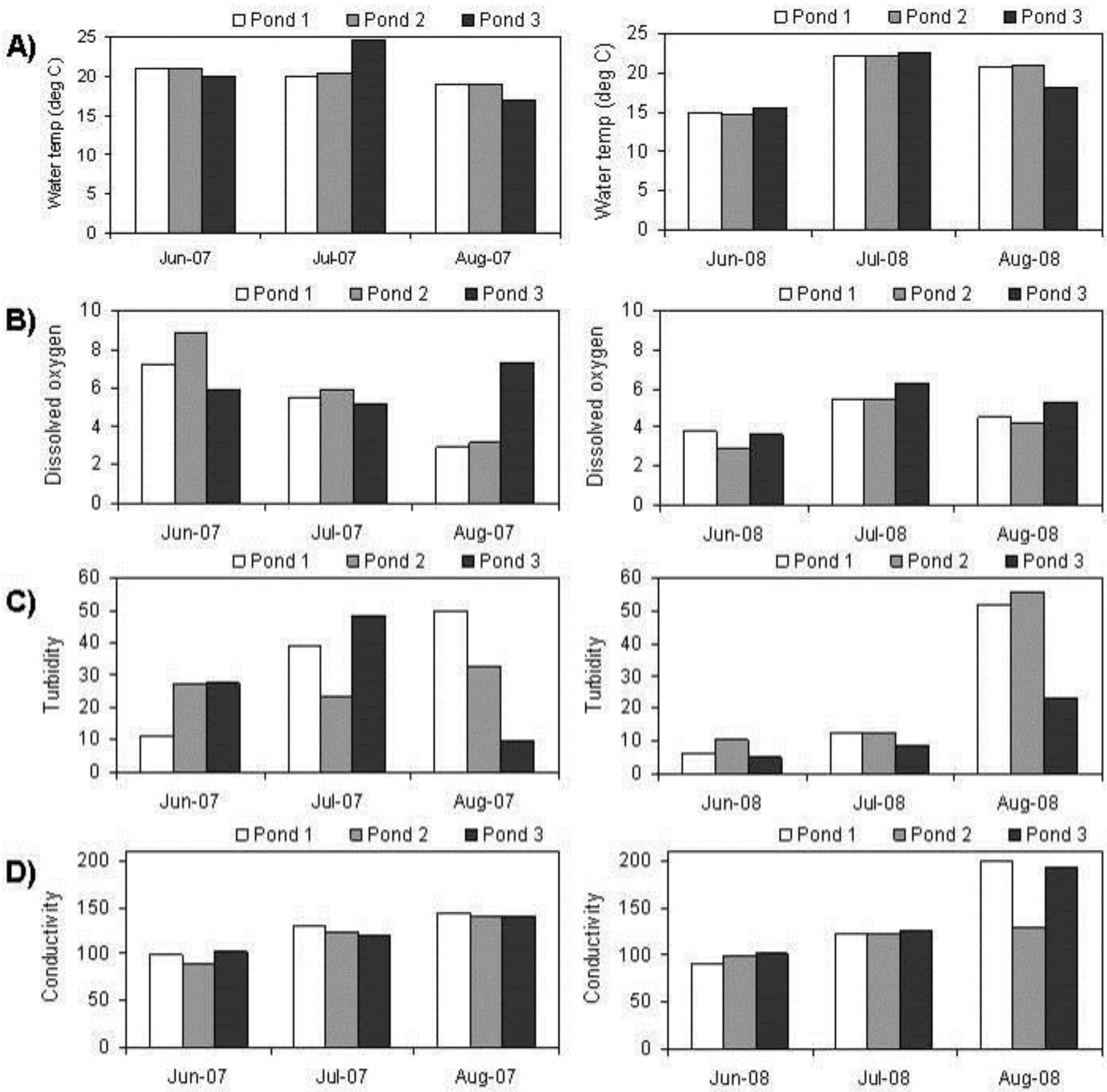
Values for estimated water depths varied by pond and sampling time (Table 29; Figure 29H). In 2007, estimated depths for all three ponds peaked in July and dropped in August for Ponds #2 and #3. In 2008, estimated depths peaked in June and decreased throughout the summer. Pond #1 retained more water than Ponds #2 and 3 in August. Overall, greater water depths were observed in 2008 due to greater river flows and dam releases.

Table 28: Water quality and depth data collected monthly for Scappoose Creek.

Date	GIS Site	Time	Water Depth (ft)	Air Temp (Cº)	Water Temp (ºC)	DO (ppm)	Turbidity (NTU)	Conductivity (mhod/cm)	pH
4/11/2007	SSCA05	11:30		14.3	12.7	9.98	3.81	73.1	6.2
	SSCA01	23:15		18.5	13.4	9.28	4.72	73.09	5.9
6/15/2007	SSCA05	11:00	3.5-4	19.7	16	7.58	2.82	95	7.1
	SSCA01	10:15	3.5-4	18.6	16	7.2	2.76	94.1	7.0
7/13/2007	SSCA05	10:00	1.3	22	20.9	7.04	2.84	113.5	6.6
	SSCA01	8:20	2.5	20.4	21.7	4.76	2.84	112.3	6.9
8/8/2007	SSCA05	12:45	1	27	20	9	2.06	115.9	6.8
	SSCA01	10:00	1.5	24	22	7.8	1.75	116.1	7.2
9/8/2007	SSCA05	9:10	3-5	18.5	18	6.96	2.37	126.7	6.7
	SSCA01	10:05	3-4	27.3	18	6.1	1.94	126	6.8
6/1/2008	Water was too high to access sites.								
7/3/2008	SSCA05	14:00	6	19.4	20.4	7.7	2.37	98.6	7.4
	SSCA01	13:30	9	19.4	20.6	7.2	2.88	100.5	7.2
8/26/2008	SSCA05	8:45	1.3	21.6	15.5	7.58	2.29	124.5	7.0
	SSCA01	9:45	1.5	21.6	16	6.72	1.95	125.5	7.3

Table 29: Water quality and depth data collected monthly for Ponds #1, 2, and 3 at Hogan Ranch.

Site	Date	Time	Air Temp (ºC)	Water Temp (ºC)	Estimated Water Depth (ft)	DO (ppm)	Turbidity (NTU)	Conductivity (mhod/cm)	pH	Bacteria Count E. coli	Bacteria Count *Total Coliform Bacteria /100 ml
Pond #1	6/15/07	13:20	20.3	21		7.2	11.1	99.7	7.0		
	7/13/07	13:25	31.5	20.01	2.5	5.5	39.2	131	6.2		
	8/9/07	10:20	19.6	19	2.5	2.9	50.0	145	6.5		
	9/7/07	12:30	25.2	19.9		5.4	46.3	157.3	7.3		
	4/17/08	13:45	15.8		2.5	23.0	5.6		6.9		
	6/11/08	12:15	13	15	6	3.8	6.2	90.2	6.9	5	5.3
	7/1/08	12:30	18	22.2	3.5	5.5	12.7	123.7	7.2	28	40.6
	8/6/08	8:23	22	20.9	2.7	4.5	51.9	199.8	7.6	4	4.1
Pond #2	6/15/07	14:15	22.3	21	2	8.9	27.0	88.4	7.0		
	7/13/07	1:25	31.5	20.5	2.5	5.9	23.2	125	6.3		
	8/9/07	10:25	31.9	19	1.25	3.2	33.0	141.9	6.7		
	9/7/07	11:15	28.4	23	4	9.3	50.9	140	7.9		
	4/17/08	14:00	14.4			8.0	6.0		6.9		
	6/11/08	12:45	13	14.9	4	2.9	10.4	97.6	6.9	2	2
	7/1/08	10:00	18	22.2	3.5	5.5	12.7	123.7	7.2	14	16.4
	8/6/08	9:00	21	21	1.2	4.2	55.8	130.3	7.1	86	657
Pond #3	6/15/07	13:10	18	20	2.5	5.9	27.7	102.5	6.8		
	7/13/07	11:56	26.5	24.7	2.5	5.1	48.3	121.1	6.5		
	8/9/07	8:45	16	17	1	7.3	9.6	140.8	6.4		
	9/7/07	11:15	20.1	20	3-5	10.4	17.5	176	7.4		
	4/17/08	9:45	12.1	10		10.8	5.1		7.5		
	6/11/08	14:00	13.4	15.6	5	3.6	5.4	100.9	6.9	9	9.9
	7/1/08	8:30	17	22.7	4	6.3	8.8	126.7	7.1	9	9.9
	8/6/08	7:30	17.8	18.2	0.7	5.3	22.9	194	7.1	30	36


A)
Pond 1
Pond 2
Pond 3
Water temp (deg C)
Jun-07
Jul-07
Aug-07
Jun-08
Jul-08
Aug-08
B)
Dissolved oxygen
C)
Turbidity
D)
Conductivity

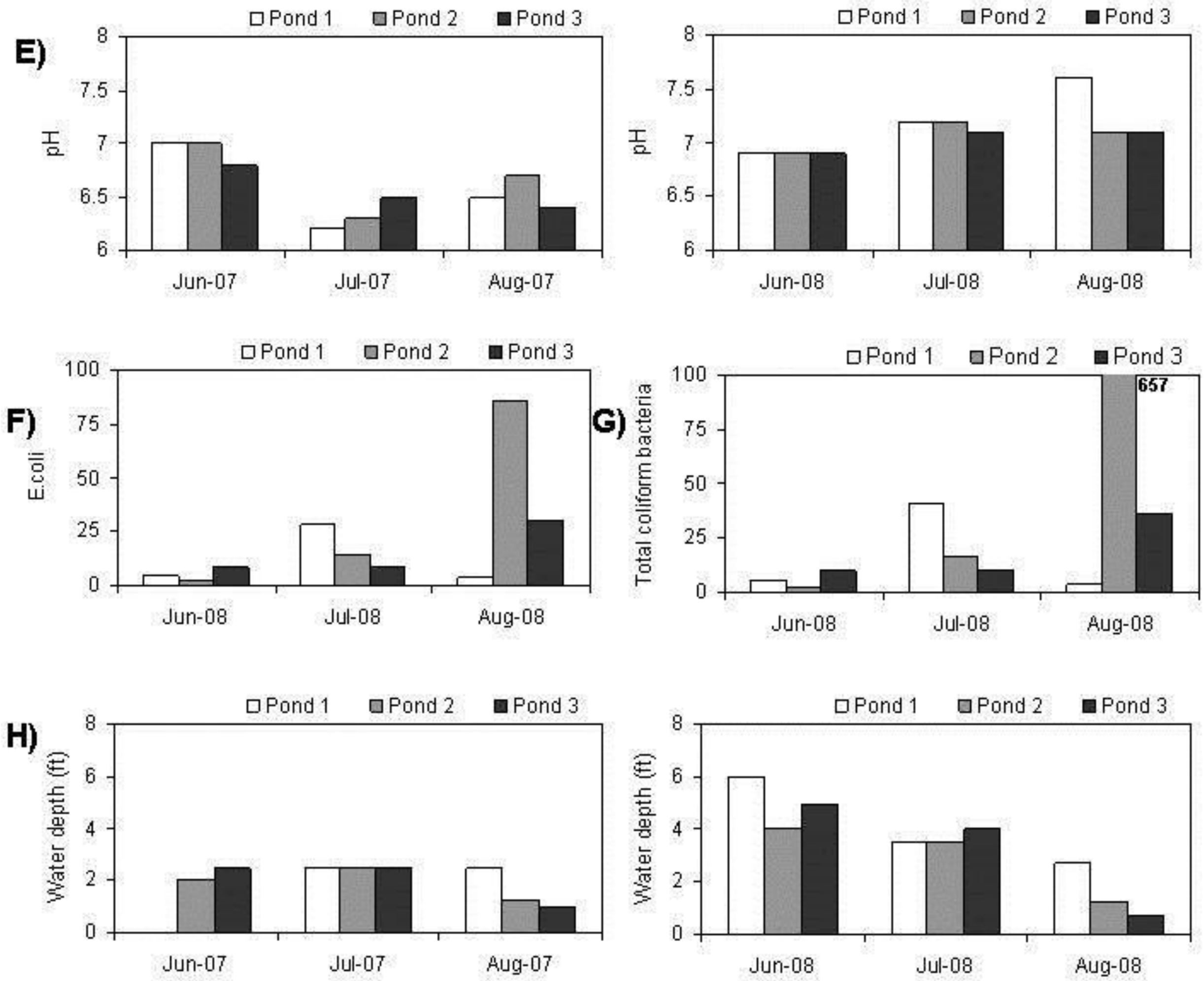


Figure 29: Monthly water quality and depth samples for Ponds #1, 2, and 3 at Hogan Ranch. A) Temperature; B) Dissolved oxygen; C) Turbidity; D) Conductivity; E) pH; F) E. coli; G) Total coliform bacteria per 100 mL; and H) Water depth.

6.3.4 Logger Water Quality and Depth Monitoring

Summary temperature data for Lower Scappoose Creek and Hogan Ranch show that while both sites have similar average diurnal temperature fluctuations, average minimum and maximum temperatures at Hogan Ranch were greater than temperatures at Lower Scappoose Creek (Table 30). The range of average daily minimum and maximum temperatures at Hogan Ranch also varied more than those temperatures for Lower Scappoose Creek.

The HOBO probes have shown that this area has a high amount of fluctuation in water levels due to tidal levels, rain events, spring snowmelts, and dam regulations on the Columbia River (Figure 30, Figure 31). Following tidal movement, water temperature decreased. The probes show that water temperature spiked at the beginning of the major rain event in December 2007 and the spring freshet in May 2008, as if it were collecting the heat from the surrounding ground before cooling off with additional inundation. In April & May and then again in July water temperatures rise as seasonal air temperatures rose. This shows that air temperature plays a significant role in the water temperature.

For Hogan Ranch, data from the HOBO logger captured the seasonal changes in water temperature depth at this site (Figure 31). In November 2007, a rain event occurred and was followed by a reduction in surface water temperature. Starting in March, surface water temperatures tended to fluctuated more than winter temperatures and were on average near ~50°F (or 10°C). Summer water temperatures rose with increasing air temperatures. From May on, surface water temperature rose with air temperatures and approached ~60°F (or 16°C) by the end of summer.

Table 30: Summary of temperature data (°C) collected from July 16 – September 11, 2008.

Site	Avg Daily Min Temp	Avg Daily Max Temp	Avg Diurnal Fluctuation	Range of Avg Daily Min Temps	Range of Avg Daily Max Temps	Range of Avg Diurnal Fluctuation
Lower Scappoose Creek	16.8	17.2	7.4	16.0 - 19.0	16.0 - 30.0	3.0 - 16.0
Hogan Ranch	18.2	25.6	7.4	12.2 - 24.5	18.3 - 33.3	3.1 - 16.0

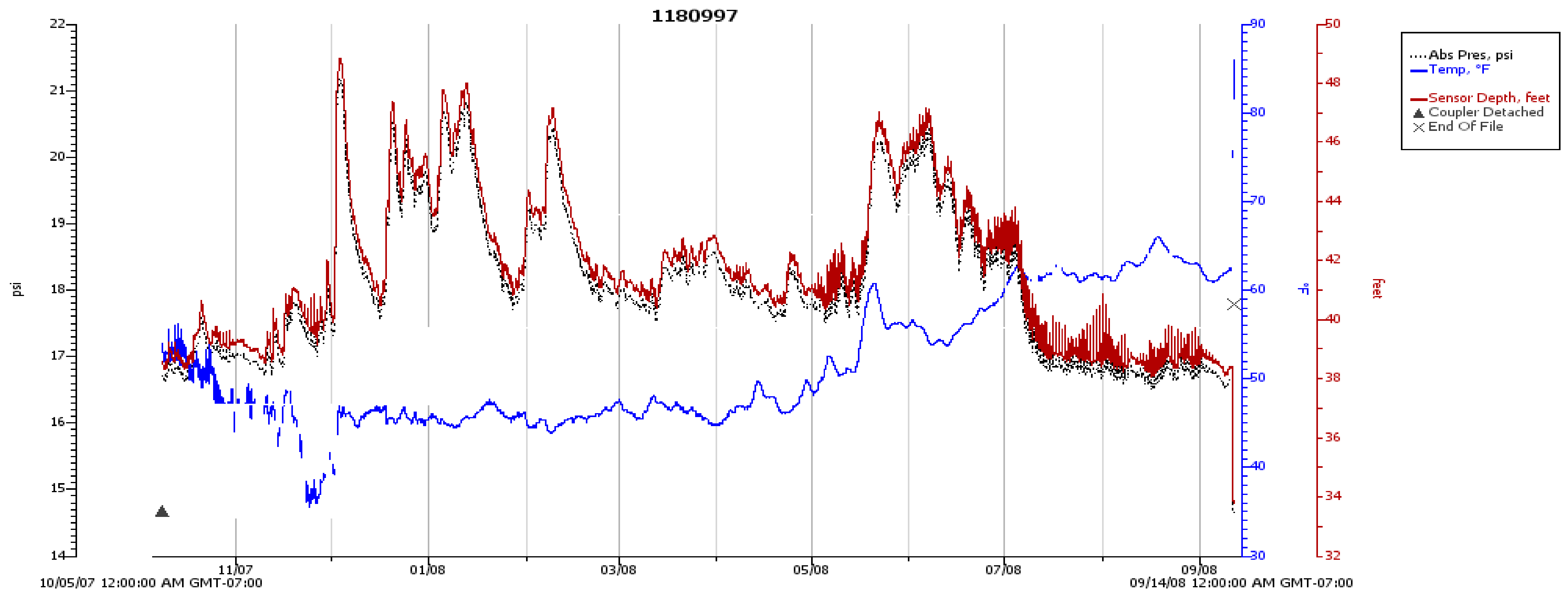


Figure 30: Water temperature and depth data from Lower Scappoose Creek recorded by HOBO logger.

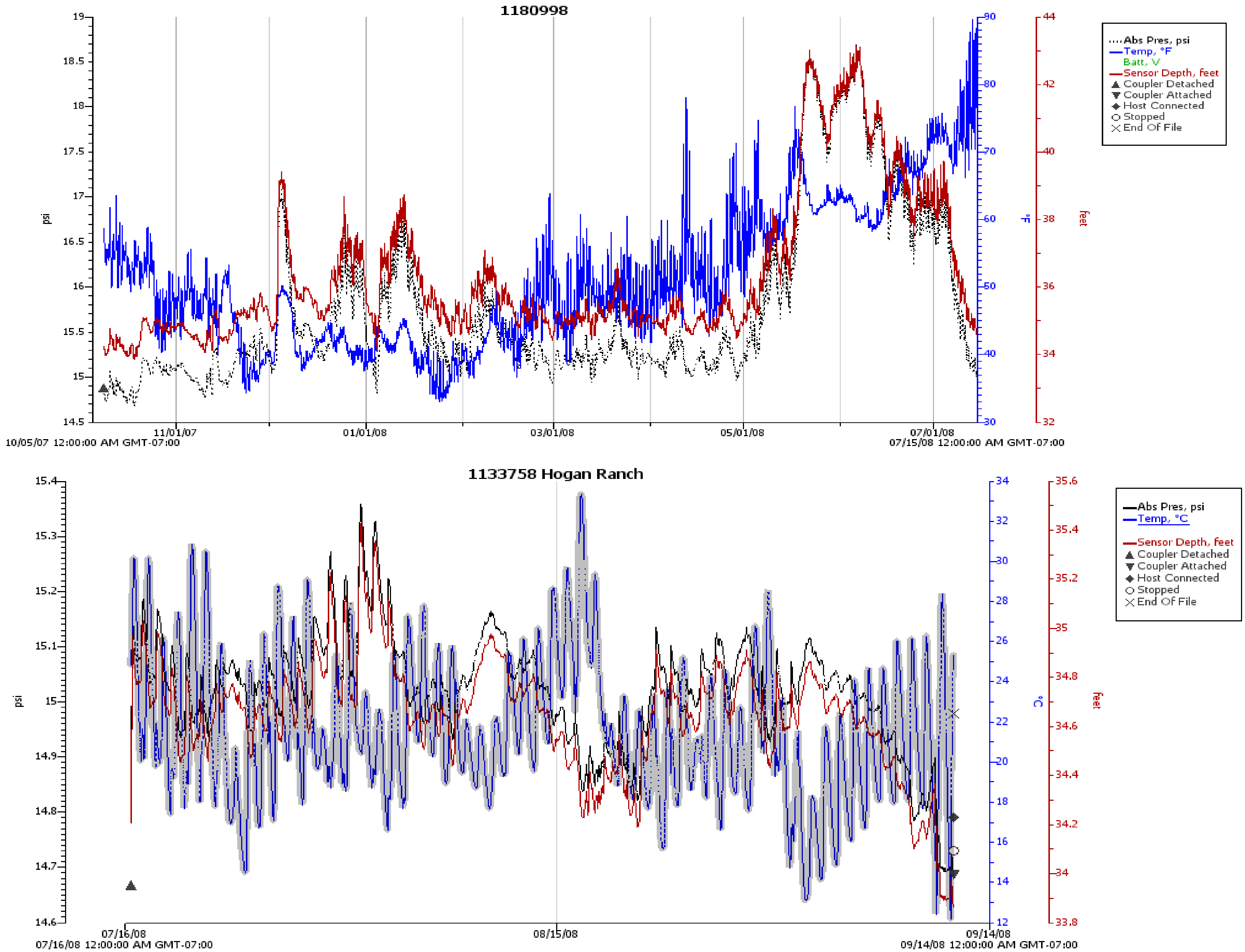


Figure 31: Water temperature and depth data from Hogan Ranch recorded by HOBO logger.

6.3.5 Success of Vegetation Plantings

The overall survival rate of plantings along Lower Scappoose Creek was 83% with an APD of 1.3 plants/m^2 (Table 31). On Hogan Ranch, the overall survival was 80% with an APD of 0.27 plants/m^2. Vigor of the surviving plantings was similar between the two sites (Table 31); most plants were of medium vigor and similar proportions of plantings fell into each vigor category.

Table 31: Vigor of plantings at Lower Scappoose Creek and Hogan Ranch planting sites.

	Vigor (%)			
Restoration Site	**High**	**Medium**	**Low**	**Dead**
Lower Scappoose Creek	25	42	16	17
Hogan Ranch	25	38	17	20

The riparian plantings at the Lower Scappoose Creek site consisted of only one community. All planted species performed satisfactorily on this site (Table 32). The herbaceous community on this site is composed of a diverse mix of introduced grasses and forbs typical of recovering pasture areas, including species such as reed canary grass, oxeye daisy (*Leucanthemum vulgare*), curly dock (*Rumex crispus*), and Canada thistle (*Cirsium arvense*). The herbaceous layer is sparse in some areas of the planting, with cover of bare ground near 15% overall.

Table 32: Survival of planting by species for the Lower Scappoose Creek site.

Species	Total	Dead	Survival (%)	Proportion of Total (%)
Western serviceberry	11	2	82	4
Red-osier dogwood	41	2	95	16
Oregon ash	20	5	75	8
Indian plum	4	1	75	2
Ninebark	59	11	81	23
Ponderosa pine	16	4	75	6
Western crabapple	7	0	100	3
Cluster rose	5	0	100	2
Thimbleberry	7	0	100	3
Cascara	17	0	100	7
Willows	14	2	86	6
Pacific willow	2	0	100	1
Douglas spiraea	18	0	100	7
Snowberry	18	0	100	7
Unknown	14	14	0	6
Total	253	41		

At the Hogan Ranch site, three vegetation communities were planted. The ash (*Fraxinus latifolia*) forest community had the highest survival, followed by the shrub communities (Table 33). The APD was lowest in the ash forest and highest in the shrub areas (Table 33). The dominant plant in the herbaceous layer was reed canary grass (*Phalaris arundinacea*) in all three communities.

Table 33: Survival and APD for vegetation communities planted at Hogan Ranch.

Community	Survival (%)	APD (Plants/m^2)
Ash Forest	86	0.19

Community	Survival (%)	APD (Plants/m^2)
Shrubs	79	0.35
Willows	72	0.29

Some woody species underperformed on Hogan Ranch (Table 34). Red-osier dogwood (*Cornus sericea*) and twinnberry (*Lonicera involucrata*) had survivals of below 50%, and the survival rate for cascara (*Rhamnus purshiana*) was below 70% (Table 34). Field observations showed that these species probably drowned due to the higher than normal water year. Additionally, a 0.24-ha sedge planting failed completely due to longer than expected inundation and, hence, was not monitored.

Table 34: Survival of planting by species for the Hogan Ranch site.

Species	Total	Dead	Survival (%)	Proportion of Total (%)
Red-osier dogwood	5	3	40	2
Black hawthorn	26	1	96	9
Oregon ash	65	12	82	23
Twinberry	11	7	36	4
Cottonwood	9	1	89	3
Western crabapple	10	0	100	4
Cascara	13	4	69	5
Cluster rose	12	1	92	4
Pacific willow	100	17	83	35
Douglas spiraea	21	0	100	7
Unknown	11	11	0	4
Total	283	57		

6.3.6 Vegetation Communities at Hogan Ranch Wetlands

The most substantial changes in vegetation community composition have occurred in the center of Pond #3 (Table 35, Appendix 5, and Appendix 6). Cattle exclusion from this pond is associated with a regeneration of native wapato (*Sagittaria latifolia*) in the central wetted area (Appendix 5). Before cattle exclusion, this area was dominated by jointed rush (*Juncus articulatus*, 55% cover) and American speedwell (*Veronica Americana*, 40% cover). One year after cattle exclusion, this area is now dominated by wapato (50% cover) and native creeping spike rush (*Eleocharis palustris*, 30% cover). Likewise, the marshy edges of the pond have experienced a similar change, from dominance by American speedwell (40% cover) and reed canary grass (*Phalaris arundinacea*, 25% cover) in 2004, to water purslane (*Ludwigia palustris*, 65% cover) in 2005, and now to wapato (75% cover) and creeping spike rush (53% cover) in 2008.

Today, the grassy outer rings of Pond #3 remain dominated by reed canary grass (Appendix 5). Since the first sampling period, plant diversity in this community area has decreased while the cover of reed canary grass is increasing. At this time, SWBC staff is unsure whether this trend will continue, and will monitor the reed canary grass and take action, if appropriate. The grassy edges of Pond #3 make up a relatively short distance along the transect compared to the wetted pond center area (Table 35), and so represent a small area of this site.

In Ponds #1 and #2, the increased water level following the construction of water control structures has altered the area of the different communities. The community widths clearly show a dramatic increase in the width of the wetted pond center community from 2004 to 2008 (Table 35). The wetted pond center community in Ponds #1 and #2 is dominated by water purslane (*Ludwigia palustris*) and water pepper

(*Polygonum hydropiper*) with a small amount of water smartweed (*Polygonum amphibium*) (Appendix 5). In Pond #2, this community also contains native western water milfoil (*Myriophyllum hippuroides*), which was present in greater abundance in areas not crossed by transects. The composition of this community has not changed significantly since the replacement of the water control structures, but its area has.

As the wetted pond center community increases at Ponds #1 and #2, the composition of the marshy shore communities has changed. In 2004, the marshy shore communities of both ponds were dominated by water purslane/water pepper. In 2005, the Pond #1 shore had high coverage of white clover (*Trifolium repens*) and reed canary grass, while the Pond #2 shore was dominated by white clover and an unknown species of fescue. One year following construction, the marshy shore of Pond #1 is largely dominated by reed canary grass with some moneywort (*Lysimachia nummularia*), while Pond #2 is dominated by spatula leafed loosestrife (*Lythrum portula*) and water purslane. Diversity of this community has changed little despite changes in species abundance. Instead, more facultative wetland plants occur at the edges of this community because of the rising water levels in the ponds.

Ponds #1 and #2 are ringed by a zone dominated by reed canary grass, sparsely forested in places (FACW grasses/forested). It is unclear how the width of this zone is changing, since in some areas it is increasing and in others it is decreasing. This zone is more diverse on Pond #1 than on Pond #2 (Appendix 5). In 2005, it was dominated by white clover, but has since returned to reed canary grass. In addition to the reed canary grass, this zone includes creeping spikerush (*Eleocharis palustris*) and moneywort on Pond #1.

The facultative upland community on Ponds #1 and #2 is composed of pasture grasses and forbs such as colonial bentgrass (*Agrostis capillaris*), creeping bentgrass (*Agrostis stolonifera*), white clover, and other unknown fescues and poas. This zone has high species richness, but consists mostly of introduced species. Reed canary grass is also present in the facultative upland zone, and its cover appears to be increasing. At this time, it is unknown if the increase in reed canary grass is associated with increased water levels, cattle exclusion, or site disturbance during installation of the water control structures. SBWC will continue to monitor the reed canary grass population at this pond and take action as necessary.

Table 35: Widths of vegetation communities along transects at the Hogan Ranch ponds.

Pond #, Transect #	Community	Community Width (m)		Trend
		2004	2008	
Pond 1, Transect #1	FACU grasses and forbs	39	36	-
	FACW grasses/forested	6		-
	Marshy shore	45	4.5	-
	Wetted area	2.5		-
	Marshy shore	8		-
	FACW grasses/forested	29		-
	Total	129.5	40.5	-
Pond 1, Transect #2	FACU grasses and forbs	80	80	
	Marshy shore	24	17	-
	Wetted area	3.5	50	+
	Marshy shore	51	5	-
	FACW grasses/forested	39	44	+
	Total	197.5	197.5	
Pond 2, Transect #3	FACU grasses and forbs	73	26.5	-
	Marshy shore	77	22.1	-

Pond #, Transect #	Community	Community Width (m)		Trend
	Wetted area	40.7	142.1	+
	FACW grasses/forested		12	+
	FACU grasses and forbs	12		-
	Total	202.7	202.7	
Pond 2, Transect #4	FACU grasses and forbs	77	28	-
	Marshy shore	53	12	-
	FACU grasses and forbs		39	+
	Wetted area	50	103	+
	FACW grasses/forested	12	10	-
	Total	192	192	
Pond 3, Transect #5	FACU grasses and forbs		26	+
	Marshy shore		10	+
	Wetted area		255	+
	Marshy shore	32	7.5	-
	FACW grasses/forested	62	80.5	+
	Total	94	379	+

6.4 Conclusions

Monitoring indicated that plantings along Lower Scappoose Creek and at Hogan Ranch overall have survival 80% or greater. The ash forest at the Hogan Ranch site has highest survival but lowest APD, suggesting a potential trade-off between plant survival and density of vegetation cover in planting methods. Higher than expected water levels in 2008 and longer duration of inundation led to failure of some species, but the plantings remain healthy overall. One-year post cattle exclusion, the Hogan Ranch site is showing signs of recovery. Native wapato dominates a large area of Pond 3, providing a food resource for waterfowl and other wildlife. On Ponds #1 and #2, the wetted area is increasing and the vegetation reflects this change. One unintended consequence of the restoration has been an apparent increase in the dominance of reed canary grass on the outer edges of the ponds. AEM has made site managers aware of this potential issue concerning invasive species at the site, and they will work to make sure that this does not become a long-term outcome of the project.

7.0 Salmon, Salmon Prey, and Habitat Monitoring at Scappoose Bottomlands and Fort Clatsop

In 2008, the Estuary Partnership contracted the Columbia River Estuary Study Taskforce (CREST) to monitor the fish community and salmonid prey resources at Hogan Ranch in Scappoose Bottomlands and the Fort Clatsop restoration and reference sites (Estuary Partnership Contract #28-2008). They also monitored habitat conditions at the two Fort Clatsop sites. In addition to data collection, CREST will process salmonid prey samples collected at Scappoose Bottomlands and Fort Clatsop and those collected by NOAA Fisheries at Mirror Lake (See Section 4.2.3 for more information on the samples collected by NOAA Fisheries). A conceptual model for AEM at Fort Clatsop is presented in Appendix 1.

7.1 Sites

See Section 6.1 for a more detailed description of the Hogan Ranch site at Scappoose Bottomlands and associated restoration activities. Hogan’s Ranch is located in the floodplain of Multnomah Channel, a branch of the Willamette River located four miles upstream of the Willamette's convergence with the Columbia, and borders Scappoose Bay (Figure 32). As one of the last remaining tidally connected wetland complexes in the Scappoose Bottomlands, the ranch is a top priority for conservation and restoration. Creeks and channels that connect the ranch with Scappoose Bay, support salmon seeking food, space for rearing, and shelter from predators and high water velocity. Furthermore, although baseline fish community monitoring revealed little species diversity, salmonids that inhabit nearby wetlands demonstrate the need for a more comprehensive monitoring approach. Finally, sheeting events that occur when elevated river flow volumes breach channel banks, temporarily flood the property, potentially entrapping salmon.

Despite the ecological benefits of these tidally influenced bottomlands, human impacts to the ecosystem might hinder salmonid survival. Water control structures, previously installed by Ducks Unlimited (DU), artificially regulate flow to the lower ponds on the property (Figure 32). Though waterfowl presence was prolonged, the unintended potential for salmon stranding was introduced. Debris deterring grates and wooden water barriers associated with the structures are rarely removed, preventing volitional fish passage. Livestock have degraded the vegetative under story and trampled the riparian zones, their fecal run-off degrading water quality.

Water levels varied widely, subject to seasonal extremes, dam spill and to some degree the tide. Given these parameters, initial fish community monitoring was experimental as efforts were adjusted based on site conditions.

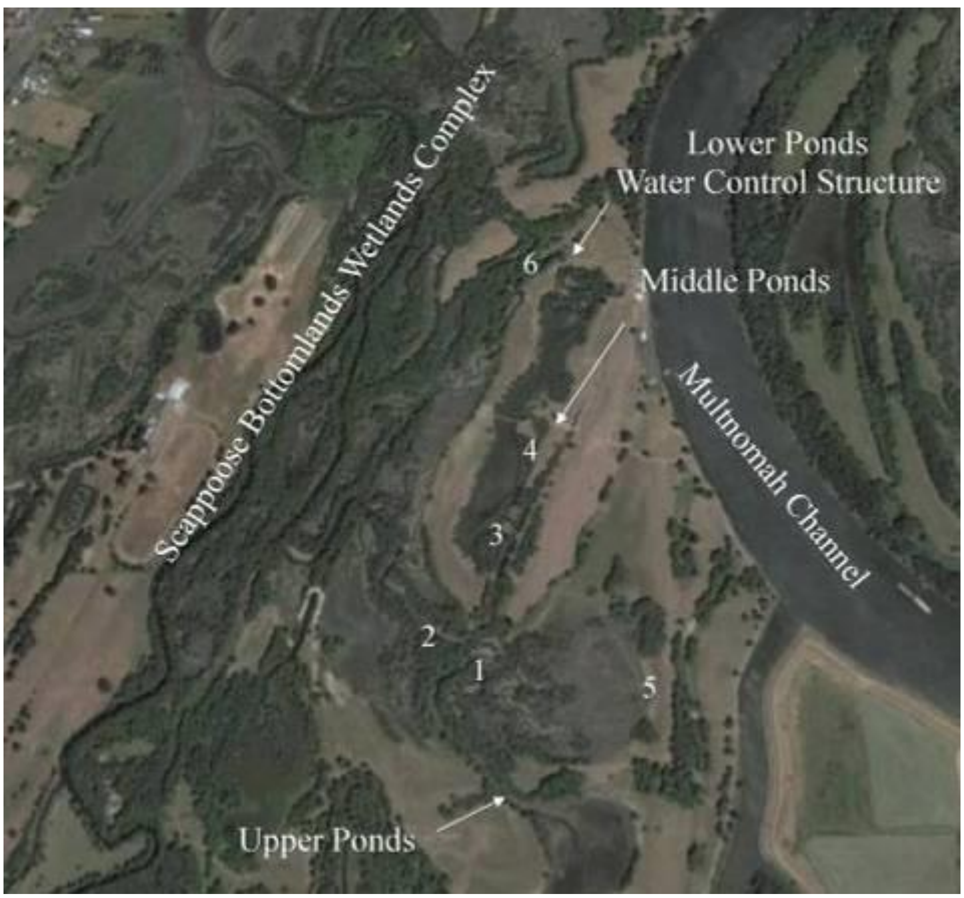


Figure 32: Hogan's Ranch conservation site illustrating proximity to Scappoose Bottomlands wetlands complex, Multnomah Channel, lower, middle and upper pond areas, water control structure location, and sample sites, 1 through 6.

For the first half of the twentieth century, dairy farming drove deforestation, floodplain diking, and marsh drainage in the Lower Columbia River Estuary. Despite the abandon of local logging practices like clear-cutting and splash-dams, on-going erosion results in turbid water and silted spawning beds. Agricultural activities produce pesticide and fertilizer run-off, while off-shore pollutants come in with the tide, collectively depleting water and habitat quality. NOAA fisheries have placed a conservation emphasis on the oligohaline and brackish aquatic transition zone because of its role in acclimating sub-yearling salmon to salt water. Estuarine wetland impacts are most felt in the Young's Bay watershed, necessitating restoration of critical habitat for endangered salmonids, seeking refuge and sustenance before ocean entry.

In 2007, LCREP reconnected 45 acres of diked pasture with the river and tide at Lewis and Clark National Historic Park's Fort Clatsop South Slough (Fort Clatsop restoration site) when they replaced a failing tide-gate with a bridge (Figure 33). A standard culvert would have deterred fish by maximizing water velocity, while larger concrete versions would sink in the substrate. Unencumbered tidal-connectivity would maximize potential for estuarine habitat enhancement restoring opportunities for fish use and community enrichment.

Ecological benefits were quantified by monitoring biological and physical parameters like fish community structure, water quality and channel cross-sections, before and after restoration. The final summary report for the Otter Point Phase I Project (Estuary Partnership Contract #06-2008) compares fish communities after the bridge installment at South Slough, to those monitored outside the failing tide-gate, and to those on the Lewis and Clark mainstem. This report highlights results from post-restoration fish community monitoring at South Slough, and investigates prey availability and utilization as well.

The Fort Clatsop reference site was selected based on the proximity to the restoration site, a history of tidal connectivity, and having environmental conditions that could support salmonids (Figure 33). Side channels yield space, surrounding spruce trees provide shade, riparian zones of native vegetation keep water in good condition, all of which should promote salmon usage. Monitoring efforts have expanded beyond fish communities, to prey availability and utilization, to qualify salmonid feeding behavior. These data will be directly compared to results from the restoration site.

Figure 33: Otter Point restoration site located on the mainstem Lewis and Clark River, including the Fort Clatsop restoration site ("South Slough") and nearby reference slough.

7.2 Methods

All sample gear and fishing techniques were consistent with the methods described in "Monitoring Protocols for Salmon habit Restoration Projects in Lower Columbia River and Estuary" (Roegner et al., 2008). Monthly sampling events between April and August ensued at both restoration sites, coincident with the spring migration period, and supplementary to monthly fish monitoring efforts at Fort Clatsop sloughs, underway since January (Estuary Partnership Contract #06-2008).

7.2.1 Fish Community

At the Hogan Ranch restoration site, Teal Slough (Figure 1, site 1) and the water control structure (site 6) were the only trap net sites. Seining at Sites 1 through 5, by boat, without the use of a motor, was the only feasible sampling method during abnormally high water.

At the restoration site at Fort Clatsop, a fyke-net trap was employed at the off-channel restoration site, whereby two ¼ in mesh, 50 ft wings that corral the fish into a 3/16 in mesh net sanctuary bag. Typically, the trap was checked every 45 min, for consistency and to minimize stress. Sampling began at high tide to low tide, capturing individuals going out to the main channel on the ebb. At the nearby restoration site, extremely low water velocity inhibited initial attempts to trap-net there in 2007. Without a swift current, the sanctuary bag will collapse on itself, releasing the catch. In 2008, a beach seine proved a more effective method for sampling, but the reference slough is inaccessible via motor boat, so crewmembers walked to set the net.

During all fish sampling events, aerated black buckets of clean water were used to keep the catch cool and comfortable while handling fish one dip-net full at a time. After separation for priority processing, CREST anesthetized the salmon individually with a buffered tricaine methanesulfonate (MS222) solution. CREST identified all fish to species, measured and counted them, and weighed the salmon. Chinook pelvic fin clips taken will provide genetic information for comparison to Mirror Lake populations upon future lab analysis.

7.2.2 Salmonid Prey

For prey availability, CREST deployed insect fall-out traps made of 30 qt rectangular plastic tubs and filled with an inch of soapy water. These traps captured bugs that land by disrupting their flight ability. Five trap sites were selected near each trap site and while the contract stipulated 5 events per site, 6 occurred at Fort Clatsop South Slough and 4 at Hogan's Ranch. After 48 hours of exposure in the marsh, samples were collected, coincident with fish monitoring, and preserved for later lab analysis. Results qualify and to some degree quantify prey taxa, demonstrating what the marsh offers salmon to eat.

Prey utilization was observed for at least 10 salmon measuring 60 mm or more, per set or pull, at each site as well. The gastric-lavage technique used to collect gut contents from live salmon involves the use of pressurized, pre-filtered water, to evacuate undigested stomach matter. Samples are preserved with 10% formalin for later lab analysis. The comparison of prey available to salmon in the marsh to what they are eating may illuminate salmonid feeding behavior in the estuary.

7.2.3 Sediment Accretion

At the Fort Clatsop restoration site, two level stakes are placed one meter apart and the distance measured incrementally from there to the ground, occasionally throughout the sample season accumulatively reveal temporal and spatial shifts in sedimentation.

Figure 34: Sediment accretion measurements, 2008.

7.2.4 Channel Cross-Section Surveys

Immobile stakes planted at the vegetation line on each stream bank served as points to measure bathymetry at Fort Clatsop South Slough. Distance from a tape stretched between the two stakes, measured in 0.5 m increments, yielded points for plotting the channel morphology. The reference slough results will be made available with results from the Cumulative Effects study.

7.2.5 Landscape Change Photo-Points

Subtle changes in landscape can be measured using rudimentary time-lapse photography, where consistency is crucial. After using global positioning coordinates (GPS) combined with compass readings to establish the location and ensure photo-point replication ability, CREST recorded the restoration site and the reference site on film. We attempted to use a reference point in each photo. Later in the summer, CREST took a second round of photos at the restoration site and plan to do the same soon at the reference site.

7.3 Results

7.3.1 Fish Community

At Hogan's Ranch, experimental seining and trap-netting events were remarkably successful given the dynamic water levels. June water levels were higher than the preceding winter, due to spill at Bonneville dam and high temperature snowmelt, inducing sheeting. Resultant flooding conditions, negated initial trap-netting, but seining near the trap site and in the middle pond-area still did not reveal any entrapped salmon. Later, trap-netting at one of the controlled ponds, after removing barrier boards to induce flow, proved salmon to be absent there as well. By late summer, when water levels had receded and trap-netting ensued, only the handful of native and invasive species of fish already documented elsewhere on the property were found using Teal Slough (Table 36).

A single fall sampling event occurred in November, following initial winter water recession, when fall salmonid migrants were likely to access the restoration site. One coho was recorded, measuring 116 mm and weighing 12.19 g. We obtained prey availability and utilization samples for future analysis. By-catch species composition did not differ from those sampled previously in the season, though abundance varied.

Table 36: 2008 season totals and species composition for Hogan's Ranch by site and date.

	Site and Date									
	1				2	3	4	5	6	
Fish Common Name	**6/18**	**7/16**	**8/8**	**11/19**	**7/18**	**7/18**	**7/9**	**7/6**	**7/16**	**Species Total**
Coho				1						1
Northern Pikeminnow		8	33	1						42
Goldfish	22	26	412	19		642	44	80	30	1,275
Sculpin					1					1
Stickleback		30	24	3,457	1	67	2	23	30	3,634
Banded Killifish		1	615	79		94			18	807
Mosquito fish			56	3						59
Pumpkinseed Sunfish		4		3	19	619			1	646
Black Crappie			150	126		3	31	112		422
Largemouth Bass			2							2
Bullhead			174						1	175
Dojo Loach			1							1
Peamouth Chub		8	172	207			76	59	30	552
Large-scale Sucker			224	27						251
Dace			3	5						8

	Site and Date									
	1				2	3	4	5	6	
Fish Common Name	**6/18**	**7/16**	**8/8**	**11/19**	**7/18**	**7/18**	**7/9**	**7/6**	**7/16**	**Species Total**
Lamprey				1						1
Daily Total	22	77	1,866	3,929	21	1,425	153	274	110	7,877

At the Fort Clatsop restoration site, temporal patterns of salmonid distribution at the restoration site reflect documented life history strategies (Dawley et al., 1986). Salmonids were absent during January and February, then observations steadily increased from March through June, and then decreased through late August. Initially, chum used the Slough exclusively, and then disappeared with the arrival of Chinook, and then coho. Chinook observations peaked in June, consistent with the spring migration period of juvenile salmon. Coho displayed a bimodal temporal distribution, with peak observations in May and again in June. Coho were more abundant than other species of salmonids, and resided in the slough for longer than did the rest, supporting evidence suggesting that they are more temperature resilient than other species of salmonids.

Hatchery fish have not been observed using the restoration habitat to date. Chum averaged between 32 and 50 mm, making them too small to be hatchery stock. Adipose fin-clips used to mark hatchery stock were absent from all yearling sized coho and Chinook observed in 2008.

Salmonids were more abundant and diverse this year as compared to last, when restoration had not yet occurred (Figure 35). In 2007, only 10 salmon were found inside the failing tide-gate, whereas, 122 were recorded since the tide-gate was removed and the bridge installed (Figure 36). Diversity increased as Chinook salmon, steelhead and cutthroat trout began using South Slough this year, in addition to the coho and chum found there since last year.

The seasonal mean length distribution for Chinook salmon demonstrated that subyearling sized individuals use the restoration site more-so than did the yearlings, as their length remained primarily consistent over time (Table 37). We observed a single yearling in April and another in August, but only subyearling sized Chinook were present in the interim. Despite the low sample number, these results suggest that Chinook salmon use the off-channel estuarine habitat briefly to acclimate and enter the ocean shortly thereafter. These results are consistent with migration behavior associated with Chinook salmon whereby juveniles that enter the ocean as yearlings typically rear upstream of the estuary (Dawley et al., 1986).

Alternatively, coho continued to increase in size throughout the sample season. Individuals measured around 40 mm on average in April, and increased 10 mm on average per month through July (Table 37). These results suggest that unlike Chinook salmon who seem to seek temporary refuge, before moving on, coho are actively rearing in the estuary (Dawley et al., 1986). Future comparison of insect fall-out trap sample results from the restoration site with gut content samples will reveal whether coho off-channel or in the mainstem.

Overall, the total catch was similar to last year and again, dominated by the threespine stickleback (*Gasterosteus aculeatus*) (Table 38, Table 39). Other species caught included: peamouth (*Mylocheilus caurinus*), sculpin (*Cottus sp.*), banded killifish (*Fundulus rathbuni*), smelt (*Osemerus sp.*) and yellow perch (*Perca flavescens*). This community structure is typical of estuarine and some warmer, fresh-water environments.

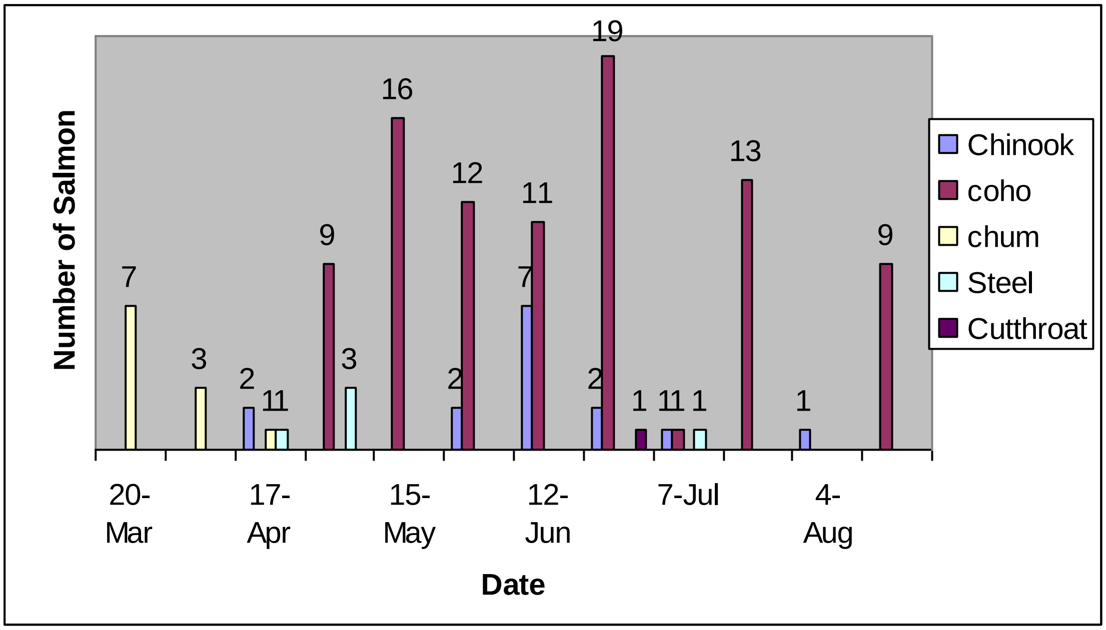


Figure 35: Relative abundance and seasonal distribution of salmonids observed at Fort Clatsop South Slough after restoration, 2008.

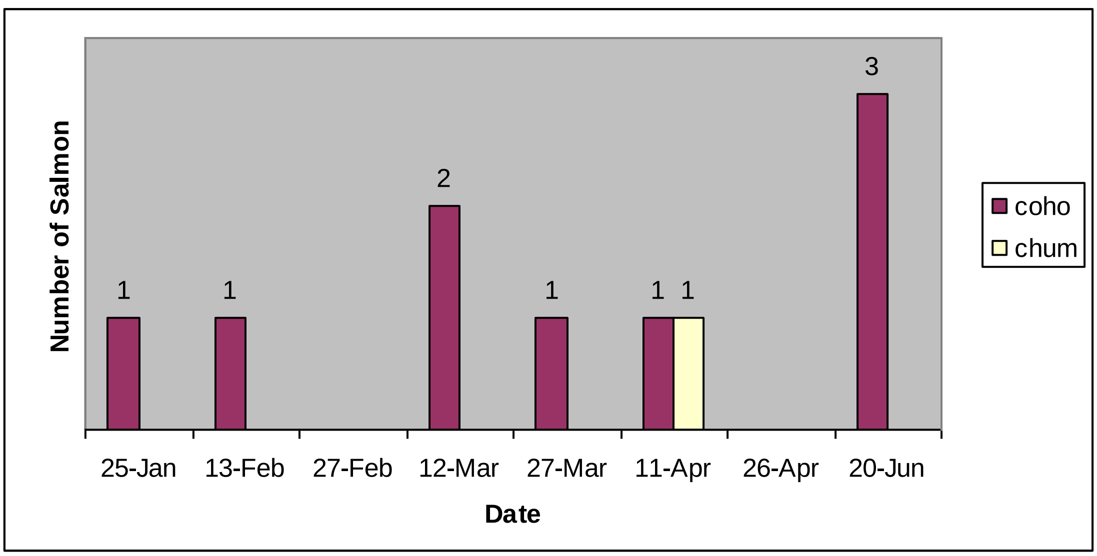


Figure 36: Relative abundance and seasonal distribution of salmonids observed at Fort Clatsop South Slough prior to restoration, 2007.

Table 37: Mean salmonid lengths following restoration at the Fort Clatsop South Slough, 2008. Lengths representing a single fish are denoted with an asterisk.

Date	Chinook Salmon	Chum	Coho	Steelhead	Cutthroat Trout
3/6		43*			
3/20		38			

Date	Chinook Salmon	Chum	Coho	Steelhead	Cutthroat Trout
4/3		32			
4/17	104	50*		192*	
5/1			40	119	
5/15			43		
5/30	46		51		
6/12	50		56		
6/26	55		59		139
7/7	51*		73*	78*	
7/24			69		
8/4	127*				
8/22			69		

Table 38: Fort Clatsop South Slough, bycatch species composition, 2007.

Fish Common Name	Date							
	1/25	**2/13**	**2/27**	**3/12**	**3/27**	**4/11**	**4/26**	**6/20**
Stickleback	1,236	668	58	184	937	1,070	145	2,266
Smelt			1					
Peamouth				2	1			
Sculpin				1		1	1	8
Shad	3							
Yellow perch					1			
Banded killifish								7

Table 39: Fort Clatsop South Slough, by-catch species composition, 2008.

Fish Common Name	Date							
	1/16	**2/14**	**3/6**	**3/20**	**4/3**	**4/17**	**5/1**	**5/15**
Stickleback	1,917	2,000	315	1,281	6,547	4,224	7,298	2,010
Yellow perch					6	7	5	2
Peamouth		1		13				
Sculpin		2		1	6	1	4	5
Banded killifish					2	1	1	9
Pumpkinseed sunfish								
Smelt								
Fish Common Name	**Date**							
	5/30	**6/12**	**6/26**	**7/7**	**7/24**	**8/4**	**8/22**	**Total**
Stickleback	5,146	5,256	8,841	7,024	4,407	2,481	2,730	61,477
Yellow perch			1				2	3
Peamouth	6				5		14	59
Sculpin	3	7	6			1		36
Banded killifish	1	5	5	1	2		2	29
Pumpkinseed sunfish		1			11		12	
Smelt		1		3				4

At the reference slough, species diversity was similar between years, though fishes were more abundant in 2008 than 2007 (Figure 37).

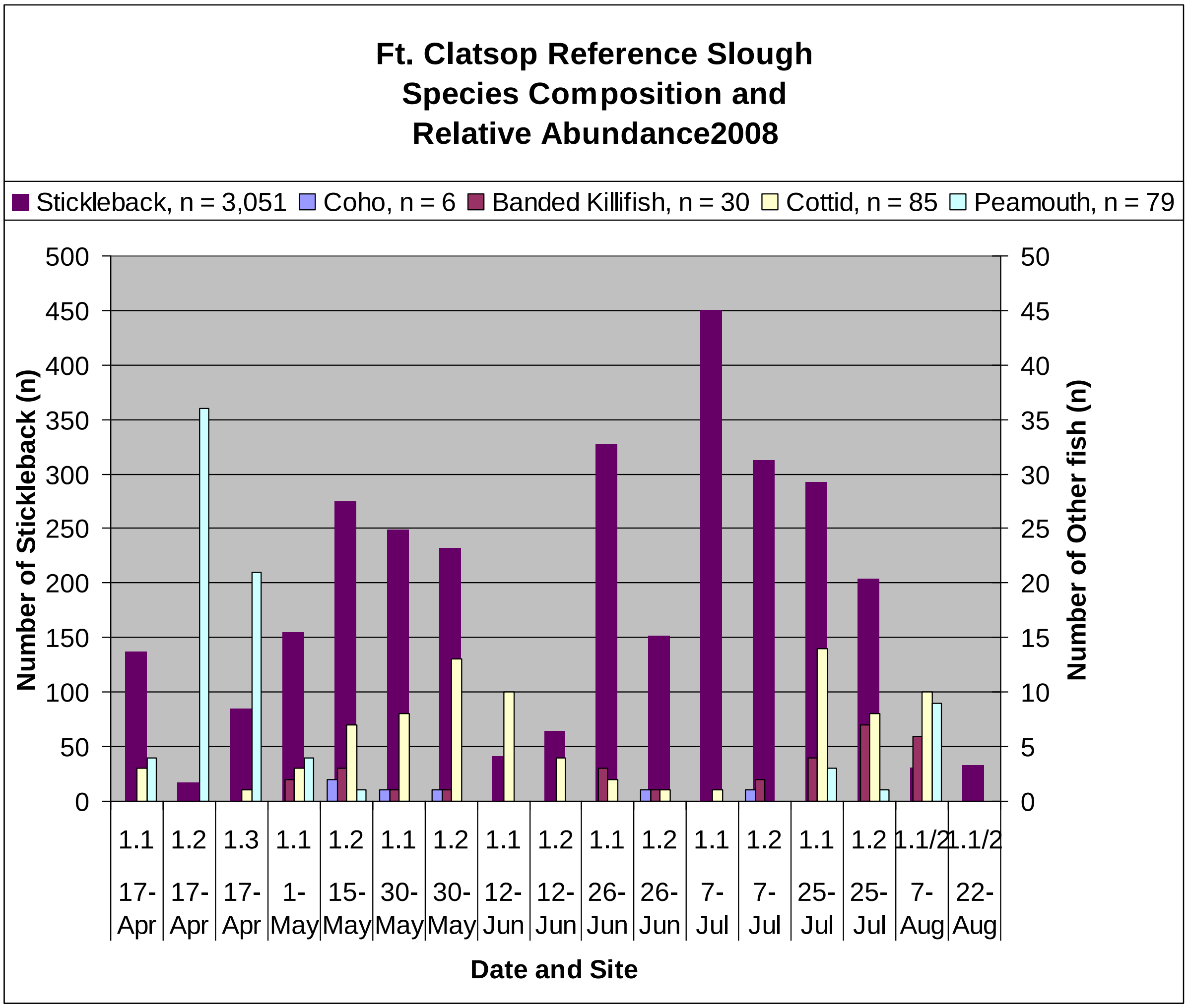


Figure 37: Fish species composition and relative abundance for Fort Clatsop reference slough, by date and seine site.location, 2008.

Table 40: Species composition at Fort Clatsop reference slough, 2007.

Fish Common Name	Date			
	4/11	4/26	5/25	6/20
Chinook salmon			1	
Coho			1	
Sculpin		1	4	1
Stickleback	1	50	164	4
Banded killifish	1			

7.3.2 Prey-Availability

At Hogan’s Ranch, CREST collected fall-out trap and benthic core samples from two sites, at four events. CREST set and retrieved five traps at Teal Slough, site 1, a total of three times throughout the season (1, N 45° 4816.7 W 122°4959.0; 2, 45° 4815.9 W 122°4959.2; 3, 45° 4815.7 W 122°4958.9; 4, 45° 4815.7 W 122°4958.7; 5, 45° 4815.1 W 122°4958.4). Considering the absence of salmonids at this or any other site on the ranch, no corresponding gut contents are available for comparison. As such, samples from Teal slough and the temporary fall-out trap, site 4, will not be analyzed. Priority instead will go to those sites and samples with relevant prey utilization samples.

At the Fort Clatsop South Slough, CREST collected prey from fall-out trap and benthic core samples on six occasions, five of which corresponded to gut content samples taken from salmonids on the same date. Results from May through August correspond directly to dates when CREST collected diet samples from salmonids. Benthic sample results continue to be compiled and will be presented in the annual summary report for the 2009 field season.

By in large, prey utilization samples showed that salmon diets consisted primarily of adult insects, like Chironomids, than other life history stages (e.g. pupae, larvae, or nymphs). Species readily available for consumption were primarily representative of the Homopteran and Dipteran orders of insects. Chironomids (order Diptera) were more abundant than other insect prey taxa. In May, trap 5 was most productive in terms of abundance, but least productive in terms of species richness; trap 4 displayed just the opposite (Figure 38). Similarly, Trap 1 was most productive in terms of abundance, but least in terms of species richness throughout June. Results from traps 4 and 5 were similar to each other; trap 2 flooded out (Figure 39 and Figure 40). Insect prey peaked in richness and abundance by June and July and began to decrease in August (Figure 41). By August, traps 1 and 5 were still most productive, having similar species, with more life history stages of insects seemingly available (Figure 42 and Figure 43).

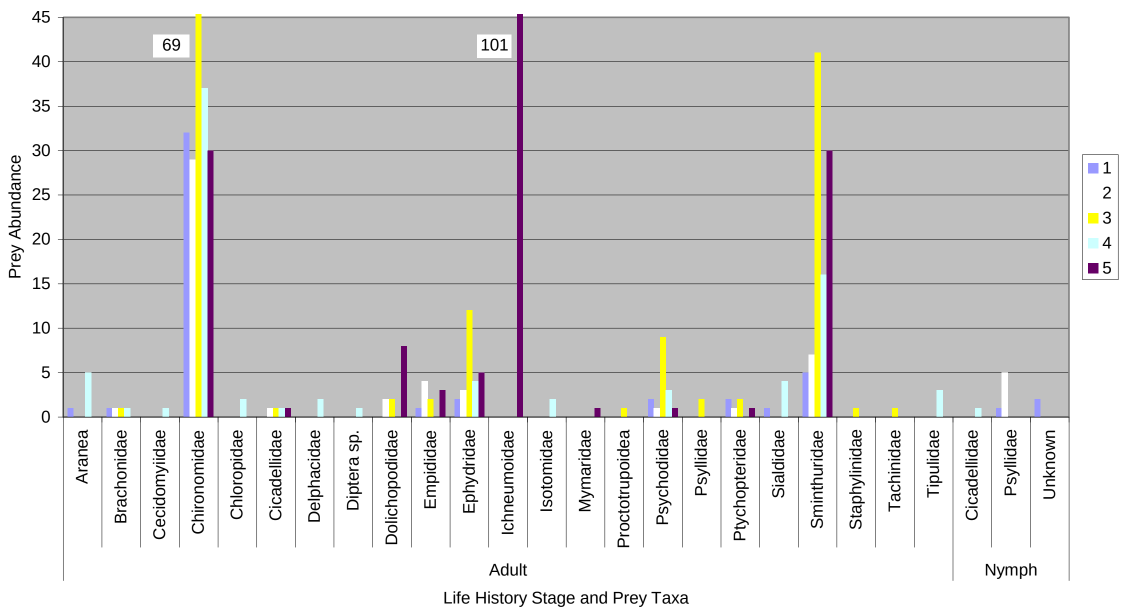


Figure 38: Insect prey availability at the South Slough traps 1-5, 30 May, 2008.

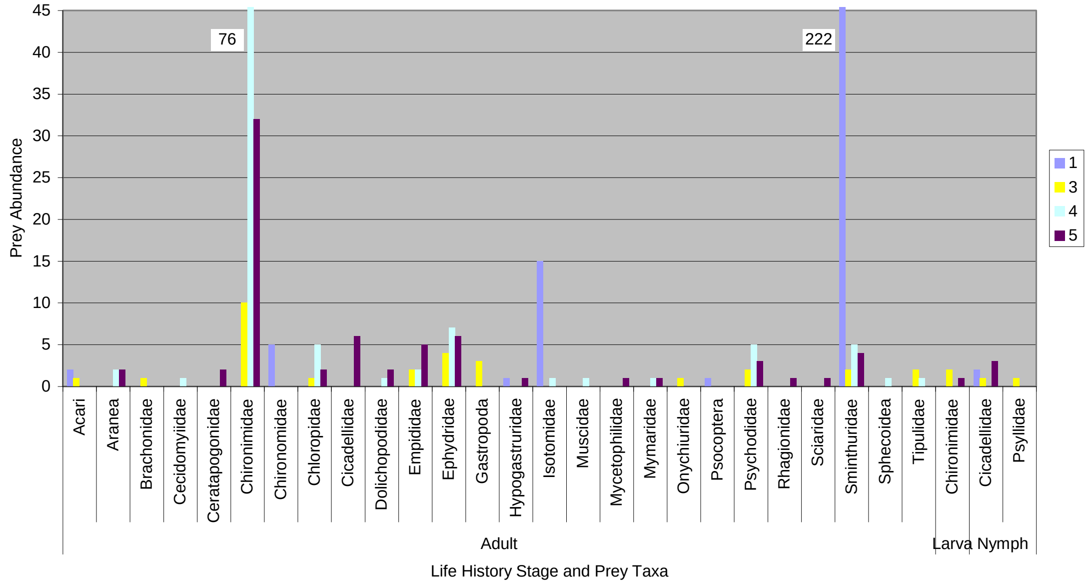


Figure 39: Insect Prey Availability at the South Slough traps 1-5, 12 June 2008.

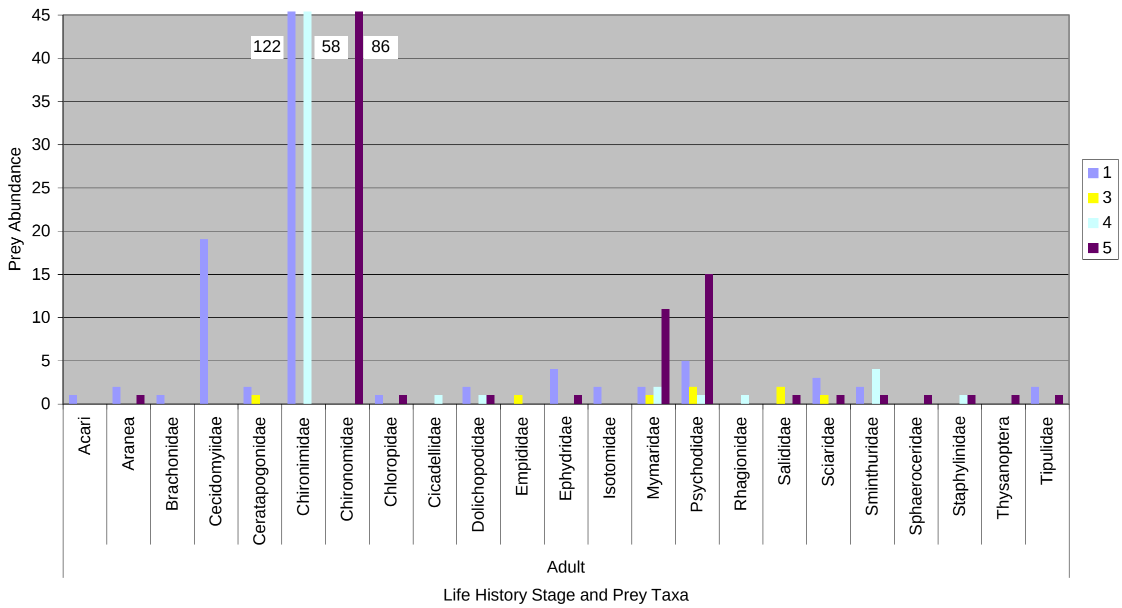


Figure 40: Insect prey availability at the South Slough traps 1-5, 26 June 2008.

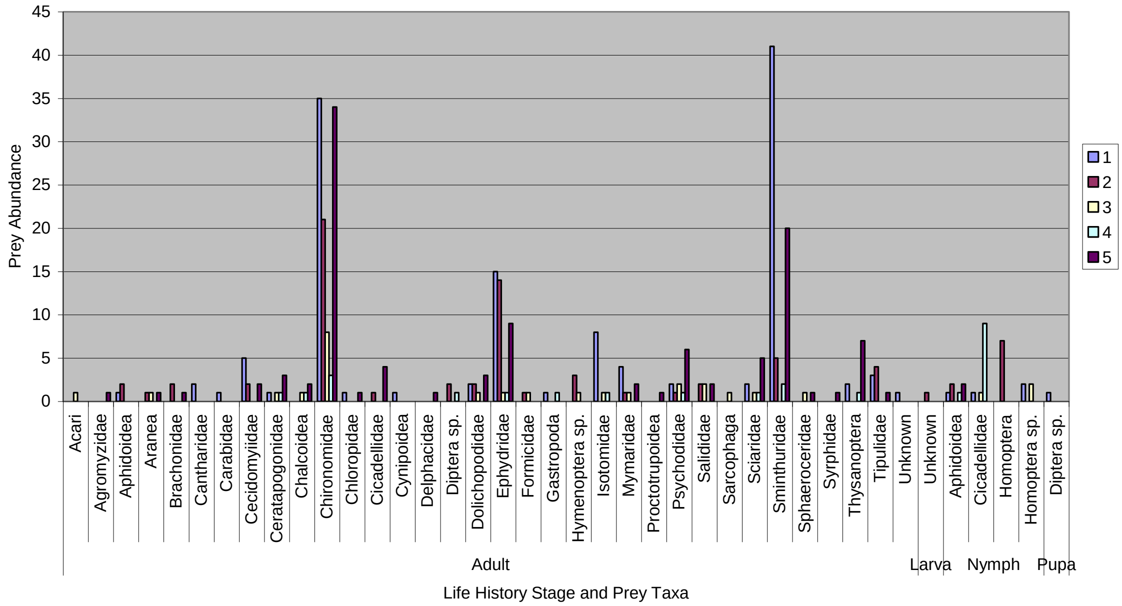


Figure 41: Insect prey availability at the South Slough traps 1-5, 07 July 2008.

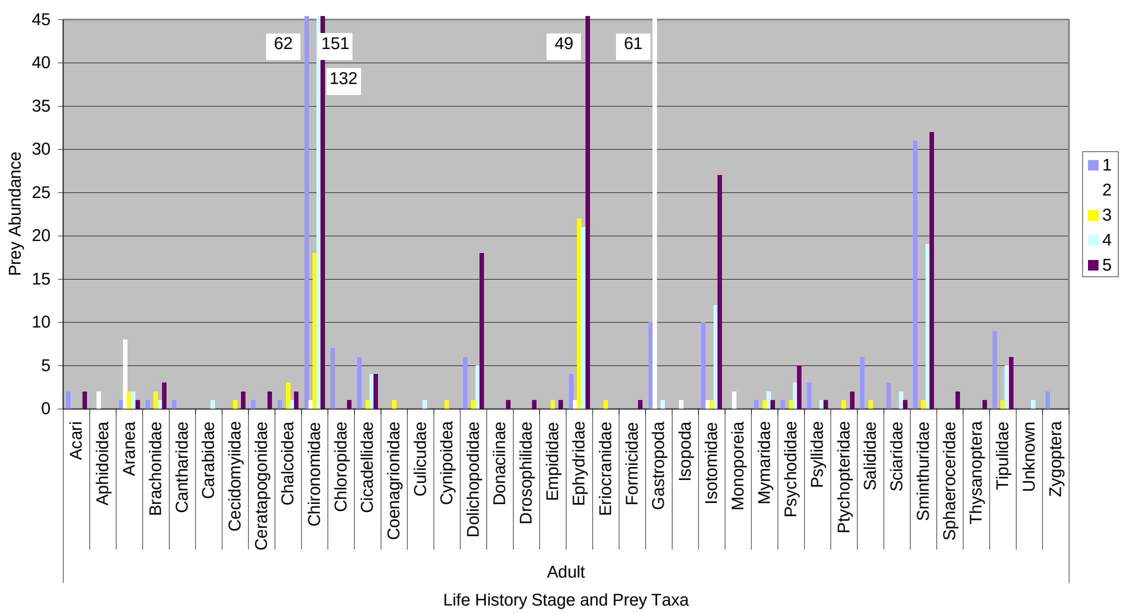


Figure 42: Adult insect prey availability at the South Slough traps 1-5, 04 August 2008.

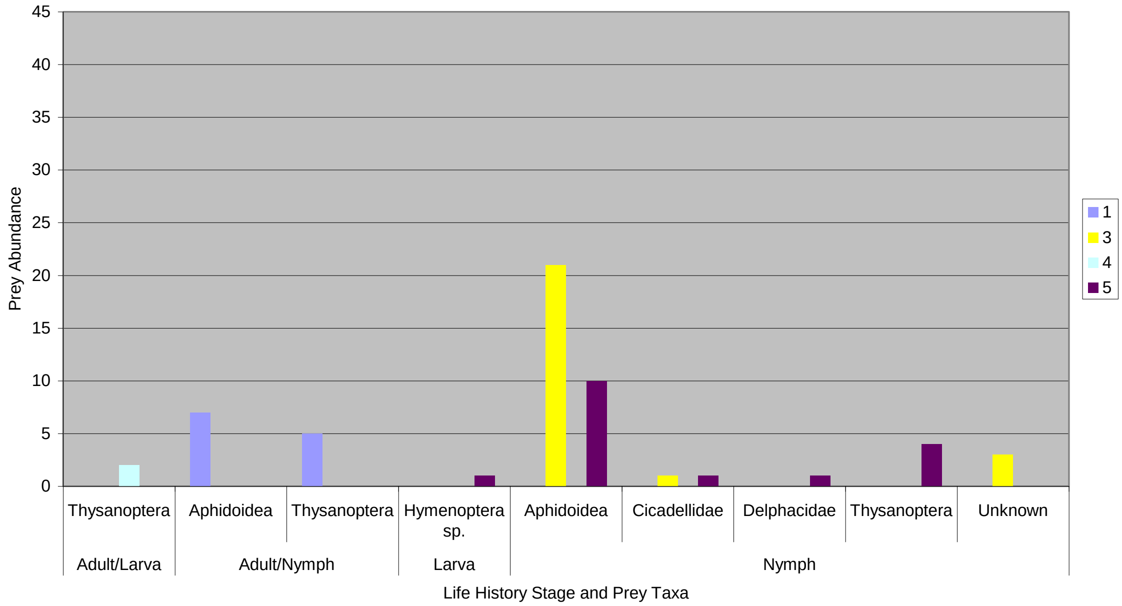


Figure 43: Non-adult insect prey availability at the South Slough traps 1-5, 04 August 2008.

At the Fort Clatsop reference slough, the four coho collected were not large enough for the gastric-lavage procedure. Without samples of the prey utilized by salmon at the reference site, there would be little value in qualifying the prey available to them.

7.3.3 Prey Utilization

At Fort Clatsop South Slough, diets from all salmon large enough to sample were qualified and quantified by species and date, for comparison to prey found available at South Slough (Figure 44). The temporal distribution of sample-sized individuals, coincident with species-specific life history strategies, precluded the sample date range. Therefore, more diet data were collected during June and July, than during May or August. Coho were sampled most often, as they dominated our catch at South Slough.

Insect nymphs and pupa were more numerous than were adults, in the gut content samples as compared to the fall-out trap and benthic-core samples. On the contrary, adult insects were more prevalent amongst gut content and fall-out trap samples then were other life stages. Winged insects were more numerous than were benthic macro-invertebrates like worms and copepods salmonid gut contents were concerned.

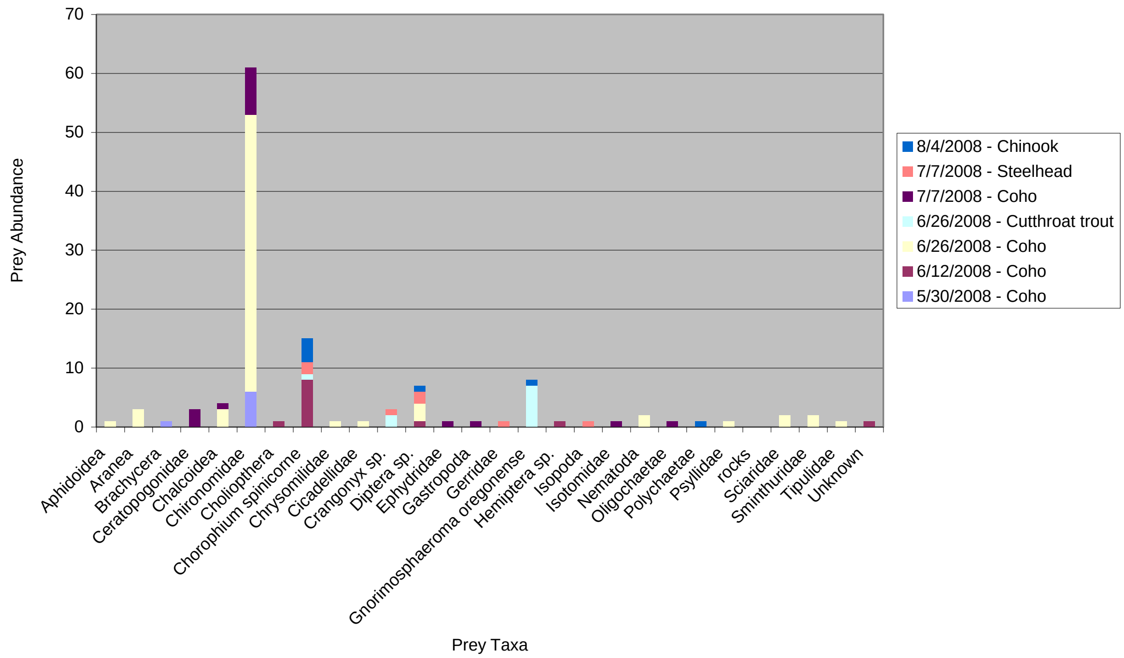


Figure 44: Salmonid diet composition, South Slough, 2008.

7.3.4 Sediment Accretion

Sediment accretion measurements from South Slough will reveal shifts in sedimentation when additional data points have been collected for comparison. Stakes were parallel to the channel, and degree of sedimentation declines almost steadily from the first stake at 0 cm to the second, 110 cm downstream (Figure 45).

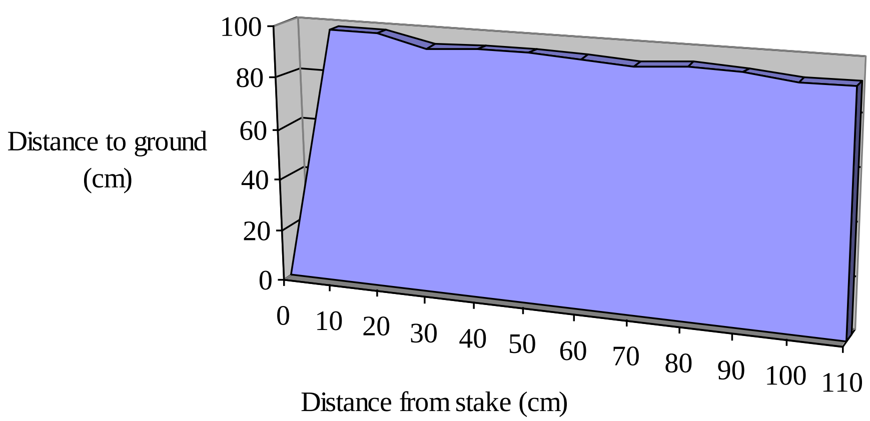


Figure 45: Sediment accretion values at Fort Clatsop restoration site, "South Slough," 2008.

7.3.5 Channel Cross-section Surveys

Bathymetry at South Slough revealed the thalweg and water-line to be proportionally lower in elevation near the site of restoration, with reference to the upstream cross-section (Figure 46). Channel morphology will continue to be recorded, revealing the affects the restoration and resultant reduction in water flow velocity have on the site. The elevation measurements recorded at each location correlates directly with the known height of the bridge, 12.92 ft above sea level, and with each other.

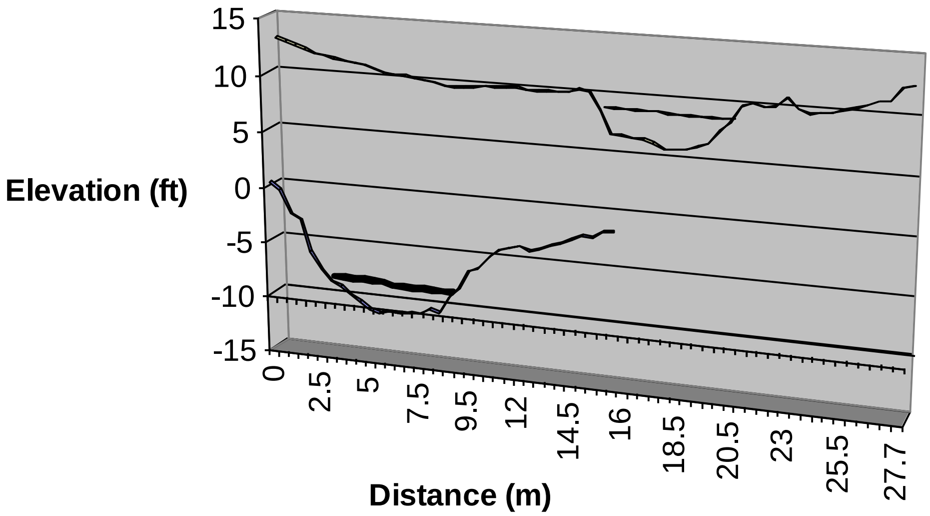


Figure 46: Fort Clatsop restoration site, "South Slough," channel morphology, August 2008.

7.3.6 Landscape Change Photo-Points

Pre-restoration photo points are not available for comparison, but subtle landscape changes at South Slough appear in photos taken during mid and late summer. The Northward shots reveal the invasive Reed Canary grass that has somewhat dried-up in the foreground by late summer; while the native Bull Rush remains prevalent in the background, bordering the sloughs edge (Figure 47A1 and A2). An initial compass bearing was not recorded at the Southward point at South Slough, so the August shot was taken a few degrees to the East, with respect to the July photo (Figure 47B1 and B2). However, the vegetation is still comparable between photos and show the Bull Rush thriving on the near bank, and the Reed Canary grass in the foreground getting taller by later in the summer. The July Southwest shot, facing up the restoration stream, were apparently zoomed in compared to August, but by comparison they show the vegetation has been visibly reduced as summer has progressed (Figure 47C1 and C2).

Reference site photo-points were mistakenly recorded on a single occasion only in 2008. Despite this designation and supposed healthy habitat, riparian vegetation is obviously dominated by Reed Canary grass there as well (Figure 48).

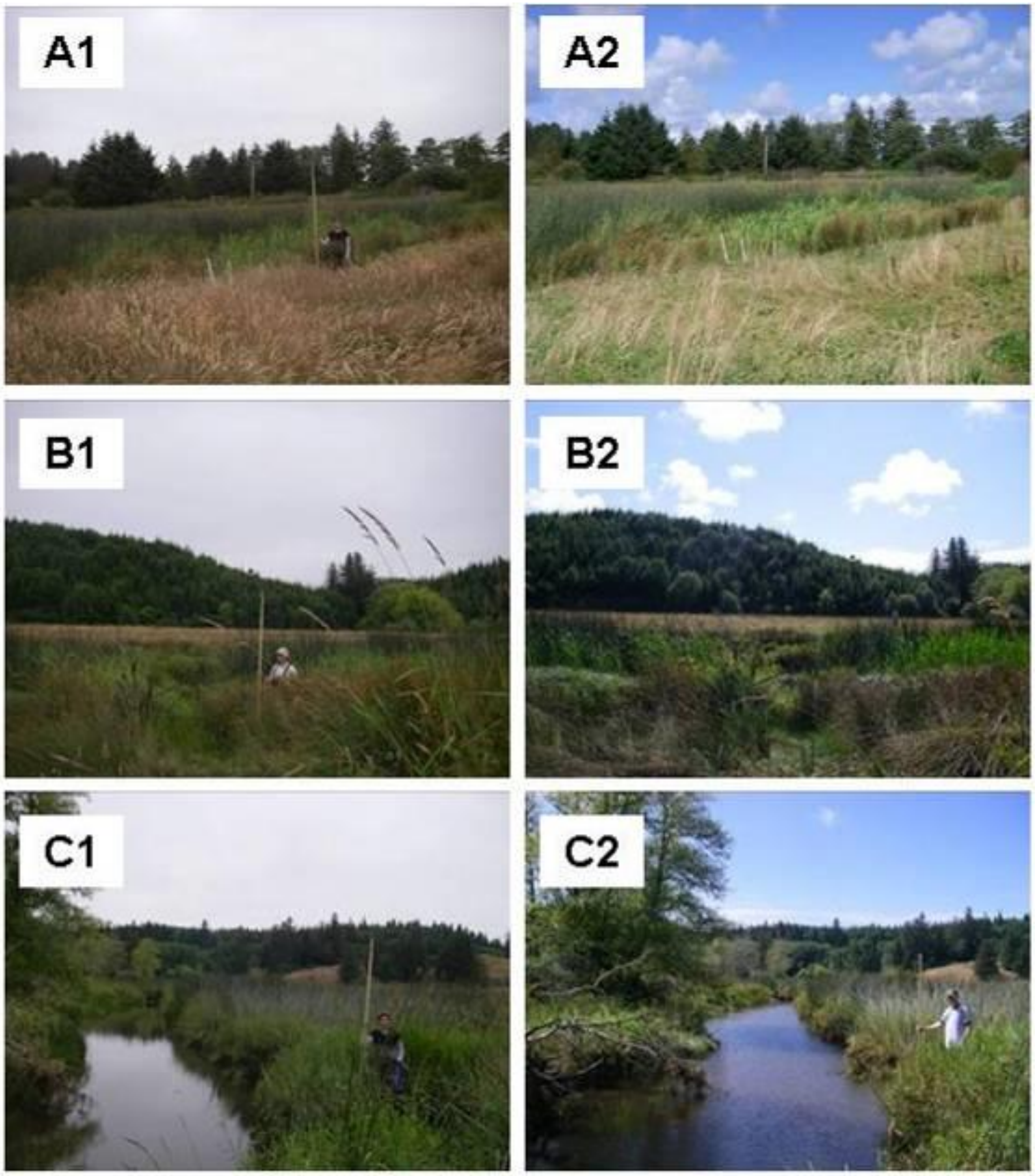


Figure 47: Photo points taken at Fort Clatsop South Slough. Photo point 1 at N 46° 0753.5, W 123° 5244.8, 360° North in: A1) July 2008 and A2) August 2008. Photo point 2 at N 46° 0743.4, W 123° 5248.6, South in: B1) July 2008 and B2) August 2008. Photo point 3 at N 46° 0743.5, W 123° 5244.3, 250,° Southwest in: C1) July 2008 and C2) August 2008.

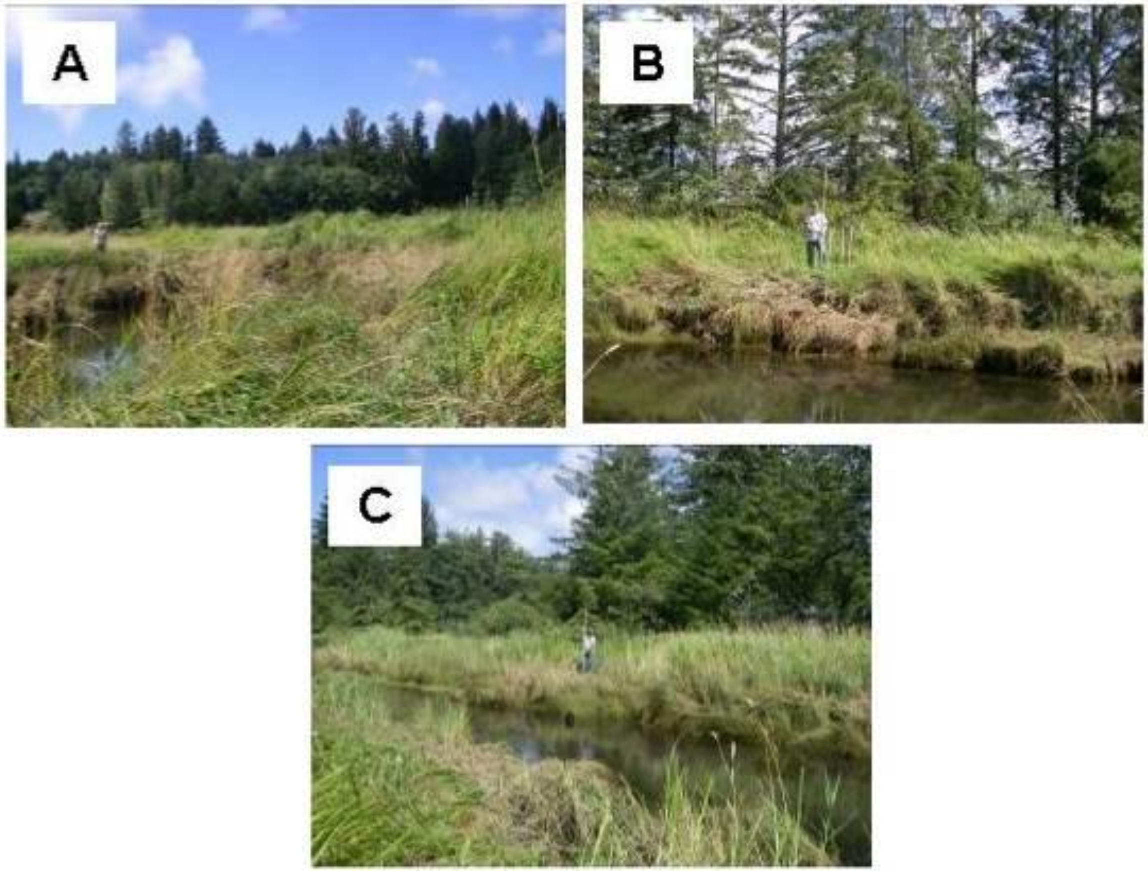


Figure 48: Photo points taken at Fort Clatsop Reference Slough. Photo points at: A) N 46° 0753.5, W 123° 5244.8, 250° West, B) N 46° 0753.5, W 123° 5244.8, 70° East, and C) N 46° 0753.5, W 123° 5244.8, 10° North.

7.4 Discussion

Biweekly sampling at South Slough in 2008, made possible by coinciding fish monitoring contracts, revealed increases in species diversity and abundance in the year following construction. Wild chum, observed at Fort Clatsop both before and after restoration, point to healthy salmon habitat, as they have been absent from the system for some decades. One Chinook recaptured at South Slough suggested that yearling sized individuals might be utilizing this area more substantially than once believed, before heading out to sea. South slough retains Coho inhabitants far longer than any other species, consistent with their life history strategy and increased temperature resiliency. The reference slough has not been productive enough for comparison, and calls for another change in gear-type to effectively sample there.

Insect fall-out traps demonstrated variable diversity amongst insect prey taxa, and a potential bias towards adult versus other life history stages. There were shifts in temporal and spatial distributions of prey available for consumption throughout the season. Prey taxa diversity was higher in June and July than May or August, consistent with peak riparian vegetation growth, and coincident with and potentially precluding the peak of larger sized-fish trapped.

Most diet samples were obtained from coho during June and July, consistent with their rearing behavior, and peak marsh productivity. Salmonids at South Slough fed on more winged insects than benthic macro-invertebrates, eating majority Chironomids, followed by Isopods and Amphipods. Furthermore, gut content insects were of the same prey taxa captured in fall-out traps, suggesting that the salmon fed in the slough. Insect and macro-invertebrate sampling on the mainstem would be necessary to determine whether or not South Slough salmonids are feeding in the marsh exclusively. These results might reflect prey selectivity by salmon at South Slough, or opportunistic feeding behavior, based on prey availability and distribution in the slough and water column.

Initial landscape photos and channel cross-section measurements taken will prove more useful in time, by demonstrating changes in vegetation and channel. Sediment accretion measured throughout time will also demonstrate just how this previously pasture-land is shifting, as side-channels continue to carve routes through the marsh.

While Hogan's Ranch lacks the healthy riparian and water qualities Fort Clatsop has to offer, the seeming absence of salmonids there might be an artifact of sample methods or locations. Flooding events there may entrap salmon, but without an effective method of sampling them during extreme high water, they may go unnoticed. Furthermore, sampling focused on ponds and stopped short of the extensive wetland complex bordering the property (Figure 32) which may well support salmonids. Finally, sampling was limited by previous engagements and geographic location, resulting in opportunistic efforts that were not comprehensive. Additional sampling in the winter or spring is warranted.

8.0 AEM Conclusions

This report documents AEM activities implemented in Spring and Summer 2008 under the Estuary Partnership's Habitat Restoration Program. Parametrix, NOAA Fisheries, ACFM, SBWC, and CREST reported on their efforts during a January 2009 Science Work Group meeting at the Estuary Partnership. Since AEM data collected over multiple years is necessary to evaluate project success, the Estuary Partnership contracted with these partners to conduct complementary AEM activities from September 2008 – August 2009 at the Mirror Lake, Sandy River Delta, Scappoose Bottomlands, and Fort Clatsop sites.

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Appendix 1: AEM Conceptual Models

Invasive Species and Native Vegetation Reforestation

Mirror Lake. During the early 1900's Young Creek's riparian corridor was cleared and subsequently farmed for approximately 100 years. Once farming/grazing ceased, invasive species replaced the bottomland hardwood forest that previously inhabited the site and prevented its reestablishment (Figure A1). This degraded riparian area poses a stressor that affects numerous controlling factors within the creek, e.g., hydrodynamics, bathymetry, and substrate. These controlling factors define the structure of the stream channel, as well as the wetland bench that flanks it, and help maintain its simplified structure. The homogenized channel affects several ecosystem processes within the site. These range from food web interactions to sediment supply and trapping, with habitat formation and productivity perhaps being the most significant. These altered ecosystem processes negatively affect salmonid performance.

Two controlling factors (temperature and light) will be monitored to assess the effectiveness of restoration actions at improving ecosystem processes, primarily habitat formation. Two stressors (riparian condition and invasive species) also will be monitored to assess the effectiveness of restoration actions at improving their condition, i.e., improving the riparian area's structure and increasing its species diversity.

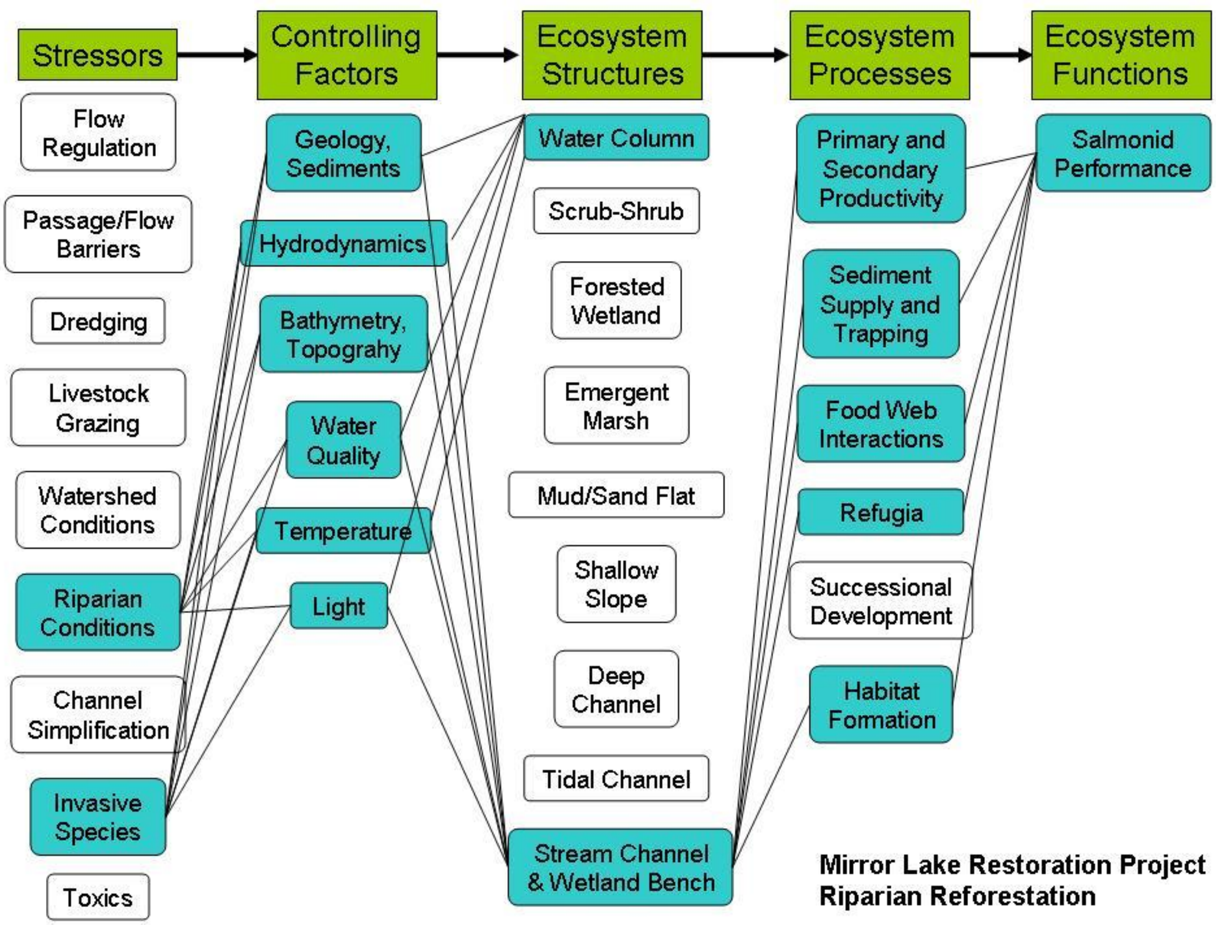

Figure A1: Conceptual model for riparian reforestation actions at Mirror Lake.

A similar conceptual model is applicable for planting at Sandy River Delta and Scappoose Bottomlands, though the "Ecosystem Structures" for Scappoose Bottomlands would include "emergent marsh" and "tidal channel" in addition to "water column" and "stream channel."

Cattle Exclusion at Scappoose Bottomlands

Restoration actions at Scappoose Bottomlands include the installation of fencing to exclude cattle so that sensitive wetland areas can recover from cattle impacts without active replanting of emergent wetland species. The riparian areas, on the other hand, require active management because the understory conditions have been significantly degraded by grazing and invasive species introduction. The purpose of the effectiveness monitoring was to determine the level of success of the work completed in the project area to date.

Our assumptions were that once cattle were excluded from the sites, the emergent wetland plant communities would be influenced by the sediment supply, topography, hydrodynamics, water quality, temperature, and available light. Changes in the plant communities would affect mud flats, tidal channels, water column conditions and various wetland types including emergent, shrub-scrub, and forested. We were unable to develop assumptions about benefits to salmonids due to a lack of data on potential use of the site, but expect that salmonid populations are apt to benefit from improved water quality and habitat conditions resulting from cattle exclusion.

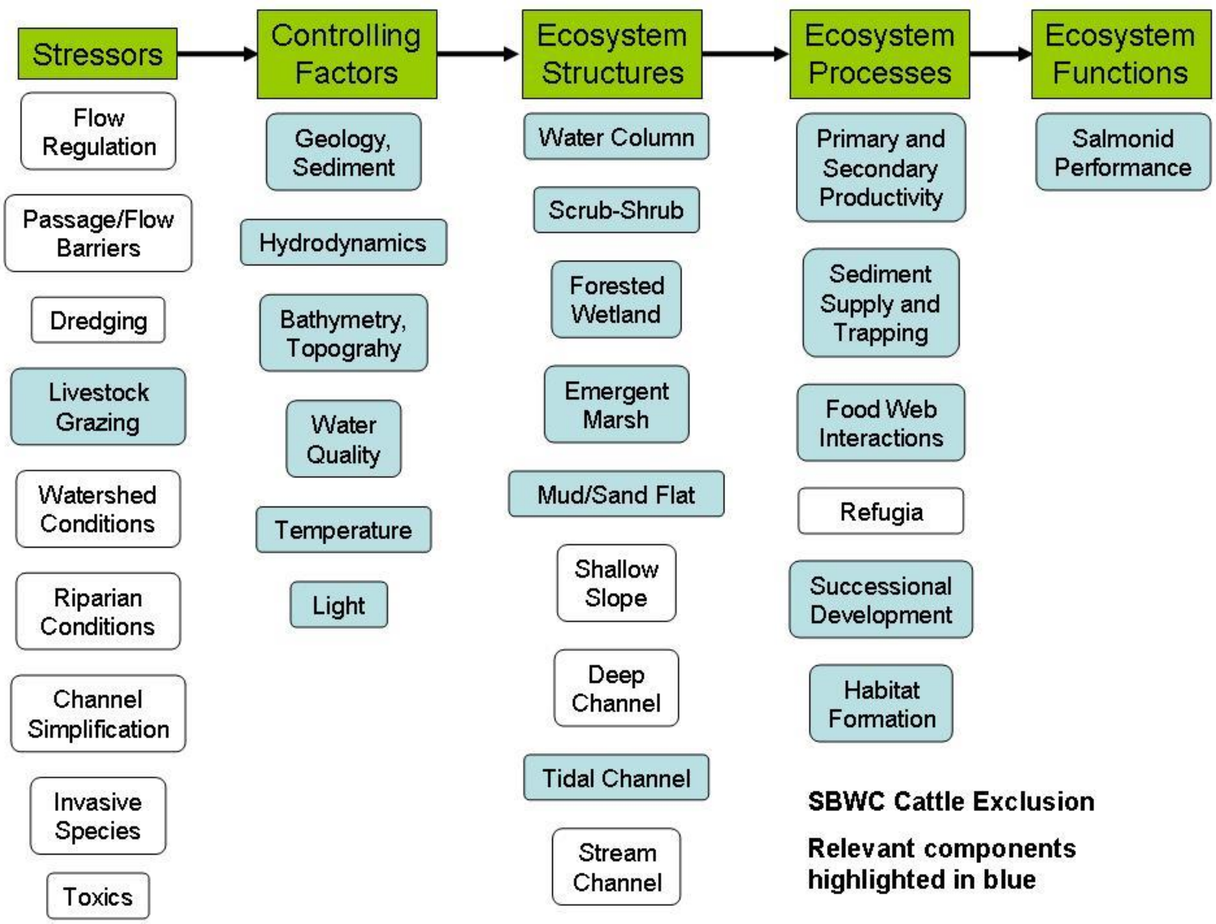

Figure A2: Conceptual model for cattle exclusion actions at Scappoose Bottomlands.

Culvert Replacement at Fort Clatsop

At the Fort Clatsop restoration site, the roadway and culvert posed an obstacle ("Passage/Flow Barrier" stressor) to fish passage that affected five controlling factors within South Slough: sediment, hydrodynamics, bathymetry/topography, water quality and temperature (Figure A3). Secondarily, livestock grazing impacted the topography and channel bathymetry of the site resulting in a simplified channel network, and degraded water quality. The tide gate that was only minimally passable during specific tidal stages made for suboptimal in-stream habitat conditions and modified hydrodynamics. Tidal reconnection improvements have increased hydrodynamic interactions with the site, enhancing the water column and promoting emergent marsh, more complex tidal channels, and other habitats on the periphery of the marsh (e.g. forested wetland, scrub-shrub and upland stream channel). The tidal reconnection will also improve nutrient and sediment flux, thus enhancing the following ecosystem processes: primary and secondary productivity in the water column, food web interactions, sediment supply and trapping, habitat formation, and refuge for fish and wildlife. Ultimately, these improvements in ecosystem processes should fuel improvement in salmonid performance, which can be quantified with specific monitoring metrics over time.

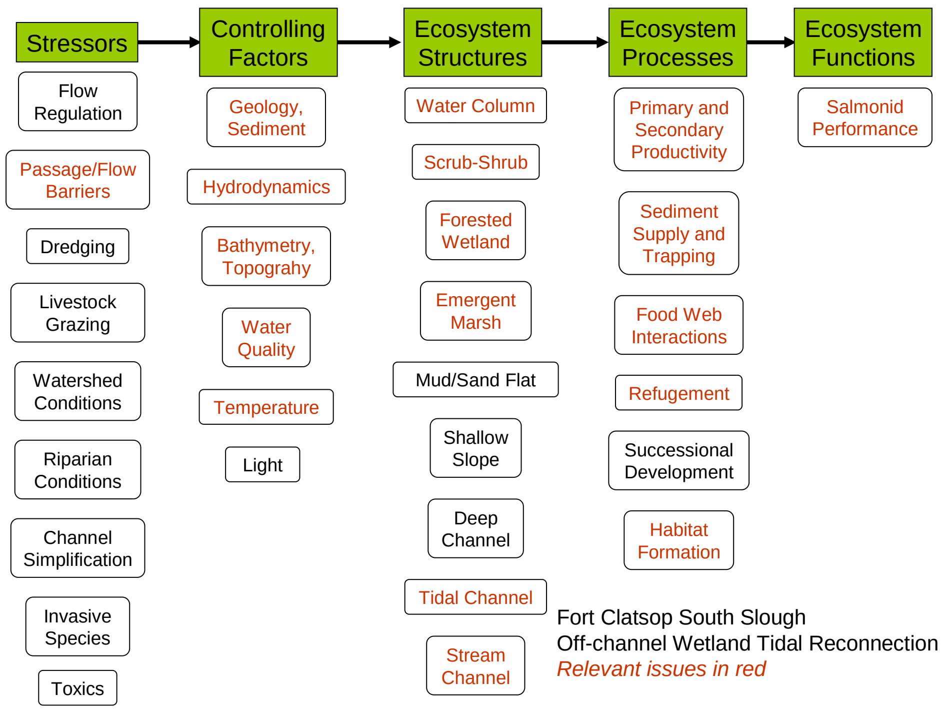

Figure A3: Conceptual model for culvert replacement actions at Fort Clatsop.

Appendix 2: Stream Flow Estimates for Mirror Lake

There are no stream flow records for Young Creek, Latourell Creek, or other nearby streams in the Columbia Gorge. Median monthly stream flows for Young Creek and Latourell Creek were estimated using the Water Availability Report System database maintained by OWRD. This database uses correlations between physiographic and climatic variables (such as drainage area, relief, slope, precipitation, and temperature) and gauged stream flows as the basis for regression equations that predict 50%-exceedance flows (Q50) on a monthly basis for pre-defined "Water Availability Basins" (Cooper, 2002). Q50 stream flow estimates were obtained for six streams in the vicinity of the project area: Dry Creek, Eagle Creek, Gorton Creek, Herman Creek, Moody Creek, and Ruckel Creek. For each of these six streams, the Q50 was divided by drainage area to determine the 50%-exceedance monthly flow per square mile (Q*50). For the sample population of the six streams, the median value of the Q*50 flows was then determined. To estimate the median monthly flows in Young Creek and Latourell Creek for each month, the median Q*50 was multiplied by the respective drainage areas of the two streams. The drainage area for each stream was delineated based on the area that contributes to stream flows entering the project area (i.e., at the culverts beneath the railroad). Latourell Creek's drainage area also was delineated at its mouth (the I-84 culvert), providing a flow estimate for the entire basin (including Young Creek, its largest tributary). Table 1 and Figure 1 below summarize the results of this analysis.

Table 1: Median monthly stream flow estimates for Latourell and Young Creeks.

	Young Cr @ RR	**Latourell Cr @ RR**	**Latourell Cr @ I-84**
	Drainage area (square miles)		
	2.0	4.2	8.9
Month	**Discharge (cubic feet per second, cfs)**		
Jan	11.3	26.3	55.8
Feb	11.9	27.7	58.7
Mar	10.1	23.1	49.1
Apr	11.3	25.2	53.3
May	13.4	25.2	53.4
Jun	7.3	13.3	28.2
Jul	2.9	5.6	11.9
Aug	1.6	3.4	7.3
Sep	1.6	3.3	7.0
Oct	2.8	6.0	12.7
Nov	8.1	18.3	38.7
Dec	11.3	26.5	56.1

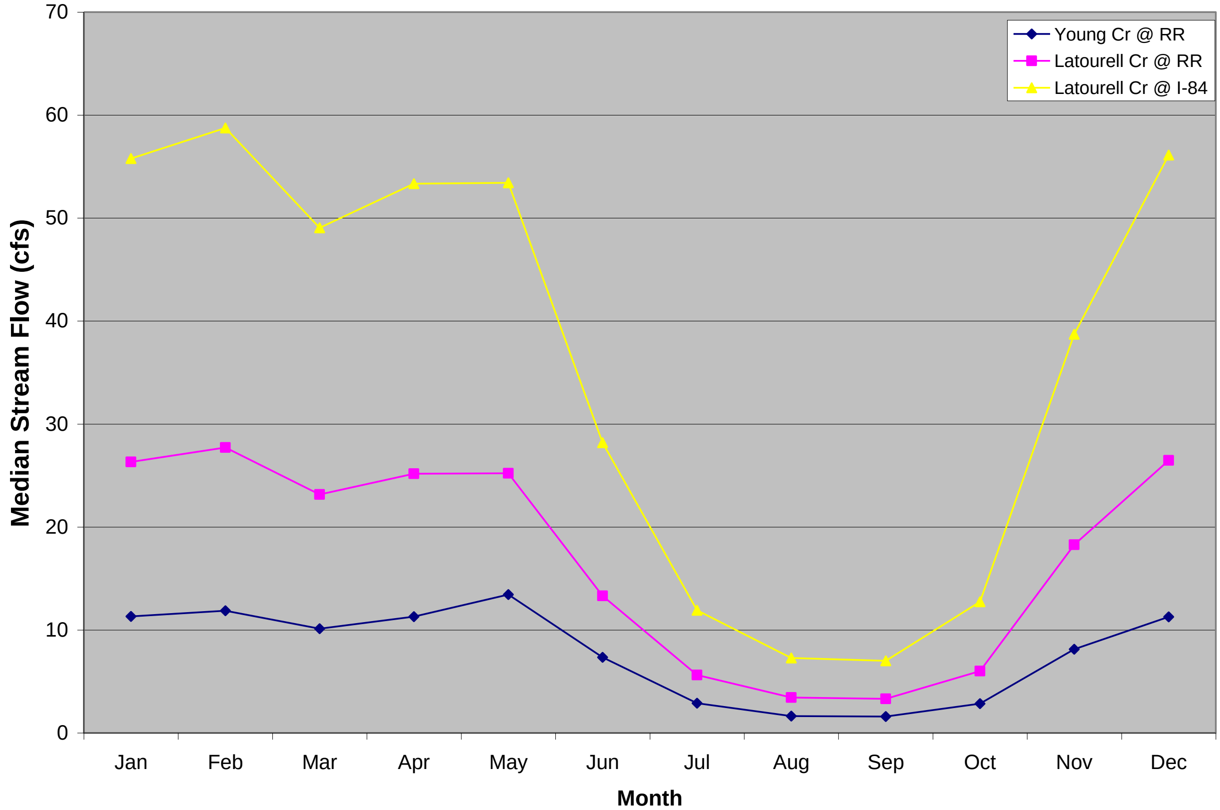

Figure 1: Median monthly flow estimates.

Reference

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Appendix 3: Salmonid and Smallmouth Bass Habitat Classification.

Monitoring Station	Temp Increase per 1,000 ft (°C)	Added Distance (ft)	Average Daily High (Measured)	Estimated Average Daily High	Salmon Habitat Classification	Smallmouth Habitat Classification
Young (Railroad)		0	14.2		Functional	Poor
to	0.2	1000		14.5	Functional	Poor
		2000		14.7	Functional	Poor
Young (Bridge)		3000	14.9		Functional	Poor
to	1.4	750		15.9	Functional	Poor
		1500		17.0	Functional	Poor
		2250		18.0	Functional	Poor
Young (Mid)		3200	19.3		Poor	Functional
to	1.3	1275		21.0	Poor	Functional
Young (Confluence)		2550	22.6		Poor	Ideal
Latourell (Railroad)		0	15.1		Functional	Poor
to	0.4	400		15.3	Functional	Poor
Latourell (u/s of lake)		750	15.4		Functional	Poor
to	4.1				Functional	Poor
Latourell (d/s of lake)		100	15.8		Functional	Poor
to	0.2	500		15.9	Functional	Poor
Latourell (Mid)		1000	16.0		Functional	Poor
to	0.7	1000		16.7	Functional	Poor
		2000		17.4	Functional	Poor
Latourell (u/s of Conf.)		2300	17.6		Functional	Poor
to	7.9				Poor	Functional
Latourell (d/s of Conf.)		200	19.2		Poor	Functional
to	0.8	1000		20.0	Poor	Functional
		2000		20.9	Poor	Functional
Mirror Lake (Inlet)		3000	21.7		Poor	Ideal

[1] Based on temperature criteria only; Ideal < 14°C; Functional = 14-18°C; Poor = 18-23°C; Unusable > 23°C

[2] Based on temperature criteria only; Poor < 19°C; Functional = 19-21°C; Ideal = 21-31°C

Total Reach (ft) = 18,250

	Ideal		Functional		Poor		Unusable		Total
Salmon Habitat	0	0.0%	9,400	51.5%	6,700	36.7%	2,150	11.8%	18,250
Smallmouth Hab.	4,425	24.2%	3,725	20.4%	10,100	55.3%	NA	NA	18,250

Note: These totals assume that all habitat downstream of the Mirror Lake (Inlet) probe is "unusable" for salmonids and "ideal" for smallmouth bass.

Appendix 4: 2008 Instream Temperatures at Mirror Lake Relative to Climate Conditions.

Precipitation Data

Data from the Bonneville Dam and Troutdale weather stations (Table 1) indicate that in the months leading up to and during the 2008 study period, monthly precipitation totals at the two stations differed considerably in their relationship to historic averages. Monthly totals at the Troutdale Airport were consistently lower than historic averages; however, the relationship between historic averages and 2008 monthly totals varied considerably at the Bonneville Dam station. Overall, total precipitation from May 1, 2008 through August 31, 2008[1] at the Troutdale Airport was 1.92 inches (30 percent) below average. Total precipitation at the Bonneville Dam station during the same period was 1.15 inches (13 percent) above average; however, this figure likely underestimates the effect elevated stream flows may have had on surface water temperatures as precipitation during the month of August (the bulk of the study period) was 1.76 inches (135 percent) above normal.

Additionally, total monthly precipitation at the two reference weather stations varied considerably during the study period. For example, the Bonneville Dam station reported 3.06 inches of rain in August, while the Troutdale Airport reported less than one inch. Based on these discrepancies, it is not possible to predict how precipitation at the site compared to historic averages and therefore how stream flow may have affected temperatures during the study period.

Table 1: 2008 and Historic Precipitation Data[1] from Bonneville Dam and Troutdale Airport Weather Stations.

	Bonneville Dam[2]			**Troutdale Airport[3]**		
Date	**Historic**	**2008**	**Delta**	**Historic**	**2008**	**Delta**
May	3.75	3.30	-0.45	2.64	1.88	-0.76
June	2.76	3.22	+0.46	1.96	1.48	-0.48
July	0.87	0.25	-0.62	0.73	0.18	-0.55
August	1.30	3.06	+1.76	1.07	0.94	-0.13
Sept.	2.83	NA[4]	NA	1.99	NA	NA
Total (May 1 – Aug 31)	**8.68**	**9.83**	**+1.15**	**6.40**	**4.48**	**-1.92**

[1] All values reported in inches.

[2] Historic data range for Bonneville Dam is from 1938–2007. Source: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or0897

[3] Historic data range for Portland is from 1949–2007. Source: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or8634

[4] NA = Not Available. Data from September 2008 were not available at the time this report was completed.

Ambient Air Temperatures

Data from the Bonneville Dam and Troutdale weather stations (Table 2) indicate that during the 2008 study period, ambient air temperatures varied little from historic averages. Overall, the average high temperature from July 1, 2008 through August 31, 2008[1] at the Troutdale Airport was 0.4°C below average. The average high temperature at the Bonneville Dam station during the same period was 0.3°C above average. Based on these minor deviations from the historic averages, it is unlikely that ambient air temperatures would have contributed to abnormally high or low surface water temperatures during the 2008 study period.

[1] September 2008 data were not available at the time this report was written and therefore are not included in this analysis.

Table 2: Historic and 2008 Average Maximum Air Temperature Data from Bonneville Dam and Troutdale Airport Weather Stations.

	Bonneville Dam[1] (°C)			Troutdale Airport[2] (°C)		
Date	**Historic**	**2008**	**Delta**	**Historic**	**2008**	**Delta**
July	26.0	26.3	0.3	27.6	26.9	-0.7
August	26.1	26.4	0.3	27.3	27.1	-0.2
September	23.3	NA[3]	NA	24.4	NA	NA
Average (July 1 – Aug 31)	26.1	26.4	0.3	27.4	27.0	-0.4

[1] Historic data range for Bonneville Dam is from 1938–2007. Source: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or0897

[2] Historic data range for Portland is from 1949–2007. Source: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or8634

[3] NA = Not Available. Data from September 2008 were not available at the time this report was completed.

In conclusion, based on available data, air temperatures in the area surrounding the Mirror Lake site appear to have been very close to average during the 2008 study period, while monthly precipitation totals varied considerably. Based on the data available, it is unlikely that ambient air temperatures would have caused abnormally high or low surface water temperatures; however, it is not possible to ascertain how precipitation leading up to and during the study period may have caused the site's 2008 thermal regime to deviate from historic patterns.

Appendix 5: Species Cover on Hogan Ranch, 2004-2008. % cover values greater than 25% are highlighted in yellow. "T" denotes trace cover.

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
1	Wetted area	Water purslane	*Ludwigia palustris*	Native	OBL			24%
		Algae						13%
		Water pepper	*Polygonum hydropiper*		OBL			12%
		Water smartweed	*Polygonum amphibium*	Native	OBL			2%
1	Marshy shore	Water purslane	*Ludwigia palustris*	Native	OBL	79%		
		Water pepper	*Polygonum hydropiper*		OBL	41%		T
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	6%	24%	48%
		Yellow pond lily	*Nuphar polysepala*	Native	OBL	2%		
		Jointed rush	*Juncus articulatus*	Native	OBL	1%		
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	T		
		White clover	*Trifolium repens*	Introduced	FAC*		31%	
		Moneywort	*Lysimachia nummularia*	Introduced	FACW		13%	13%
		Poa	*Poa sp.*				8%	
		Three-square bulrush	*Scirpus americanus*	Native	OBL		5%	
		Fescue	*Festuca sp.*				4%	
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		3%	
		Tapertip Rush	*Juncus acuminatus*	Native	OBL		1%	
		English plantain	*Plantago lanceolata*	Introduced	FAC		T	
		Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			8%
		Creeping spike rush	*Eleocharis palustris*	Native	OBL			3%
		Pointed rush	*Juncus oxymeris*	Native	FACW+			3%
1	FACW grass/forested	Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	75%	1%	58%
		Moneywort	*Lysimachia nummularia*	Introduced	FACW	70%	1%	4%
		Jointed rush	*Juncus articulatus*	Native	OBL	10%		
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	4%		
		Creeping spike rush	*Eleocharis palustris*	Native	OBL	4%		8%
		White clover	*Trifolium repens*	Introduced	FAC*	1%	59%	T
		Water pepper	*Polygonum hydropiper*		OBL	1%		T
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	T	6%	

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
1	FACW grass/forested	Broadleaf plantain	*Plantago major*	Introduced	FACU+	T		T
		Unk #1				T		
		Fescue	*Festuca sp.*				17%	
		Unk OBL plant					13%	
		Poa	*Poa sp.*				4%	
		Pointed rush	*Juncus oxymeris*	Native	FACW+		3%	
		Geranium	*Geranium sp.*				2%	
		Self heal	*Prunella vulgaris*	Native	FACU+		1%	
		Creeping buttercup	*Ranunculus repens*	Introduced	FACW		1%	
		Vetch	*Vicia sp.*				T	
		English plantain	*Plantago lanceolata*	Introduced	FAC		T	
		Small buttercup	*Ranunculus sp.*				T	
		Unk grass						T
		Unk sedge	*Carex sp.*					T
		Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			T
		Horsetail	*Equisetum sp.*					T
		Small forget-me-not	*Myosotis laxa*	Native	OBL			T
		Water smartweed	*Polygonum amphibium*	Native	OBL			T
1	FACU grasses and forbs	Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC	36%		10%
		White clover	*Trifolium repens*	Introduced	FAC*	31%	67%	
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	28%	1%	43%
		Fescue	*Festuca sp.*			16%	40%	
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	7%	3%	T
		Moneywort	*Lysimachia nummularia*	Introduced	FACW	7%		1%
		Jointed rush	*Juncus articulatus*	Native	OBL	2%		
		Unk #2				1%		
		Broadleaf plantain	*Plantago major*	Introduced	FACU+	T		
		Creeping buttercup	*Ranunculus repens*	Introduced	FACW	T		T
		Dandelion	*Taraxacum officinale*		FACU	T	T	
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	T		1%
		Pointed rush	*Juncus oxymeris*	Native	FACW+	T		T
		Thistle				T		

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
1	FACU grasses and forbs	Unk #4				T		
		Vetch	*Vicia sp.*			T		
		Water pepper	*Polygonum hydropiper*		OBL	T		
		Mix grass (Fescueand Poa)					3%	7%
		Poa	*Poa sp.*				2%	
		Common velvet grass	*Holcus lanatus*	Introduced	FAC		1%	
		English plantain	*Plantago lanceolata*	Introduced	FAC		1%	
		Unk sedge	*Carex sp.*				T	
		Geranium	*Geraniumsp.*				T	
		"small Rush	*Juncus sp.*				T	
		Self heal	*Prunella vulgaris*	Native	FACU+		T	
		Pasture grasses						13%
		Unk other grass						9%
		Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			3%
		Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			1%
		Canada thistle	*Cirsium arvense*	Introduced	FACU+			T
		Orchard grass	*Dactylis glomerata*	Introduced	FACU			T
		Dock	*Rumex occidentalis*	Native	FACW+			T
		Field bindweed	*Convolvulus arvensis*	Introduced				T
		Sheep sorrel	*Rumex acetosella*	Introduced	FACU+			T
		Water smartweed	*Polygonum amphibium*	Native	OBL			T
2	Wetted area	Water purslane	*Ludwigia palustris*	Native	OBL	87%	40%	21%
		Water pepper	*Polygonum hydropiper*		OBL	31%	10%	18%
		Unk #6				25%		
		Bur-reed	*Sparganium emersum*	Introduced	OBL	6%		
		Broad leaf wapato	*Sagittaria latifolia*	Native	OBL	4%		
		Rush				2%		
		Western water milfoil	*Myriophyllum hippuroides*	Native	OBL			8%

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
2	Wetted area	Water smartweed	*Polygonum amphibium*	Native	OBL			6%
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW			T
		Moneywort	*Lysimachia nummularia*	Introduced	FACW			T
		Small forget-me-not	*Myosotis laxa*	Native	OBL			T
2	Marshy shore	water purslane	*Ludwigia palustris*	Native	OBL	63%		24%
		Water pepper	*Polygonum hydropiper*		OBL	30%		1%
		American speedwell	*Veronica americana*	Native	OBL	17%		
		Western water milfoil	*Myriophyllum hippuroides*	Native	OBL	15%		8%
		Unk	*Guard pg 52A*			15%		
		Broad leaf wapato	*Sagittaria latifolia*	Native	OBL	7%		
		Yellow pond lily	*Nuphar polysepala*			3%		
		Pointed rush	*Juncus oxymeris*	Native	FACW+	2%		T
		Unk				2%		
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW		45%	5%
		Fescue	*Festuca sp.*				20%	
		Self heal	*Prunella vulgaris*	Native	FACU+		5%	
		White clover	*Trifolium repens*	Introduced	FAC*		3%	
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		1%	
		Geranium	*Geranium sp.*				T	
		Small forget-me-not	*Myosotis laxa*	Native	OBL		1%	
		Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			36%
		Creeping spike rush	*Eleocharis palustris*	Native	OBL			7%
		Moneywort	*Lysimachia nummularia*	Introduced	FACW			1%
		Water smartweed	*Polygonum amphibium*	Native	OBL			T
		Pennyroyal	*Mentha pulegium*	Introduced	OBL			T
		Wapato	*Sagittaria latifolia*	Native	OBL			T
		Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			T
		Curly dock	*Rumex crispus*	Introduced	FAC+			T
2	FACW grass/forested	Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	40%	T	100%
		White clover	*Trifolium repens*	Introduced	FAC*	31%	39%	

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
2	FACW grass/forested	Moneywort	*Lysimachia nummularia*	Introduced	FACW	13%	3%	1%
		Water purslane	*Ludwigia palustris*	Native	OBL	13%		
		Unk				8%		
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	3%		
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	3%		
		Tapertip rush	*Juncus acuminatus*	Native	OBL	3%		
		Unk #5				T		
		Fescue	*Festuca sp.*				45%	
		Bog Saint Johns wort?	*Hypericum anagalloides*	Native	OBL		8%	
		Sedge	*Carex sp.*				4%	
		Thistle					4%	
		Geranium	*Geranium sp.*				3%	
		Pointed rush	*Juncus oxymeris*	Native	FACW+		3%	
		Vetch	*Vicia sp.*				2%	
		Bugleweed	*Lycopus sp.*				1%	
		Northern starwort?	*Stellaria calycantha?*	Native	FACW+		1%	
		Self heal	*Prunella vulgaris*	Native	FACU+		1%	
		Water smartweed	*Polygonum amphibium*	Native	OBL		1%	
		Buttercup	*Ranunculus repens?*				T	
		Horsetail	*Equisetum sp.*				T	
		Small buttercup	*Ranunculus sp.*				T	
2	FACU grasses and forbs	White clover	*Trifolium repens*	Introduced	FAC*	45%	63%	
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	18%	18%	29%
		Moneywort	*Lysimachia nummularia*	Introduced	FACW	8%		2%
		English plantain	*Plantago lanceolata*	Introduced	FAC	6%	2%	4%
		Unk grass				5%	1%	T
		Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*	5%	T	T
		Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC	5%		4%
		unk "barley grass"				2%		
		Unk (photos)				2%		
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC	1%	3%	

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
2	FACU grasses and forbs	Self heal	*Prunella vulgaris*	Native	FACU+	1%	T	T
		Chicory	*Cichorium intybus*	Introduced		1%		
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	1%		6%
		Marsh speedwell	*Veronica scutellata*	Native	OBL	1%		
		Horsetail	*Equisetum sp.*			T	T	2%
		Bugleweed	*Lycopus sp.*			T	2%	
		Small forget-me-not	*Myosotis laxa*	Native	OBL	T		T
		Creeping buttercup	*Ranunculus repens*	Introduced	FACW	T		
		Unk				T		
		Unk #11				T		
		unk small violet flower				T		
		Water purslane	*Ludwigia palustris*	Native	OBL	T		
		Fescue	*Festuca sp.*				17%	
		Sedge	*Carex sp.*				3%	
		Unk #1					1%	
		Geranium	*Geraniumsp.*				1%	T
		Creeping spike rush	*Eleocharis palustris*	Native	OBL		T	
		Poa	*Poa sp.*				T	
		Small buttercup	*Ranunculus sp.*				T	
		Annual chickweed	*Stellaria media*	Introduced	FACU		T	
		Cudweed	*Gnaphalium macrocephalum*	Native			T	
		Northern starwort?	*Stellaria calycantha?*	Native	FACW+		T	
		White puffball fungi					T	
		Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*			12%
		Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI			10%
		Meadow foxtail	*Alopecurus sp.*					T
		Smartweed	*Polygonum sp.*					T
		Dandelion	*Taraxacum officinale*		FACU			T
		Curly dock	*Rumex crispus*	Introduced	FAC+			T

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
2	FACU grasses and forbs	Meafow foxtail	*Alopecurus sp.*					T
		Pointed rush	*Juncus oxymeris*	Native	FACW+			T
		Timothy	*Phleum pratense*	Introduced	FAC-			T
3	Wetted area	Jointed rush	*Juncus articulatus*	Native	OBL	55%		
		American speedwell	*Veronica americana*	Native	OBL	40%		
		Forget me not	*Myosotis laxa*	Native	OBL	15%		
		Yellow pond lily	*Nuphar polysepala*	Native	OBL	15%		
		Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL	5%		
		Water pepper	*Polygonum hydropiper*		OBL	5%		
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	1%		
		Wapato	*Sagittaria latifolia*	Native	OBL			50%
		Creeping spike rush	*Eleocharis palustris*	Native	OBL			30%
		Hard stem bulrush	*Scirpus acutus*	Native	OBL			1%
		Willow	*Salix sp.*					1%
		Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL			
3	Marshy shore	Water purslane	*Ludwigia palustris*	Native	OBL	34%	65%	1%
		American speedwell	*Veronica americana*	Native	OBL	30%		
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	19%	40%	3%
		Water pepper	*Polygonum hydropiper*		OBL	10%	20%	
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	9%		
		Rush				9%		
		Beak rush				6%		
		Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL	4%		
		Moneywort	*Lysimachia nummularia*	Introduced	FACW	1%		
		Needle spike rush	*Eleocharis acicularis*	Native	OBL	1%		
		Scarlet pimpernel	*Analgallis arvensis*	Introduced	FAC	1%		
		Unk grass				1%		
		Creeping spike rush	*Eleocharis palustris*	Native	OBL		20%	53%
		Tapertip rush	*Juncus acuminatus*	Native	OBL		20%	
		Broad leaf wapato	*Sagittaria latifolia*	Native	OBL			75%
		Bur-reed	*Sparganium emersum*	Introduced	OBL			1%
3	FACW grass/forested	Unk #9 or 10				4%		

Pond	Description	Common Name	Scientific Name	Native or Introduced?	Wetland Indicator	% Cover		
						2004	2005	2008
3	FACW grass/forested	Reed canary grass	*Phalaris arundinacea*	Introduced	FACW	88%	100%	98%
		Moneywort	*Lysimachia nummularia*	Introduced	FACW	45%		
		Water purslane	*Ludwigia palustris*	Native	OBL	23%		
		Mountain sneezeweed	*Helenium autumnale*	Native	FACW	15%		
		Broadleaf plantain	*Plantago major*	Introduced	FACU+	3%		
		Pennyroyal	*Mentha pulegium*	Introduced	OBL	3%		
		White clover	*Trifolium repens*	Introduced	FAC*	T		
		Creeping spike rush	*Eleocharis palustris*	Native	OBL			1%
		Water pepper	*Polygonum hydropiper*		OBL			T
3	FACU grasses and forbs	Fescue	*Festuca sp.*				33%	
		Reed canary grass	*Phalaris arundinacea*	Introduced	FACW		30%	90%
		Unk grass					24%	
		White clover	*Trifolium repens*	Introduced	FAC*		18%	
		Timothy	*Phleum pratense*	Introduced	FAC-		3%	
		Big red-stemmed moss					2%	
		Himalayan blackberry	*Rubus armeniacus*	Introduced	FACU		2%	
		Small buttercup	*Ranunculus sp.*				2%	
		Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC		1%	
		Moneywort	*Lysimachia nummularia*	Introduced	FACW		T	2%

Appendix 6: Species List for Hogan Ranch 2004-2008.

Common Name	Scientific Name	Native or Introduced	Wetland Indicator
American speedwell	*Veronica americana*	Native	OBL
Annual chickweed	*Stellaria media*	Introduced	FACU
Birdsfoot trefoil	*Lotus corniculatus*	Introduced	FAC
Bog Saint Johns wort?	*Hypericum anagalloides*	Native	OBL
Broad leaf wapato	*Sagittaria latifolia*	Native	OBL
Broadleaf plantain	*Plantago major*	Introduced	FACU+
Bugleweed	*Lycopus sp.*		
Bur-reed	*Sparganium emersum*	Introduced	OBL
Canada thistle	*Cirsium arvense*	Introduced	FACU+
Chicory	*Cichorium intybus*	Introduced	
Colonial bentgrass	*Agrostis capillaris*	Introduced	FAC
Common velvet grass	*Holcus lanatus*	Introduced	FAC
Creeping bentgrass	*Agrostis stolonifera*	Introduced	FAC*
Creeping buttercup	*Ranunculus repens*	Introduced	FACW
Creeping spike rush	*Eleocharis palustris*	Native	OBL
Cudweed	*Gnapthalium macrocephalum*		
Curly dock	*Rumex crispus*	Introduced	FAC+
Dandelion	*Taraxacum officinale*		FACU
Dock	*Rumex occidentalis*	Native	FACW+
English plantain	*Plantago lanceolata*	Introduced	FAC
Fescue	*Festuca sp.*		
Field bindweed	*Convolvulus arvensis*	Introduced	
Geranium	*Geraniumsp.*		
Hairy cats ear	*Hypochaeris radicata*	Introduced	FACU*
Hard stem bulrush	*Scirpus acutus*	Native	OBL
Himalayan blackberry	*Rubus armeniacus*	Introduced	FACU
Horsetail	*Equisetum sp.*		
Jointed rush	*Juncus articulatus*	Native	OBL
Marsh speedwell	*Veronica scutellata*	Native	OBL
Meadow foxtail	*Alopecurus sp.*		
Moneywort	*Lysimachia nummularia*	Introduced	FACW
Mountain sneezeweed	*Helenium autumnale*	Native	FACW
Narrow leaf wapato	*Sagittaria cuneata*	Native	OBL
Needle spike rush	*Eleocharis acicularis*		
Northern starwort?	*Stellaria calycantha?*	Native	FACW+
Orchard grass	*Dactylis glomerata*	Introduced	FACU
Pennyroyal	*Mentha pulegium*	Introduced	OBL

Common Name	Scientific Name	Native or Introduced	Wetland Indicator
Poa	*Poa sp.*		
Pointed rush	*Juncus oxymeris*	Native	FACW+
Reed canary grass	*Phalaris arundinacea*	Introduced	FACW
Scarlet pimpernel	*Analgallis arvensis*		
Sedge	*Carex sp.*		
Self heal	*Prunella vulgaris*	Native	FACU+
Sheep sorrel	*Rumex acetosella*	Introduced	FACU+
Small buttercup	*Ranunculus sp.*		
Small forget-me-not	*Myosotis laxa*	Native	OBL
Smartweed	*Polygonum sp.*		
Spatula leaf loosestrife	*Lythrum portula*	Introduced	NI
Tapertip Rush	*Juncus acuminatus*	Native	OBL
Three-square bulrush	*Scirpus americanus*	Native	OBL
Timothy	*Phleum pratense*	Introduced	FAC-
Vetch	*Vicia sp.*		
Wapato	*Sagittaria latifolia*	Native	OBL
Water forget-me-not	*Myosotis laxa*	Native	OBL
Water pepper	*Polygonum hydropiper*		OBL
Water purslane	*Ludwigia palustra*		
Water purslane	*Ludwigia palustris*	Native	OBL
Water smartweed	*Polgonum amphibium*		
Water smartweed	*Polygonum amphibium*	Native	OBL
Western water milfoil	*Myriophyllum hippuroides*	Native	OBL
White clover	*Trifolium repens*	Introduced	FAC*
Willow	*Salix sp.*		
Yellow pond lily	*Nuphar polysepala*	Native	OBL