

A Macro-Invertebrate Assessment of Stream Restoration at Lake Creek Lodge

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Abstract. Stream restoration projects are increasingly common, but budgets often are exhausted after projects are completed, leaving few resources to assess their efficacy. A relatively easy method to assess stream quality in the wake of restoration is to measure the abundance of invertebrate taxa that are sensitive to disturbance and poor water quality (Ephemeroptera, Plecoptera, and Trichoptera, or **EPT**) relative to other invertebrates in the community. Here, we employ EPT indices to measure the effects of a restoration project that removed a pond and artificial channel and replaced them with a naturalistic meander bend in a small section of Lake Creek, on the grounds of Lake Creek Lodge, just upstream of the creek's confluence with the Metolius River in Central Oregon. EPT levels in the stream section where restoration occurred were low both before and immediately after restoration, but rose significantly eight months after restoration. In a section downstream of the restoration project, which may have received large amounts of sediment during restoration, EPT levels were initially high but dropped immediately after restoration, then rebounded to their pre-restoration levels eight months later. EPT levels in a control section, upstream from the restoration project, varied over time, indicating that effects other than restoration-related disturbance may influence EPT indices at our study sites. However, the pattern of changes in the control section did not mirror the patterns of changes seen in the within-restoration or downstream sections. Moreover, like EPT ratios, invertebrate abundance dropped immediately after restoration, but rebounded eight months later, and the effect was stronger in the sections influenced by restoration than in the control section. Our results suggest that the restoration project may have had short-term negative effects on invertebrate abundance and on water quality (as measured by EPT indices), but that these effects were abated over the subsequent eight months, leading to no net negative effects, and possible positive gains, in reaches of Lake Creek where restoration occurred. Finally, invertebrates sampled from the artificial pond and from the meander bend that replaced it showed almost no overlap in species composition, indicating that the new meander bend successfully restored riffle-like conditions to the Lake Creek Lodge property.

Introduction

Euro-American settlement in the western US has contributed to substantial riverine habitat modification. Before being dammed, the Columbia River and its tributaries historically hosted all five species of Pacific salmon: coho, chinook, sockeye, pink, and chum in addition to steelhead trout (*Oncorhynchus mykiss iridis*). Anadromous fish migration into the Columbia River Basin may have been as high as sixteen million individuals per year during the era prior to Euro-American settlement (Ambrose 1996). In 2006, approximately 1.6 million anadromous fish passed through Bonneville Dam, the first in a series of thirteen dams on the mainstem Columbia and Snake Rivers (ACE 2007). Only six Pink and 121 Chum salmon migrated above Bonneville Dam in 2006 (ACE 2007).

The Deschutes River and its tributaries are important spawning and rearing habitat for Columbia River anadromous fish. The Pelton/Round Butte Hydroelectric Dam Complex on the Deschutes River eliminated anadromous fish passage to the Upper Deschutes Basin and its tributaries, including Lake Creek, by the early 1960's. Although these species are extirpated from the Upper Deschutes Basin, the Pelton/Round Butte fifty-year license came due for renewal in 2003, and relicensing created a variety of programs that benefit fish, wildlife, and recreation (PGE 2006). After 19 months of dialogue, an unprecedented 22 organizations signed the relicensing accord on July 13, 2004 (PGE 2006). As part of the agreement, significant funding was made available for restoration projects within the Upper Deschutes Basin in preparation for reintroduction of anadromous fish in 2008.

Lake Creek Lodge is a private property on lower Lake Creek near Camp Sherman, OR surrounded by Deschutes National Forest. Before the Pelton/Round Butte dams blocked fish passage, both Chinook and Sockeye salmon migrated from the Columbia up the Deschutes into the Metolius River. Many of these Chinook spawned in Lake Creek and in the Metolius River near Lake Creek. Sockeye continued their migration up Lake Creek to Suttle Lake, where they spawned in the lake and in Link Creek, a small tributary. Lake Creek spans six miles between Suttle Lake and the Metolius River; therefore, each reach

along this short tributary is important in sustaining local fisheries (UDWC 2006).

Lake Creek is currently violating the Federal Clean Water Act (1977) and is consequently listed as a 303(d) impaired waterway mainly due to unnaturally high water temperatures and reduced dissolved oxygen levels (UDWC 2006). A restored Lake Creek can provide important spawning/rearing habitat and act as a transportation corridor for reintroduced anadromous fish in addition to providing high quality conditions for resident salmonids like endemic redband rainbow trout (*Oncorhynchus mykiss gairdneri*) and ESA-listed bull trout (*Salvelinus confluentus*).

In the 1930s, part of the creek's main channel flowing through the Lodge property was straightened, and a large diversion pond flanked with concrete and rock retaining walls (Photo 1) was built over the old stream bed. In 2004, the Upper Deschutes Watershed Council, headquartered in Bend, OR, partnered with Lake Creek Lodge and the US Forest Service to begin plans to remove the artificial pond and restore 725 feet of stream, including reaches upstream and downstream of the pond (LCL 2007). The restoration project began in October 2006 (Photo 2).



Photo 1 (left) shows the former pond at Lake Creek Lodge. Rails in front are part of a bridge crossing both the pond outflow (center) and the creek diversion (out of picture, bottom right).



Photo 2 (right) shows the new stream meander, on the site of the old pond. This photo is shot from the opposite side as Photo 1, with a new bridge (background) replacing the bridge in the foreground of Photo 1.

This study examines benthic macro-invertebrate communities to assess the efficacy and impacts of the Lake Creek Lodge restoration project. Macro-invertebrates are aquatic insects (often pre-adult stages) that are visible without a microscope. Aquatic macro-invertebrates are numerous, have short life cycles, and are directly affected by changes in water chemistry and flow. Aquatic invertebrate communities are usually more diverse than vertebrates such as fish. These factors, coupled with their

relative ease of sampling, make macro-invertebrates excellent indicators of aquatic ecosystem health. A change in aquatic insect species composition is relatively easy to detect and can be used to assess stream decline or recovery (NPS 2003).

Methods

Pond vs. Riffles. Invertebrates were sampled from riffles (see below) and the pond (Photo 1) for comparison of community composition. To sample the pond, nets were swept across the bottom on September 7, 2006. The pond subsequently was removed during the restoration project (Photo 2).

Riffle Sampling Protocol. While sampling riffle invertebrates (see cover photo), we implemented standardized procedures used by the Oregon Department of Environmental Quality (DEQ). Standardization facilitates comparison of macro-invertebrates collected by different researchers at different sites (Adams 2004). The version of the protocol that we used (see Appendix 1) was from a cd produced by the Xerces Society, "Stream bugs as biomonitors: Guide to Pacific Northwest macro-invertebrate monitoring and identification" (Adams 2004).

We sampled on September 7, 2006, shortly before the restoration project began, one month after the restoration project was complete in November 2006, and approximately eight months later on June 28, 2007. On each sampling date, we sampled in three different sections of Lake Creek: **upstream** of the restoration project (a control unaffected by downstream disturbance), **within** the restoration project, and **downstream** from the project. Samples in **upstream** and **downstream** sections were collected in identical riffles on each date, in reaches spanning 25 – 200 m above or below where restoration occurred. Ideally, the DEQ sampling protocol calls for taking one sample at each of eight riffles in a section. However, due to a dearth of riffles in **upstream** and **downstream** sections, we instituted the DEQ's backup protocol, and sampled twice per riffle in four riffles (equivalent to twice within each 3 x 3 riffle grid described in Appendix 1). **Within** samples (from inside the reach where restoration occurred)

were collected at some identical but also some different riffles before and after restoration because of modifications to the stream made during restoration. Prior to restoration, we sampled along the straightened reach adjacent to the pond and upstream and downstream of the pond. Significant subsequent riparian modifications were made in all of these reaches. After restoration, we sampled in the same riffles above and below where the pond had been, but since the straight reach adjacent to the pond was gone, we sampled in the newly created meander bend (Photo 2). Riffles were more frequent in the **within** reach than in the **upstream** or **downstream** reaches, so eight riffles in the **within** area were sampled once on each date (equivalent to once within each 3 x 3 grid described in Appendix 1) for a total of eight samples per sampling date. More details of our sampling procedure are in Appendix 1.

Identification. We divided identified and sorted macro-invertebrates into four orders: Ephemeroptera (mayflies), Tricoptera (caddis flies), Plecoptera (stoneflies), and “other” (mainly beetles, worms, and fly larvae). We focused on Ephemeroptera (E), Tricoptera (T), and Plecoptera (P) because of their sensitivity to stream conditions and viability as stream health indicators. The Others (O) inventory helped to determine the ratio of sensitive macro-invertebrates (E, T, P) with more tolerant species (O). Each order was separated and stored in capped test tubes filled with 95% alcohol solution, which remain in our lab. We stopped our inventory at 500 individual macro-invertebrates, as this is a widely accepted sample size (EPA 2007). In order to generate a rough estimate of the total number of invertebrates in the sample, the amount of sample used to identify 500 individuals was quantified relative to the size of the remaining sample. This was easy to do because the sample consisted of a lot of vegetation, so the area of vegetation removed from the tray to count invertebrates could be compared to the area of vegetation left over to estimate what proportion of the sample was examined to reach 500 individuals.)

For each sample, we measured the EPT index using the following equation:

$$\text{EPT index} = \#EPT / (\#O + \#EPT)$$

EPT indices were compared between collecting dates within a section using 2 x 2 contingency tables and

a chi-square test (Preacher 2001). No adjustments were made for multiple comparisons (Rothman 1990).

Results

Pond vs. Riffles. Species sampled from the pond were very different than those sampled from riffles. Of the first 135 individuals identified from the pond, only five (4%) were characteristic of the riffle community (3 midge larvae, 1 unidentified diptera pupae, and 1 riffle beetle adult). The rest of the species in the pond (19 amphipod or amphipod-like, 3 Hemiptera or hemiptera-like, 73 snails, 33 damselfly larvae, and 3 water boatmen beetles) never, or, in the case of damselflies and the hemiptera-like species, very seldom, appeared in riffle samples.

Invertebrate Abundance. Immediately after restoration, invertebrate abundance was low, especially in the **within** and **downstream** sections (Table 1, Fig. 1).

Condition	Year	Month	Stream Section	Total Inverts Caught	EPT	O	EPT/ALL
Pre-restoration	2006	Sept.	Upstream	900	90	425	0.17
			Within	2500	166	334	0.33
			Downstream	1300	199	294	0.40
1 mo. post-rest.		Nov.	Upstream	750	126	374	0.25
			Within	232	71	161	0.31
			Downstream	320	107	213	0.33
8 mo. post-rest.	2007	June	Upstream	2000	127	373	0.25
			Within	?	224	282	0.44
			Downstream	2000	222	278	0.44

Table 1. Ratios of sampled macroinvertebrates. “Upstream,” “Within,” and “Downstream” are sections of the stream relative to where restoration occurred. Totals below 500 in the “Total Inverts Caught” column are exact counts; totals above 500 are estimates made using a technique described in the Methods; ? = neither exact counts nor estimates were made of the total individuals in the sample because students mistakenly discarded the sample after extracting 500 individuals. EPT = total number of Ephemeroptera, Plecoptera, and Trichoptera in the first 500 individuals identified from a sample. O = total number of remaining taxa. EPT + O totals slightly exceeded 500 when student groups working separately identified more than 500 individuals due to a lack of coordinated tallying.

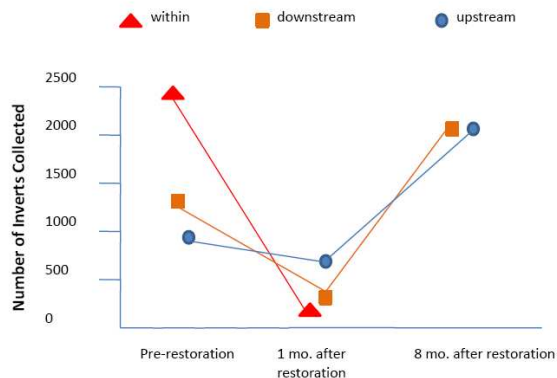


Figure 1. Invertebrate abundance in the three stream sections (symbols) on different collecting dates (x axis).

EPT Ratios. On every sampling date, EPT ratios occurred in the order **upstream** < **within** ≤ **downstream** (Table 1). EPT ratios in the **upstream** samples rose immediately after restoration (chi sq = 9.0, df = 1, p = 0.003) and then remained unchanged eight months later (chi sq = 0.005, df = 1, p = 0.95; Fig. 2). Changes in EPT ratios in the **within** and **downstream** sections did not mirror those seen in the **upstream** (control) section (Fig. 2). EPT ratios in the **within** section did not change immediately after restoration (chi sq = 0.48, df = 1, p = 0.48), but rose significantly eight months later (chi sq = 12.38, df = 1, p < 0.001; Fig. 2). EPT ratios in the **below** section dipped immediately after restoration (chi sq = 4.0, df = 1, p = 0.046), then rose significantly eight months later (chi sq = 9.8, df = 1, p = 0.002) to a level that was not significantly different from the pre-restoration ratio (chi sq = 1.7, df = 1, p = 0.2; Fig. 2).

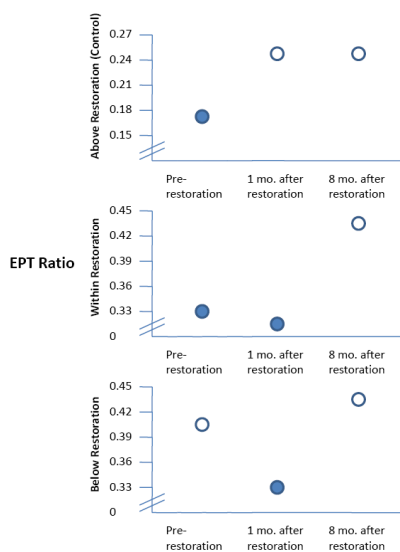


Figure 2. EPT ratios (y axis values) in the three stream sections sampled (y axis labels) on three sampling dates (x axis labels). Within each panel, symbols with different fill differed at the 0.01 level (except for the pre-restoration vs. 1-month-after restoration comparison in the bottom panel, which differed at the 0.05 level.) See Methods for calculation of EPT ratios.

Discussion

Pond vs. Riffles. The invertebrate community in the old pond was completely different than the community found in riffles, including the meander bend that replaced the pond. This is not surprising, since standing water and running water host different species of stream invertebrates. Nonetheless, it shows that removal of the pond significantly altered the habitat characteristics of the site, and brought it into line with surrounding stream habitat, at least as far as invertebrate indicators are concerned.

Invertebrate Abundance. The total number of invertebrates collected always exceeded 500 per sample, except in the **within** and **downstream** reaches sampled immediately after restoration (Fig. 1). This may mean that the restoration project reduced invertebrate densities. However, collections made immediately after restoration were made in the late fall, when stream invertebrate populations are likely to be stressed for seasonal reasons (Adams 2004). Consistent with a seasonal effect, the total number of invertebrates caught in the **upstream** (control) section was lowest in the late-fall sample too (Fig. 1). However, seasonal differences do not appear to explain all of the variation in abundance seen between sampling dates, since invertebrate abundance in the **upstream** (control) reach did not dip as much as it did in the **within** and **downstream** reaches adjacent to restoration. We tentatively conclude that the restoration project interacted with seasonal effects to reduce invertebrate abundance in the **within** and **downstream** sections. Notably, eight months after the project, invertebrate abundance (where measured) was high again (Fig. 1). It would appear, therefore, that any effects of the project on invertebrate abundance were temporary. (Regrettably, students discarded the **within** sample from eight months after the project after separating 500 individuals, and they did not record the number of grids used to sample 500 individuals, so estimates of total inverts in the **within** collection could not be made for 2007.)

EPT Ratios. On each sampling date, the EPT ratios of the three sections generally were lowest in

the **upstream** section, higher in the **within** section, and highest in the **downstream** section (Table 1). This is not surprising, since **upstream** (control) riffles were slower and less rocky than riffles in the other two sampling areas, making the **upstream** section generally poorer habitat for Ephemeroptera, Plecoptera, and Trichoptera. The **within** section may have had lower EPT ratios than the **downstream** section on the first two sampling dates because we sampled from the artificial pond bypass (pre-restoration) and just downstream of where warm pondwater reentered the creek, and because disturbance was greatest in this section during restoration. Notably, however, the **within** and **downstream** EPT values were at their highest levels, and equal to one another, eight months after the restoration project, suggesting that any negative impacts of the pond and of restoration-related disturbance abated over time.

EPT ratios in the **upstream** samples differed among sampling dates (Fig. 2), which indicates that factors other than restoration, like changes in flow or temperature, affected EPT ratios over our study period. (Adams 2004) Since EPT ratios fluctuated in our control section, fluctuating EPT ratios in the two sections cannot necessarily be attributed to the restoration project itself. Notably, however, fluctuations in EPT ratios in the **within** and **downstream** sections did not follow the same pattern as the control section (Fig. 2). Furthermore, changes in EPT ratios in those sections were consistent with possible effects of restoration. For example, prior to restoration, the **within** section was low-quality habitat due to the artificial channel and to warm water reentering the stream from the pond. It probably remained low-quality immediately after restoration due to the disturbance caused by the project. Eight months after restoration, however, EPT ratios in the **within** section had increased significantly over the first two measures (Fig. 2). **Downstream**, habitat quality was likely to have been high during our first measurement, since this stretch of stream was relatively undisturbed. Immediately after the restoration project, however, EPT indices declined in concert possible downstream sediment loads released by the project. Note that this decline occurred at the same time that EPT ratios in the

upstream (control) section actually *increased*. Finally, like the **within** section, EPT ratios in the **downstream** section rose significantly eight months after restoration occurred, indicating that the project may have a long-term positive influence on stream quality.

Xerces recommends monitoring macro-invertebrates in late summer (July 15-September 30), when aquatic insects are most restricted in their habitat and most stressed by any unfavorable stream conditions (Adams 2004). Oregon DEQ scientists examining data from spring, early summer, and late summer samples found that at the same sites, only the late summer collections clearly differentiated between impacted and unimpacted sites (Adams 2004). Our sampling dates were constrained by the calendars of the field courses during which sampling occurred. Ideally, our 2007 collection would have been made in September, under similar seasonal conditions as the 2006 pre-restoration collection. Despite this limitation, our findings for both invertebrate abundance and EPT indices suggest that the restoration project had a short-term negative impact on stream quality, but a long-term (8 month) positive impact. This is consistent with results from other studies that have examined the impacts of restoration projects on stream invertebrates (Muotka et al. 2007). It would be informative to do another collection in September 2008 to further test our conclusions.

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Appendix 1 – Invertebrate sampling procedure

Step-by-step macroinvertebrate collection - Oregon DEQ Protocols, 2003

If you're collecting any chemical or turbidity data, do so before you collect macroinvertebrates.

(First, fill out site information on field form, including water temperature and time.)

Macroinvertebrate Sample

NOTE: Keep all activity downstream of where macros will be collected; and be careful to not lose organisms at any step along the way!

- Take 4 wetted width measurements near the sample site location that are representative of the stream's width; add the 4 together, then multiply by 10; that will give you a stream reach length approximately 40x the average wetted width. Minimum reach length = 150 m (500'); maximum = 300 m (~1000').
- Walk along the banks for a bit to see how many riffles are available and how far apart they are. Also, look for evidence of spawning salmon or redds (postpone sample if present).
- At the first riffle, think of a 3x3 grid (numbered 1 to 9 left to right downstream to upstream) over the riffle (eliminate the margins or outer 10% of the riffle)
 - If the stream is small with numerous riffles; sample the middle of section 1 in riffle one (lower left when looking upstream), section 2 in riffle 2, section 3 in riffle 3, etc.
 - If the stream is larger and the riffles are farther apart, collect twice in each of 4 riffles (i.e. sample sections 1 and 5 in the first riffle, 2 and 6 in the second, 3 and 7 in the third, and 4 and 8 in the fourth).

Collect the sample.

- ◆ place the D-frame kicknet or Surber sampler in the middle of section 1 of the first riffle such that the current is flowing directly into the net
- ◆ squat behind or to the side of the net (not upstream)
- ◆ make sure the bottom of the net is flush against the stream bottom; shift any rocks or cobbles that are keeping it from settling
- ◆ measure 1 foot upstream of the net (hint: the net is 1 foot wide)
- ◆ pick up all large rocks and debris within that area and scrub thoroughly in the net
- ◆ once only gravels remain, use a trowel and boot heel to thoroughly disturb the substrate to 4" depth
- ◆ tilt the net back and lift it off the riffle bottom; use the current to wash the material to the net bottom
- ◆ **immediately remove any fish or amphibians that were accidentally captured in the net, and record them on your datasheet**
- ◆ putting the material into the bucket; invert the net into the bucket and use forceps or a squirt bottle to transfer any remaining material into the tub; you might also repeat using the current to wash material to the bottom of the net, then inverting it into the bucket
- ◆ repeat the above steps at the other 7 locations
- ◆ remove any large debris from the bucket (make sure the debris has no attached invertebrates - you can also transfer the material from the bucket to the tub, so you can better see and enjoy the invertebrates)
- ◆ over one of the tubs, slowly pour water out of the bucket or tub, through a sieve, so only sample remains
- ◆ macros and debris will be captured on the sieve, so transfer that material into the sample jar
- ◆ place the material in the bucket or tub into the same sample jar - if sample is too big for a single container, split it into multiple containers with the same label information and 1 of 2, 2 of 2, etc.
- ◆ filter water out of the sample jar once again, then fill the jar with 95-100% alcohol.
- ◆ use a pencil to fill out labels - put one inside jar and tape the other to the outside with packing tape

A 500-um D-frame kicknet was used to collect samples. To take one sample, the kicknet was stabilized just downstream from the target grid. Large cobble rocks within one foot upstream of the kicknet were hand scoured to collect insects fastened to cobble substrate. After scouring, we disturbed remaining substrate with our boots to a four inch depth. The contents of the kicknets were then emptied into plastic tubs (approximately 30" x 20") and covered in several inches of water. Kicknets were thoroughly rinsed and inspected to ensure complete collection of the sample, and then this procedure was

repeated at another location within a stream section. Once all eight samples were collected from a section and placed together in the tub, we used a magnifying glass to remove large macro-invertebrate-free vegetation and debris. What remained was filtered through a 500-um sieve. We stored the samples in 95% ethanol in 32 ounce labeled Nalgene bottles (e.g. "June 2007, Upstream"). This produced three such Nalgene bottles per collecting date.

When we returned to the lab, the Nalgene bottles were dumped into a large plastic tray, and water was added. Contents were swished to suspend invertebrates, and then the water was poured through the soil sieve, leaving rocks and other heavy debris behind. The decanting was repeated a total of ten times, and then the debris left behind was discarded and invertebrates were stored in alcohol. Prior assessment of this technique in our lab failed to find a single invertebrate left behind in the discarded material after decanting, so we are confident that it works to separate the invertebrates from much of the heavy debris.

Sub-Sampling. Due to the vast amount of sampled material, which included large quantities of fine vegetation and pebbles, we sub-sampled our collection. A wooden-framed sampling tray (15" x 12.5") covered with a wire screen and fine mesh for filtering was used. Within the sub-sampling tray, a grid was outlined in 2.5" squares and numbered accordingly. The sample from a single section on one collecting date was then poured into the sub-sampling tray and evenly dispersed over the tray screen through water action. A random number was generated to correspond to individual squares in the sub-sampling tray's grid. Material from a randomly selected square was removed from the sub-sampling tray and placed in Petri dishes for sorting and identification using tweezers, dissecting microscopes, and the Xerces Society's guide to macro-invertebrate species identification book. Unused samples were labeled, preserved, and stored for future study.