Recolonization of the Cedar River by Pacific salmon: 2006-2007 Annual report

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1.0 Introduction

As part of the city of Seattle's Habitat Conservation Plan (HCP) for the Cedar River Watershed, a fish ladder was opened at the Landsburg Diversion Dam located on the Cedar River main stem in September 2003. This diversion blocked anadromous fish migration to approximately 33 km of main stem and tributary habitat for over 100 years potentially contributing to population declines of a number of fish species as well as resulting in losses of important food resources for a variety of species.

We initiated a long-term study to evaluate recolonization success of anadromous fish above Landsburg Diversion in 2000, to describe the ecological effects of these colonizing salmon on resident species and ecosystems, and determine potential restoration actions to promote colonization success. This project presents a unique opportunity to understand the colonization process of Pacific salmon under natural conditions when a barrier is removed or altered to allow fish passage.

The objectives and tasks of the 2007 Scope of Work were:

Objective 1: Does fish abundance, diversity, growth, movement, and survival vary by habitat, reach or stream?

> Task 1: Quantify variation in nutrient chemistry, algal biomass, and fish density and diversity among habitats, tributaries and main stem reaches.
>
> Task 2: Quantify growth, movement and survival of trout and salmon in upper Rock Creek and main stem reaches.

Objective 2: What are the interactions between sculpin, different life stages of trout and juvenile salmon?

Task 1: Quantify diet of sculpin and large trout captured from the main stem and tributaries seasonally.

Task 2: Quantify stable isotope concentrations in trout and salmon collected from main stem (above and below Landsburg) and tributaries to determine relative importance of marine-derived N in their diet.

Results from this study will inform natural resource managers on the effectiveness of the Landsburg passage facility in restoring populations of anadromous fish in the Cedar River above Landsburg, and provide insights into the ecological effects of salmon on the Cedar River ecosystem, as well as potential restoration or conservation measures that will benefit resident and anadromous fish.

2.0 Accomplishments

Papers:

Kiffney, P.M., G. R. Pess, J. H. Anderson, P. Faulds, K. Burton, and S. C. Riley. (In press) Changes in fish communities following recolonization of the Cedar River, WA, USA by Pacific salmon after 103 years of local extripation. River Research and Applications.

Anderson, J., P. Kiffney, G. Pess, and T. Quinn (2008) Distribution and growth of juvenile coho salmon (*Oncorhynchus kisutch*) during colonization of newly accessible habitat. Transactions of the American Fisheries Society. 137: 722-781.

Theses:

Cram, J. (successfully defended June, 5 2008; currently revising thesis for publication). How do experimental stream food webs respond to carcass loading rates? MS thesis, College of Forest Resources, University of Washington.

Arhmein, S. (in preparation). Spatial distribution of macroinvertebrate drift in the Cedar River, Washington, between the Landsburg diversion dam and Cedar Falls. MS Capstone thesis, College of Forest Resources, University of Washington.

Certo, M. (in revision, defense set for October 2008). Nutrient dynamics in the Cedar River, Washington, USA. MS thesis, Department of Biology, Western Washington University

<u>Presentations:</u>

Pess, G. 2008. Tagging techniques to help monitor watershed restoration" Western Division AFS meeting, Portland, OR.

Kiffney, P. M., C. Greene, and T. Good. 2007. Spatial gradients created by tributary streams. American Geophysical Union Annual Meeting, San. Francisco, CA.

J. M. Cram, P. M. Kiffney, R.Edmonds, and R. Klett. 2007. Recolonization in action: Effects of salmon carcass density on experimental stream ecology. Ecological Society of America Annual Meeting, San Jose, CA.

P. Kiffney and G. Pess. 2007. Recolonization of the Cedar River by Pacific salmon: effects on fish populations. Ecological Society of America Annual Meeting, San Jose, CA.

Kiffney, P. M. 2007. Recolonization of the Cedar River, WA by anadromous fish. Cedar River Habitat Conservation Committee, Seattle, WA.

Kiffney, P. M. 2007. Recolonization of the Cedar River, WA by anadromous fish: patterns and process. University of Washington's Center for Water Annual Review, Seattle, WA.

Kiffney, P. M. 2007. Recolonization of the Cedar River, WA by anadromous fish. Pacific Salmon Recovery Conference, Seattle, WA.

Proposals:

2008-2010. "Are large trout constraining population growth of juvenile salmon?" Cedar River Anadromous Fish Commission. Funded.

2008-2009. "Population biology of trout and salmon in the Cedar River, WA." Seattle Public Utilities. Funded.

Kiffney, P., G. Pess, D. Chapin, J. Olden, and T. Quinn. Long-term effects of species reintroduction at multiple levels of biological organization. Proposal in development for submission to National Science Foundation Long-term Research in Environmental Biology Program.

Status of samples processing or field tasks:

- 450 isotopes samples (vegetation, biofilm, stream invertebrates, fish) processes; collected during fall 2007; negotiating contract with analytical laboratory
- ~50 water samples collected during winter, spring and summer 2007; samples submitted to laboratory for analysis
- Collected 450 diet samples from trout or coho on the mainstem and tributaries during summer/fall 2007
    - 150 diet samples processed

    - ~50 samples sorted and ready for analysis

- Completed summer mainstem habitat and snorkel survey
- Completed 1 spring 2007 mainstem habitat and snorkel survey
- Completed 3 winter/spring 2008 mainstem habitat and snorkel surveys
- Completed 5 habitat and snorkel surveys of tributary stream pools (Taylor, Williams, upper and lower Rock creeks)
- Captured over 3,000 fish in 6 tagging events. Of those, over 1,700 fish were tagged in the main stem and upper Rock Creek.

3.0 Methods

To quantify variation in nutrient chemistry, algal biomass, and fish density and diversity among habitats, tributaries and main stem reaches we used methods described in previous reports (Kiffney et al. 2002, Kiffney et al. 2006). In addition to these efforts, two new study components were implemented in 2006-2007 to increase our understanding of spatial variation in trophic level productivity. First, we conducted benthic habitat surveys in the mainstem during summer 2007 to complement ongoing snorkel surveys for water-column species. This survey will provide an indicator of the spatial variation in the abundance of important consumers and intermediate predators of the Cedar River food web. Second, we began to measure invertebrate drift at select mainstem and Rock Creek reaches to quantify spatial variation in secondary productivity and to augment our fish diet studies. We will use these data in two ways: 1) How do lower trophic level organisms change along the mainstem as a function of environmental gradients including water temperature, nutrients and algal biomass? and 2) Are the density and biomass of lower trophic level organisms associated with spatial patterns in the density, growth, movement and diet biomass of resident and anadromous fish?

To quantify density of benthic animals (organisms associated with stream inorganic material such as large caddis fly larvae, sculpins, crayfish), a 0.7 m^2 quadrat made of PVC pipe was placed on the stream bottom; all caddis flies (Trichoptera), large stoneflies, crayfish and sculpin (*Cottus* spp.) were counted within the frame. Counts were conducted at three randomly selected locations across three different riffles within each reach of the mainstem (Figure 1). Drift nets were deployed at reaches where trout and coho were collected for marking. Three nets were deployed in riffles sections for ~24 hours within each reach where fish were marked. Contents in nets were preserved in 95% ethanol; invertebrates were identified to family. Head capsule widths of invertebrates were measured and converted to biomass using published reqression equations. We also collected water samples for nutrient chemistry and rocks to quantify algal biomass from each mainsten and select tributary reaches.

To examine potential interactions between resident trout and sculpin and Pacific salmon we collected diet samples from fish during summer and fall 2007. Fin clips were also collected and measured for carbon (C) and nitrogen (N) isotopic values. This fall collection period overlaps with previous isotope and diet collections before the ladder was installed and peak spawning for Chinook salmon. Diet and isotope samples were collected from across mainstem reaches that varied in spawner density and two tributary streams (Rock and Taylor creeks). We also collected samples for isotopic analysis from primary producers (algae, riparian plants), primary consumers (aquatic insect larva), primary predators (stonefly larva), and intermediate predators (juvenile trout and sculpin).

Diet samples from trout, sculpin and coho were collected in the mainstem and Rock Creek during July, August and October 2007. Trout we caught by angling or electrofishing, coho were caught by electrofishing and seining, and sculpin were collected by electrofishing. Fish were anesthetized with MS-222; weighed and measured; diet samples were collected using gastric lavage; and trout > 60 mm and coho >55 mm were inserted with a PIT tag. After processing, fish were placed in a live basket to recover for ~30-60 minutes and then released from point of capture.

Diet samples were preserved with 90% ethanol in the field. These samples were processed and identified under a dissecting microscope. Aquatic and terrestrial invertebrates were identified to order; head capsule width of each individual was also measured. We used head capsule width to estimate biomass using published regression equations.

4.0 **Results and Discussion**

4.1 Objective 1: Does fish abundance, diversity, growth, movement, and survival vary by habitat, reach or stream?

<u>Fish passage</u>

Adult returns have increased by 103 fish/year since the ladder was installed, with Chinook showing relatively large increases in 2006 and 2007 and coho returns stable since 2005 (Figure 2). Spawner abundance was primarily a function of distance from the dam: ~140 Chinook and coho redds were identified (2003-2007) in reach 1, 25 redds in reach 6 and 1 redd in reach 10, which is about 10 km from the dam (Figure 3). There was a slight peak in redd abundance in reach 6, especially for Chinook salmon, providing evidence that adults were actively selecting habitat in this reach. If abundances continue to increase, we would predict the relationship between redd abundance and distance from the dam to lessen as adults spawn in other reaches due to competition for nest sites.

Trophic level abundance and biomass

Trophic level productivity (water chemistry, algal biomass, and insect abundance) exhibited spatial gradients within the study area. Total nitrogen ranged from ~150-800 μg/L and phosphorus ranged from 15-35 μg/L, and exhibited patterns similar to other years: total nitrogen and phosphorus were highest in tributaries and increased from upstream to downstream in the mainstem (Figure 4). Algal biomass, as determined by periphyton ash-free dry mass, was about 1.5-2-fold higher in some reaches in 2007 than 2006 (Figure 5). In general, periphyton biomass was highest in reaches 1 and 6 and low in reach 8 and 9. Algal biomass was also higher at mainstem sites than tributaries, likely due to higher light input because nutrient levels were higher in tributaries.

The distribution of two abundant herbivorous caddis fly larva showed contrasting patterns. Abundance of *Glossosoma* sp. peaked (~120-140 individuals/sample) in lower reaches of the mainstem (reach 1 and 2) (Figure 6a), whereas *Dicosmoecus* sp. peaked in upstream reaches (~20-25 individuals/sample) (Figure 6b). There are a number of possible explanations for these patterns. First, the different spatial patterns for these taxa may reflect competitive interactions. *Dicosmoecus* is much larger (~20-30 mm total length) and aggressive than *Glossosoma* (~5-10 mm), and they both consume biofilm off rocks. Second, their distributions reflect abundance of their food resource, algae. Correlation analysis showed that both consumers were negatively correlated with reach-scale patterns in algal biomass; these patterns were not statistically significant, however. Third, caddis fly abundances may be responding to other ecologically important gradients such as water temperature. Summer mean temperature was negatively correlated with *Glossosoma* abundance (r = -0.60, p = 0.09) but positively correlated with *Dicosmoecus* abundance (r = 0.60, p = 0.07). Overall, these patterns were likely a result of interactions between species, and responses to gradients of algal biomass and water temperature.

Trout and salmon density during spring 2007 was highest in reaches closest to Landsburg and declined with distance upstream (Figure 7a-d). For example, juvenile coho density was about 0.6 fish/m^2 in reach 1 and 0.1 fish/m^2 in reach 6. We observed no fish in reaches 7 or 8. Coho and Chinook redd abundances in 2006 were positively associated with juvenile salmon density in spring (juvenile coho density = 0.14 + 0.05*(coho redd abundance), R^2 = 0.5, p = 0.09, juvenile Chinook density = -0.001 + 0.002*(Chinook redd abundance), R^2 = 0.9, p = 0.0001). These relationships suggest that juveniles primarily rear in habitats near their natal nests. No such relationship would suggest movement away from natal sites thereby indicating lack of suitable rearing habitat. Similar to what we observe during summer, trout and salmon density was higher in slow-water habitats (depositional or pools) over fast-water habitats (riffles or runs) (Figure 8a-d). We defined depositional units as habitat along stream margins with slow water velocity and substrate comprised primarily of silt or sand. Trout fry density was higher in deeper, slow-water habitats (i.e., pools) compared to juvenile coho: trout fry density was positively correlated with habitat depth (r = 0.37, p = 0.005, n = 55). Juvenile coho density was about 3-fold higher in depositional habitats compared to pools, especially depositional habitat with abundant cover (juvenile coho density vs. in-channel wood: $r = 0.38$, $p = 0.004$, $n = 55$).

Summer densities of juvenile coho during 2007 were highest in reach 1 (~0.5 fish/m^2) followed by reach 6 (~0.1 fish/m^2), whereas juvenile Chinook densities were highest in reach 6 (~0.005 fish/m^2) followed by reach 1 (~0.002fish/m^2) (Figure 9a-b). The spatial pattern of juvenile coho density in summer was similar to distribution of redds in 2006 (coho density = 0.009 + 0.035*(coho redd abundance), $R^2 = 0.92$, $p = 0.002$), whereas the distribution of juvenile Chinook was not associated with 2006 redd distribution. The latter pattern is not surprising given that Puget Sound Chinook largely exhibit the "ocean-type" life history strategy. Although juvenile Chinook populations declined 20-fold in reach 1 from April 2007 to August 2007 corresponding to emigration patterns, we continue to observe a number of juvenile Chinook rearing in the mainstem during late summer.

The distribution of trout during summer was much different than spring 2007, as trout density was generally low in reaches 1-8 and peaked in reaches 9-10 (Figure 10a). The relative contribution of juvenile trout to total trout density also increased from upstream to downstream. These patterns were similar to what we observed during 2000 and 2001 (e.g., Kiffney et al. 2002). Juvenile coho comprised most of total salmonid density in reaches 1, 2 and 6 while trout were the only salmonid species observed in reaches 7, 9 and 10 (Figure 10b).

Trout populations during summer have remained relatively stable since the ladder was installed, except for trout >200 mm in total length, which have increased (Figure 11a-c). Juvenile trout populations ranged from ~0.015-0.03 fish/m^2, while medium trout

(91-200 mm) density ranged from 0.002-0.016 fish/m^2). Large trout density appears to be increasing over time (Figure 11c): large trout density averaged 0.004 fish/m^2 across 2000-2001 and 0.01 fish/m^2 in 2007 (large trout density = -1.5 + 0.0007*(year), R^2 = 0.01, p = 0.0007). This increase could be a result of two factors: increased survival rates resulting from an increase in prey resources provided by salmon carcasses, juveniles and eggs or an influx of larger trout from below the dam as a result of fish passage. Similarly, juvenile coho density is increasing at a rate of 0.03 fish/m^2 (juvenile coho density = -59 + 0.03*(year), R^2 = 0.01, p = 0.007) (Figure 11d). Summer density of juvenile Chinook in 2007 was also about 2-20 fold higher than previous years.

We are continuing to observe large changes in the fish community in Rock Creek as a result of fish passage largely due to colonization by juvenile coho. In June 2007, we observed juvenile coho above the culvert Road 41 crossing for the first time since we began seasonal surveys of Rock Creek in 2004. Summer density of trout >90 mm in reach 1 of Rock Creek has increased about two-fold since 2000-2001, while juvenile coho density increased 5-fold from ~0.2 in 2006 to 1.0 fish/m^2 in 2007 (Figure 12a). In contrast, total trout density during summer 2007 in Williams Creek, which is above a barrier to upstream migration of salmon, was about 2-fold lower than before the fish ladder (Figure 12b).

<u>Growth, movement and survival</u>

Two different recapture techniques, electroshocking and a PIT tag reader array, were used to enumerate growth, movement, and survival of salmonids in Rock Creek and the mainstem Cedar River. From summer 2007 to spring 2008, we conducted 6 tagging events, which were defined as one or several consecutive days where fish were collected for PIT tag insertion. Three of these events occurred in the lower 2.0 km of upper Rock Creek, while the other three tagging events occurred in the mainstem Cedar River. Over 3,000 fish (trout, sculpin, lamprey, dace), Pacific Giant Salamander (*Dicamptodon tenebrosus*), and tailed frogs (*Ascaphus truei*) have been captured during these events; the majority of vertebrates caught were coho followed by sculpin, rainbow, cutthroat, and dace (Table 1).

Mortality combined from both electroshocking and PIT tag insertion is 0.8% (23 out of 3033) (Table 2). Of the 24 fish that have died 15 were coho, 5 sculpin, 1 trout, 1 rainbow, and 1 cutthroat. All the fish mortality was related to electroshocking and not related to PIT tagging. The majority of mortality occurred in the summer (17 out of 24), followed by fall (7 out of 24). This reflects the fact that the number of fish caught during the summer is greatest. We tagged a total of 1720 fish (Table 2). The vast majority of fish were coho (68%), followed by cutthroat (16%) and rainbow trout (10%). A portion of tagged fish was classified as trout (6%) because their size precluded identification to species.

We defined recapture as a salmonid re-encountered at a later time whether by physical means or remotely sensed (i.e., detected by a PIT tag reader), and recapture rate as the total number of re-captured fish/the total number of captures in a sampling event for a given brood year. Electroshocking resulted in 194 recaptures (10%) out of the 1720 tagged salmonids, excluding the Landsburg diversion effort. The Rock Creek PIT tag reader array resulted in 349 unique tag numbers (19%) over the course of one year. Recapture rates in 2007/2008 were quite similar to those in 2006/2007 (electroshocking 13%, PIT tag reader 25%). Overall, recapture rate in Rock Creek by electroshocking varied according species. Recapture rates for cutthroat trout were highest (mean [range], 24% [15 to 25%]), followed by coho (7% [3 to 18%]), rainbow (4% [0 to 6%]), and trout (2% [0 to 5%]).

A concerted tagging effort was put forth in the mainstem during 2007. The goal of this effort was to gain a better understanding of the growth, movement, and survival of mainstem anadromous and resident salmonids, and to quantify the interactions between resident fishes and Pacific salmon. A new PIT tag reader was installed in the mainstem Cedar ~200 m upstream of Landsburg to capture both outmigration of anadromous species and movement of resident species. Hook and line sampling was used for sub-adult and adult resident salmonids in the mainstem, while seining along the channel margins was employed for juvenile resident and anadromous salmonids. Catch per unit effort using hook and line sampling averaged 1.63 (+/-0.9) with a total of 148 rainbow and cutthroat trout tagged with this method in the mainstem (Table 3). Hook and line sampling resulted in 5 recaptures out of 148 (3%) sub-adult and adult rainbow and cutthroat trout. Recapture rates were slightly higher at 5% (19 out of 333) for juvenile coho in the mainstem using seines along channel margins. Recapture rates at the mainstem PIT tag reader were higher for resident trout (19 recaptures out of 148 [13%]) and juvenile coho (94 out of 333 [28%]). The majority of the recaptures come from the nearest stream reaches (Table 4).

We developed fish growth rate estimates based on recaptures during electroshocking and PIT tag detections. We used individual length (mm) and weight (g) differences between tagging periods to estimate instantaneous growth rate (log initial weight - log recapture weight/number of days) by species. Similar to last year, instantaneous growth rates varied according to species and general habitat type (e.g., mainstem v. tributary) (Table 5). Mainstem fish had a higher growth rate relative to Rock Creek fish ($p = 0.06$), however this varied according to species. Coho rearing in the mainstem had higher growth rates than Rock Creek coho ($p = 0.03$), whereas mainstem rainbow trout did not differ in growth from Rock Creek rainbow trout ($p = 0.26$).

Because of a higher recapture rate, we had more instantaneous growth rate data for cutthroat trout from Rock Creek (Table 6). Seasonal growth rate varied and decreased as temperatures cooled from summer to winter. Mean cutthroat trout growth rate was highest in summer and decreased by ~50% by winter ($p = 0.03$ between summer and fall, and $p= 0.04$ between summer and winter). There were also differences in growth between cutthroat "movers" v. "non-movers." A mover was classified as a fish that was found in a pool other than where it was tagged or identified at the PIT tag reader in Rock Creek but caught at a later date where it was originally captured. Conversely, a non-mover was a cutthroat that was recaptured in the pool where it was tagged and was not identified at the PIT tag reader. Movers had significantly greater mean growth rates than non-movers ($p = 0.003$). Negative growth rates also occurred 50% less often in movers relative to non-movers. Similar to last year, variance in growth rate increased with size at tagging, and resulted in significant differences in growth rate variation between smaller (55 to 120 mm) and larger (>120 mm) salmonids ($p < 0.001$). Mean growth rates were not positively correlated with initial size at tagging, however. There was no evidence that cutthroat growth rate differed between reaches ($p = 0.72$ and $p = 0.30$).

Similar to last year, movement varied according to season, species, and direction. Coho outmigration from upper Rock Creek peaked in November and May, but downstream movement occurred throughout the year (Kiffney et al. 2006). The majority of fish moved downstream, with a substantial amount of within reach movement (defined as the detection of a tagged fish moving in both directions within a specific time period). Over the course of three years, the average distance moved in Rock Creek was 552 (±24) meters with cutthroat moving more than other species on average, coho similar to the overall average, and rainbow trout having a slightly lower average (Figure 13).

Overall, coho survival in Rock Creek was 39% in 2007 (brood year 2006 fish) from tagging to smolt emigration, with 136 out of 349 coho detected moving downstream at the PIT tag array (Table 7). We hypothesize this was an underestimate because of the PIT tag reader not functioning for a 10 to 14 days during a critical outmigration period in May of 2007. Of these 136 coho, 77 were detected at the Ballard Locks. Furthermore, all fish detected at the Rock Creek reader were also detected at the Locks. Detection rate of natural coho smolts at the Locks ranges between 25-65% and averaged approximately 50% for the time period that upper Rock Creek smolts were migrating (Devries 2007). Therefore, coho smolt survival estimates from Rock Creek ranged from 22% to 44%. Estimated survival to the Locks was greater in 2007 than in 2006 (brood year 2005 fish) (Table 7). Survival for the small portion of mainstem coho outmigrating in 2007 (BY 2006) was similar to Rock Creek (21% or 10 out of 47 tagged). Survival at the reach scale varied for mainstem coho, with highest survival rates occurring between Rkm 1.6 and 1.9, followed by Rkm 2.3 to 2.6 (Table 8). Survival was lowest from the mouth of Rock Creek to Rkm 0.5. Data from 2008 (BY 2007) are forthcoming.

There were significant difference in length ($p<0.00001$) between coho that survived (mean = 83mm [±1.44mm]) and those that did not survive to the Ballard Locks (mean = 76 [±0.7mm]) from Rock Creek. The difference in size between survivors and non-survivors was evident at initial tagging and remained consistent throughout all tagging events (Figure 14-15). Moreover, this size advantage increased as the cohort group became older. Initial size at tagging was also positively correlated to the percent of coho surviving at the pool scale (Figure 16).

Several prominent patterns have occurred consistently since the initial recolonization of the Cedar River watershed above Landsburg in 2003. Perhaps one of the more significant changes has been the change in species composition of Rock Creek from a predominantly cutthroat trout system to a coho dominated system (Figure 17). This shift over time has also led to a shift in habitat utilization, as coho were most abundant in deeper water habitats than trout (Figure 18). Another consistent pattern was the proportion of rainbow and cutthroat in the mainstem and tributary habitats: mainstem habitats were dominated by rainbow trout, while cutthroat were the dominant trout in tributaries (Figure 19) (Kiffney et al. 2002).

4.2 Objective 2: What are the interactions between sculpin, different life stages of trout and juvenile salmon?

Diets of juvenile coho and trout, and large trout were variable within and among sites. Aquatic larva (mayflies, stoneflies, caddis flies, and dipterans) and other aquatic larva (springtails, hemipterans, beetles) were the most abundant diet items among all sites (Figure 20). Juvenile coho in Rock Creek and the mainstem contained about 7-20× the biomass in their stomachs compared to juvenile trout collected from Rock Creek. The difference in diet biomass between juvenile coho and trout in Rock Creek suggests that coho were outcompeting smaller trout for food resources. Coho diet biomass was also

~1.5-3× higher in the mainstem than coho in Rock Creek, which may be a result of higher insect productivity in the mainstem. The relative importance of terrestrial food items for coho was greatest in reaches 4 and 6 in the mainstem: terrestrial diet items made up about half of total diet biomass for coho in reach 6. The diet biomass of medium trout (91-200 mm) was also higher in the mainstem than in Rock Creek, peaking in reach 1 at 140 mg/fish and lowest in reach 9 (~40 mg/fish). Medium trout in reach 4 ate mostly coleopteran larva, while they primarily consumed mayflies and dipterans in reaches 1 and 9. Large trout (>200 mm) diet biomass peaked at reach 6 (400 mg/fish), with fish consuming a variety of diet items. There was no evidence of trout consuming juvenile coho or Chinook during summer 2007. In addition, there was no evidence that trout captured during the Landsburg Dam drawdown in May 2007 consumed juvenile salmon. These results should be considered preliminary, as we have completely processed about 175 stomach samples out of a total of 450. Some of these samples also include trout diets collected during October 2007, during the peak of Chinook spawning. In addition, we should learn more regarding dietary habitats of large trout from stable isotope analysis.

5.0 Summary

There were several notable ecological patterns in the Cedar River during 2006-2007:

- Redd abundance was a function of distance from source population, with some evidence of habitat selection in reach 6
- Higher nutrient levels in tributary vs. mainstem habitat
- Peaks in algal biomass in reach 1, 6 and 10

- One abundant species of caddis fly larva increased from downstream to upstream (*Dicosmoecus*), while the other showed the opposite pattern (*Glossosoma*)
- Juvenile coho and Chinoook density generally decreased from downstream to upstream, except for the summer distribution of Chinook and these patterns generally reflected redd abundance
- The distribution of trout was opposite of salmon, as they increased in density from downstream to upstream
- Trout in the mainstem appeared to select deeper water habitats while salmon selected edge habitat with abundant cover
- Coho appeared to select deeper pool habitats than trout in Rock Creek
- Trout populations have remained stable over time, except for increases in larger trout (>200 mm) in the mainstem and trout >90 mm in Rock Creek
- Coho populations are increasing in both the mainstem and Rock Creek
- Coho survival was similar to previous years and similar between Rock Creek and the mainstem
- Circumstantial evidence (habitat use and diet) suggests that coho are competing with juvenile trout in Rock Creek
- To date, there was no evidence that large trout are predation on juvenile coho or Chinook.

6.0 Literature cited

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Table 1. The number of aquatic species captured from summer of 2007 (June 2007) to spring of 2008 (April 2008).

	summer 2007	fall 2007	spring 2008	total
cutthroat	94	251	34	379
rainbow	153	18	5	176
coho	539	724	77	1340
trout	96	104	3	203
Chinook	0	0	17	17
dace	43	72	14	129
lamprey	10	12	5	27
sculpin	302	351	100	753
crayfish	9	0	0	9
total	1246	1532	255	3033

Table 2. The number of fish tagged, recaptured, not tagged, and mortalities between summer of 2007 and spring 2008.

	tagged	recaptures	not tagged	mortalities
cutthroat	277	91	11	1
rainbow	166	7	3	2
coho	1174	91	75	15
trout	103	5	95	1
Chinook	0	0	17	0
dace	0	0	129	0
lamprey	0	0	27	0
sculpin	0	0	753	5
crayfish	0	0	9	0
total	1720	194	1119	24

Table 3. Catch per unit effort in the Cedar River mainstem during the summer of 2007

Reach	Date	Trout observed	Trout caught	CPUE
CR6	7/19/2007	25	17	2.9
CR9	7/23/2007	49	11	2.1
CR1	8/20/2007	23	9	1.1
CR4	8/21/2007	32	11	1
CR9	8/23/2007	59	5	0.53
CR6	8/30/2007	19	11	2.2

Table 4. Percent recaptures by stream reach for coho and rainbow at the Landsburg PIT tag reader. Distance from reader noted in parentheses.

	CR1 (~2km)	CR4 (~10km)	CR6 (~11km)
Coho	18%	14%	2%
Rainbow	44%	9%	8%

Table 5. Mean instantaneous growth rates (g/g/day) (±SE) by species and general habitat type.

	Coho	Rainbow Trout	Cutthroat Trout
Mainstem	0.0049 (±0.0013) n = 16	0.0021 (±0.0011) n = 5	0.0007 n = 1
Rock Creek	0.0019 (±0.00023) n = 64	0.0039 (±0.0011) n = 5	0.0022 (±0.00024) n = 73

Table 6. Mean instantaneous growth rates (g/g/day) (±SE) for cutthroat in Rock Creek by season, reach, and movement pattern (e.g., movers v. non movers).

Independent variable	Rock Creek cutthroat
Summer	0.0033 (±0.0004) n = 14
Fall	0.0020 (±0.0003) n = 54
Winter	0.0014 (±0.0005) n = 4
Rkm 0 to 0.5	0.0026 (±0.0007) n = 18
Rkm 1.6 to 1.9	0.0025 (±0.0004) n = 16
Rkm 2.3 to 2.6	0.0019 (±0.0003) n = 38
Movers	0.0031 (±0.0004) n = 28
Non-movers	0.0016 (±0.0003) n = 45

Table 7. Coho PIT tag hits at upper Rock Creek and the Ballard Locks – 2006 and 2007

	2006 (Brood year 2005)	2007 (Brood year 2006)
Total number of coho tagged in upper Rock Creek	164	349
Number of unique coho tags identified moving downstream at upper Rock Creek	85 (52%)	136 (39%)
Number of unique coho tags identified at Ballard Locks from upper Rock Creek	30 (18%)	77 (22%)

Table 8. Coho PIT tag hits at upper Rock Creek and the Ballard Locks – 2006 and 2007

	Rkm 0.0 to 0.5	Rkm 1.6 to 1.9	Rkm 2.3 to 2.6
Total number of coho tagged in upper Rock Creek	231	57	60
Number of unique coho tags identified moving downstream at upper Rock Creek	106 (46%)	18 (32%)	25 (42%)
Number of unique coho tags identified at Ballard Locks from upper Rock Creek	44 (19%)	17 (30%)	16 (27%)

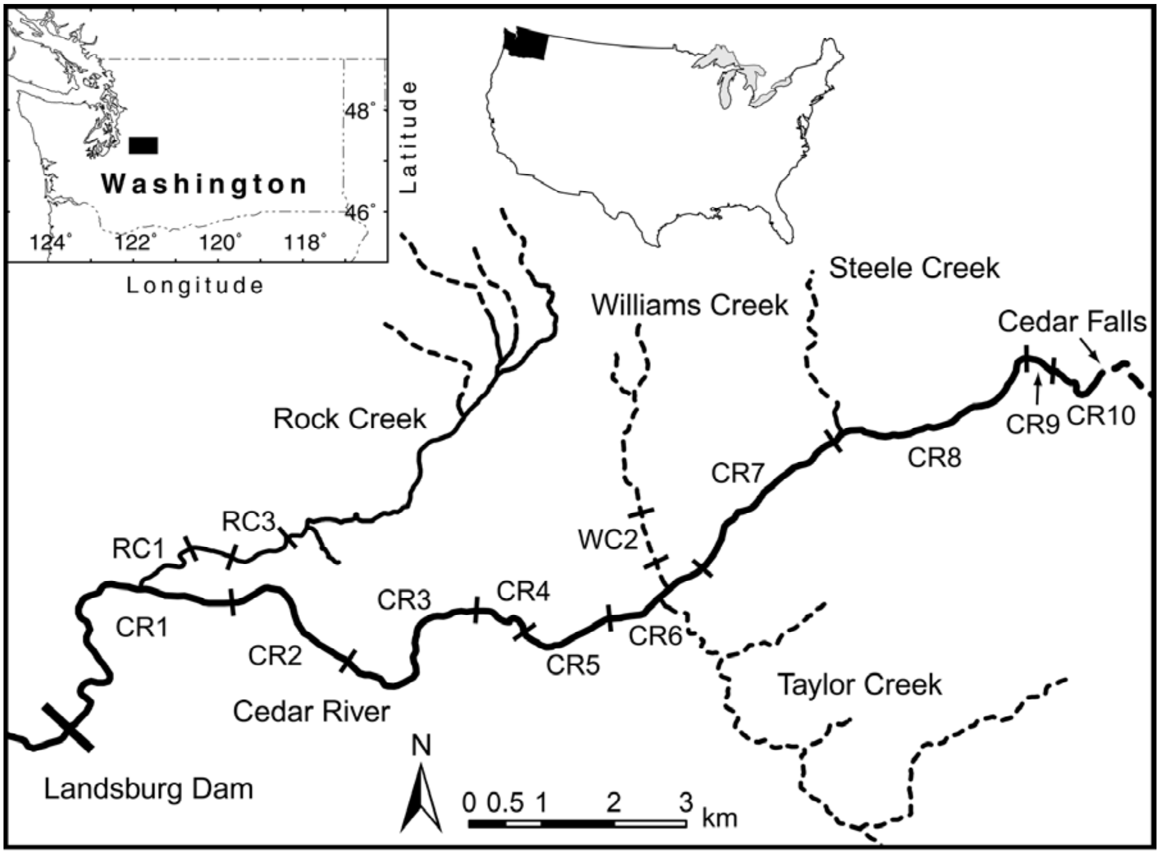

Figure 1. Map of Cedar River and tributaries. Solid lines perpendicular to river are reach breaks. Streams with solid line symbol include all mainstem and tributary habitat accessible to anadromous fish. Streams with dashed line are inaccessible to anadromous fish

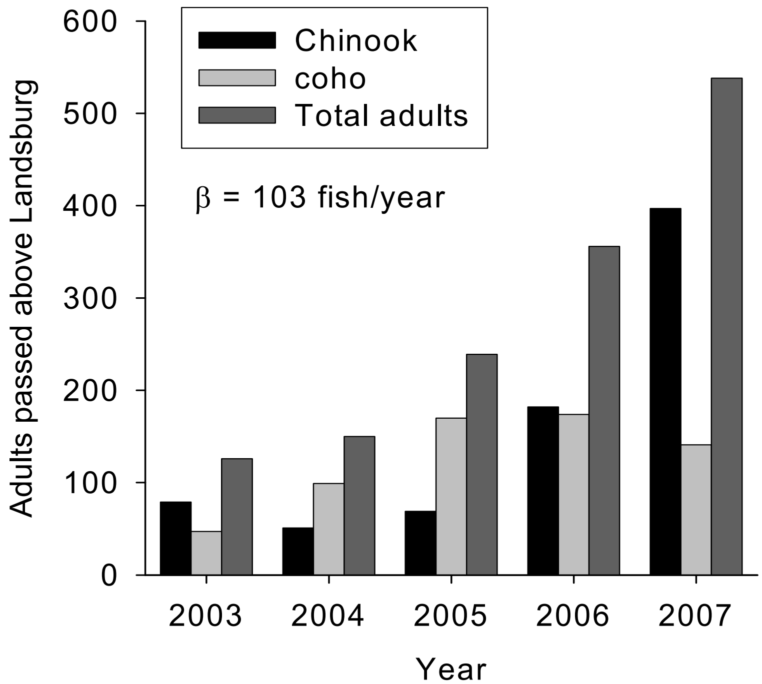

Figure 2. a) Coho and b) Chinook redd abundance above Landsburg since 2003. Total number of adults passed above the dam is increasing at 103 fish/year.

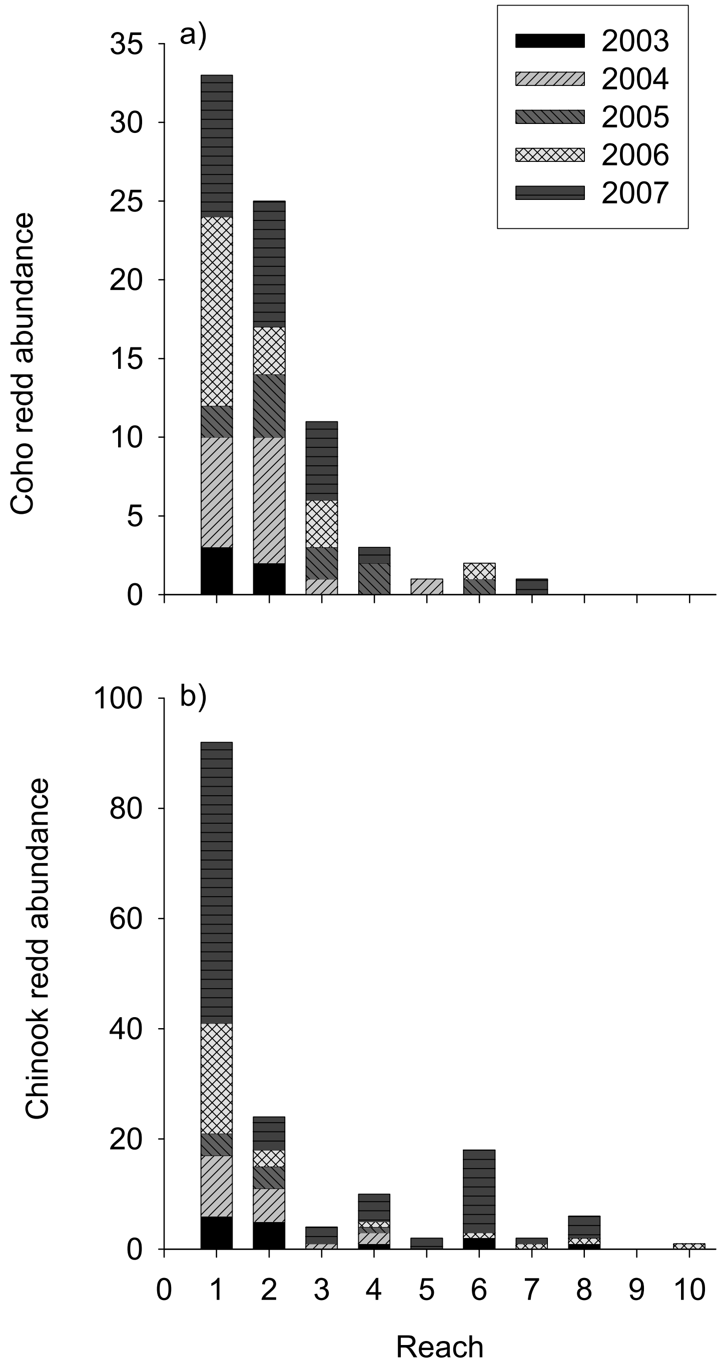

Figure 3. a) Coho and b) Chinook redd abundance by reach since 2003 (data from Burton and Barnett, SPU and Anderson, UW).

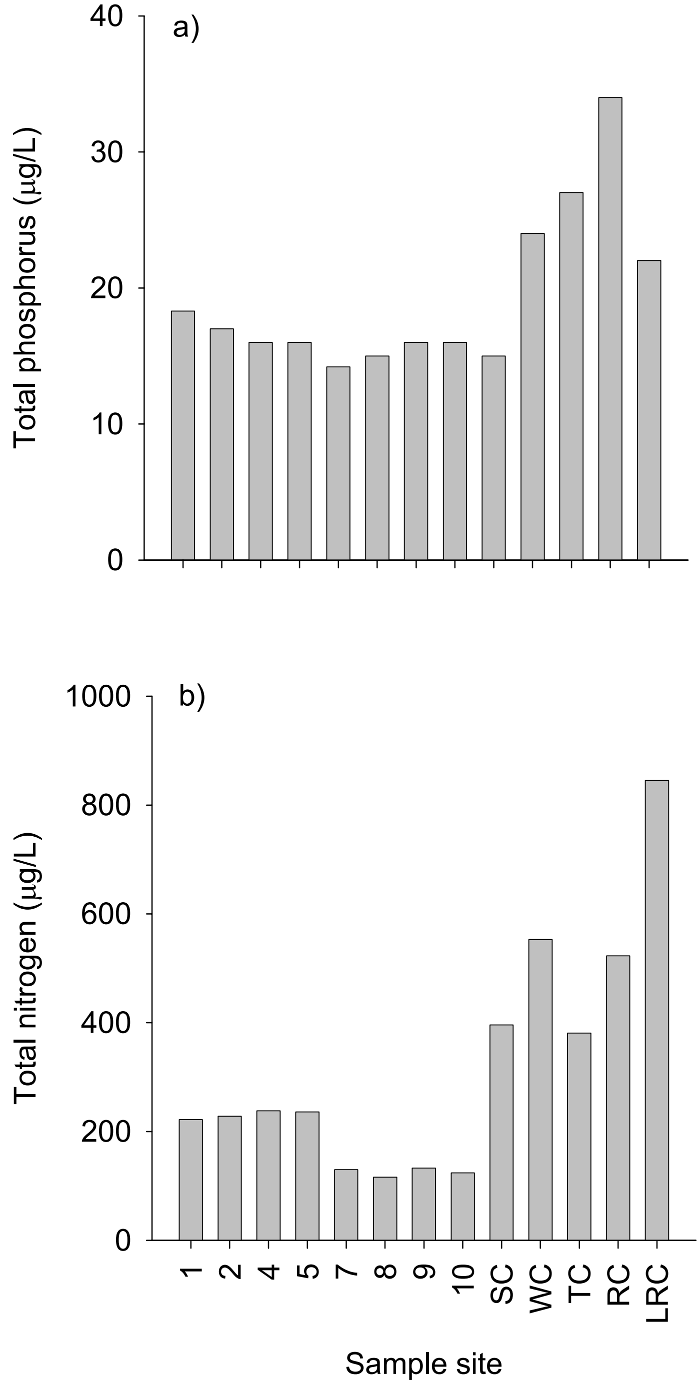

Figure 4. a) Total phosphorus and b) nitrogen (µg/L) in mainstem reaches and tributaries (SC=Steele Creek, WC=Williams, TC=Taylor Creek, RC=Rock Creek, LRC=lower Rock Creek) during summer 2007.

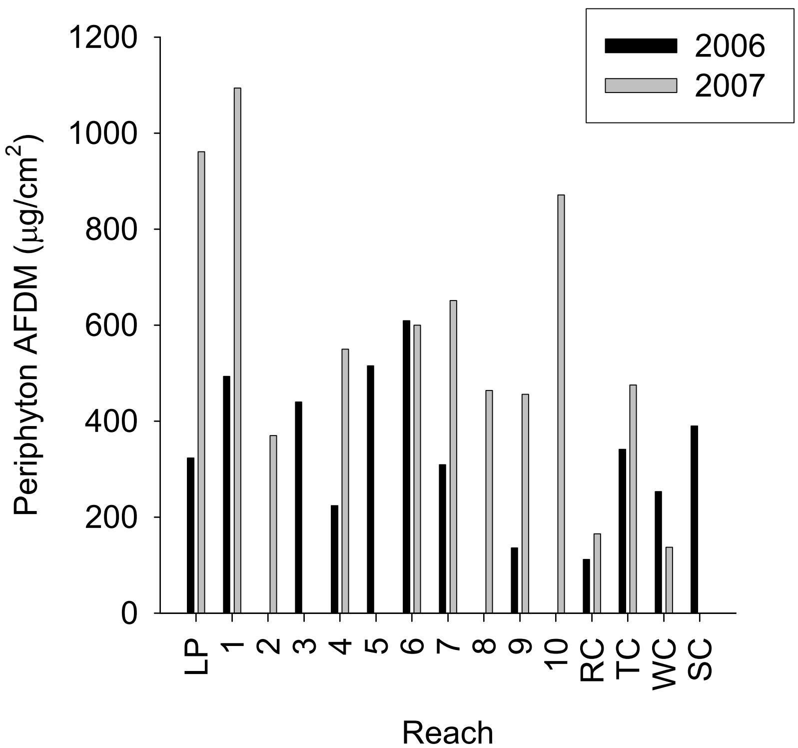

Figure 5. Algal biomass as measured by periphyton AFDM in mainstem and tributary reaches during summer 2006 and 2007.

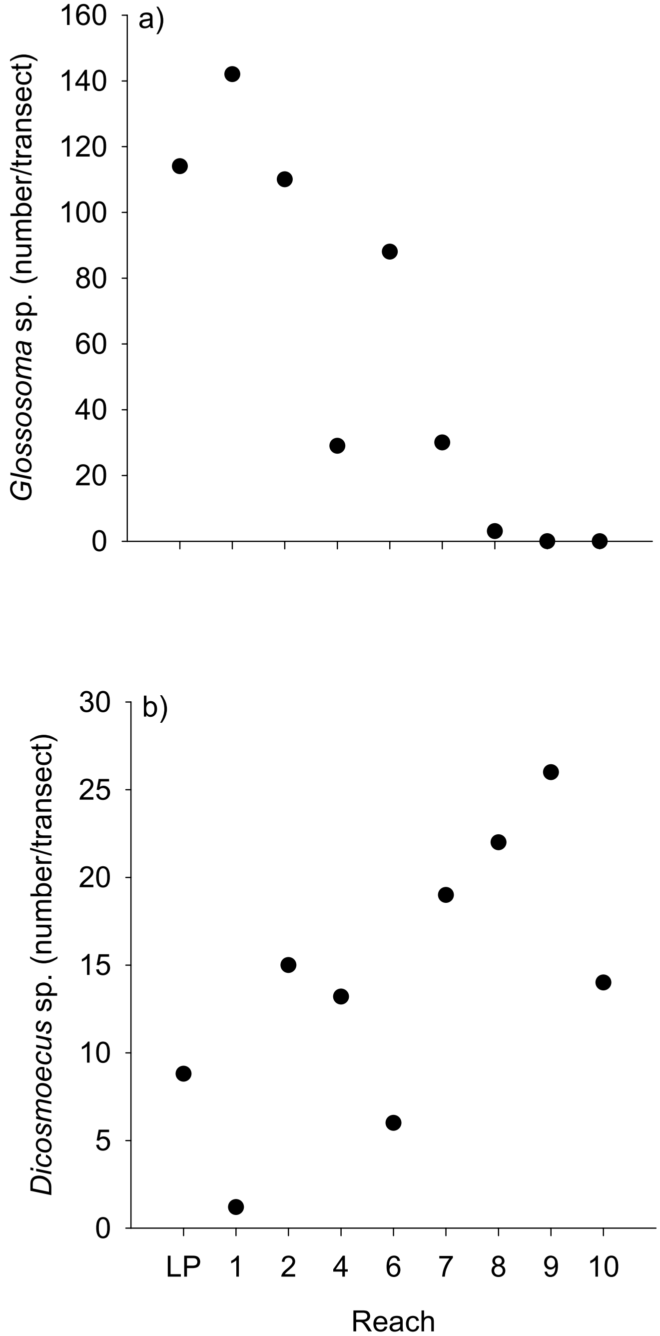

Figure 6. Abundance of the caddis fly larva a) *Glossosoma* sp. and 2) *Dicosmoecus* sp. during summer 2007 from Landsburg Park (LP) to reach 10 of the mainstem.

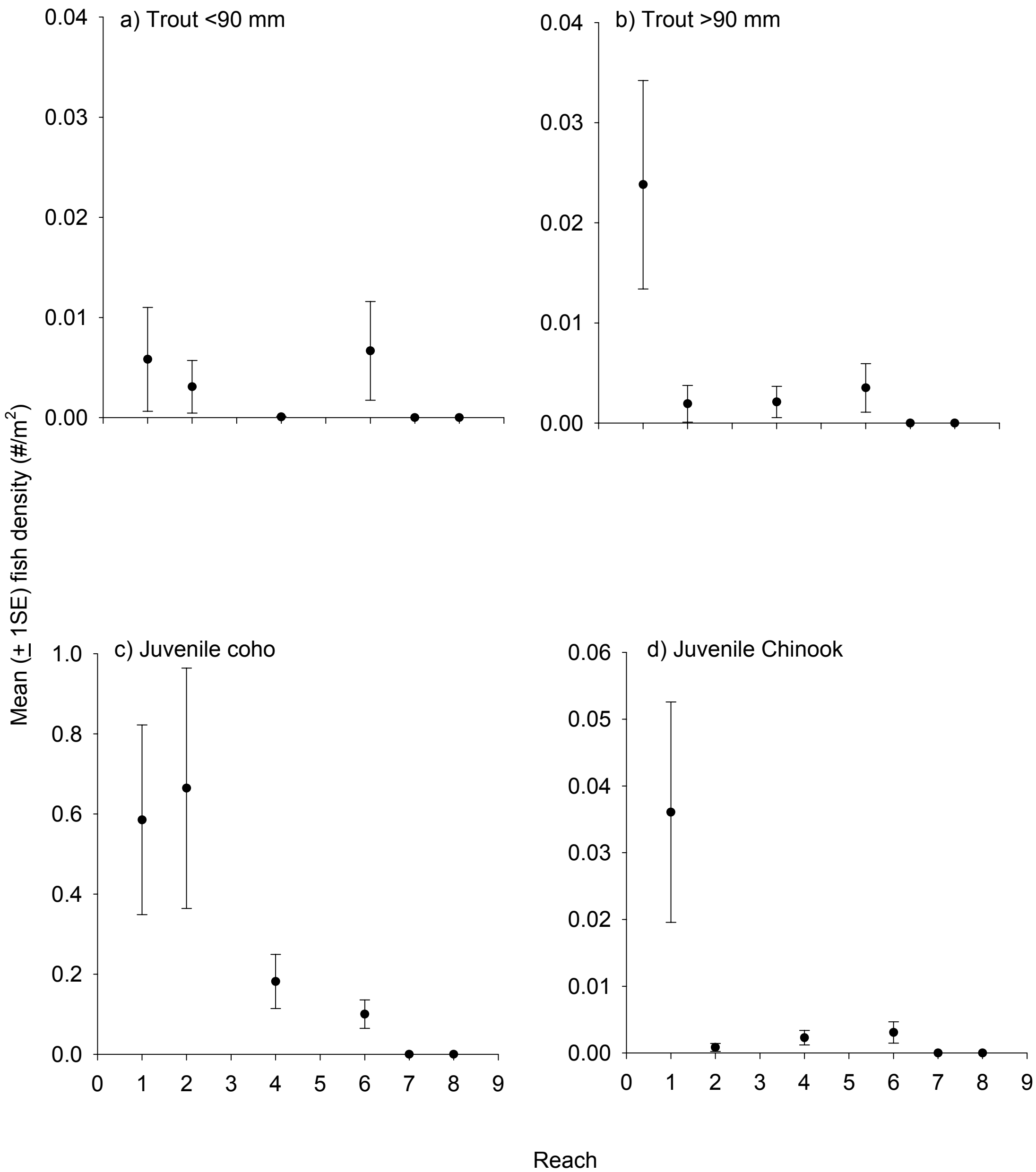

Figure 7. Mean (±1se) density of a) juvenile trout, b) large trout, c) juvenile coho and d) Chinook by reach during April 2007.

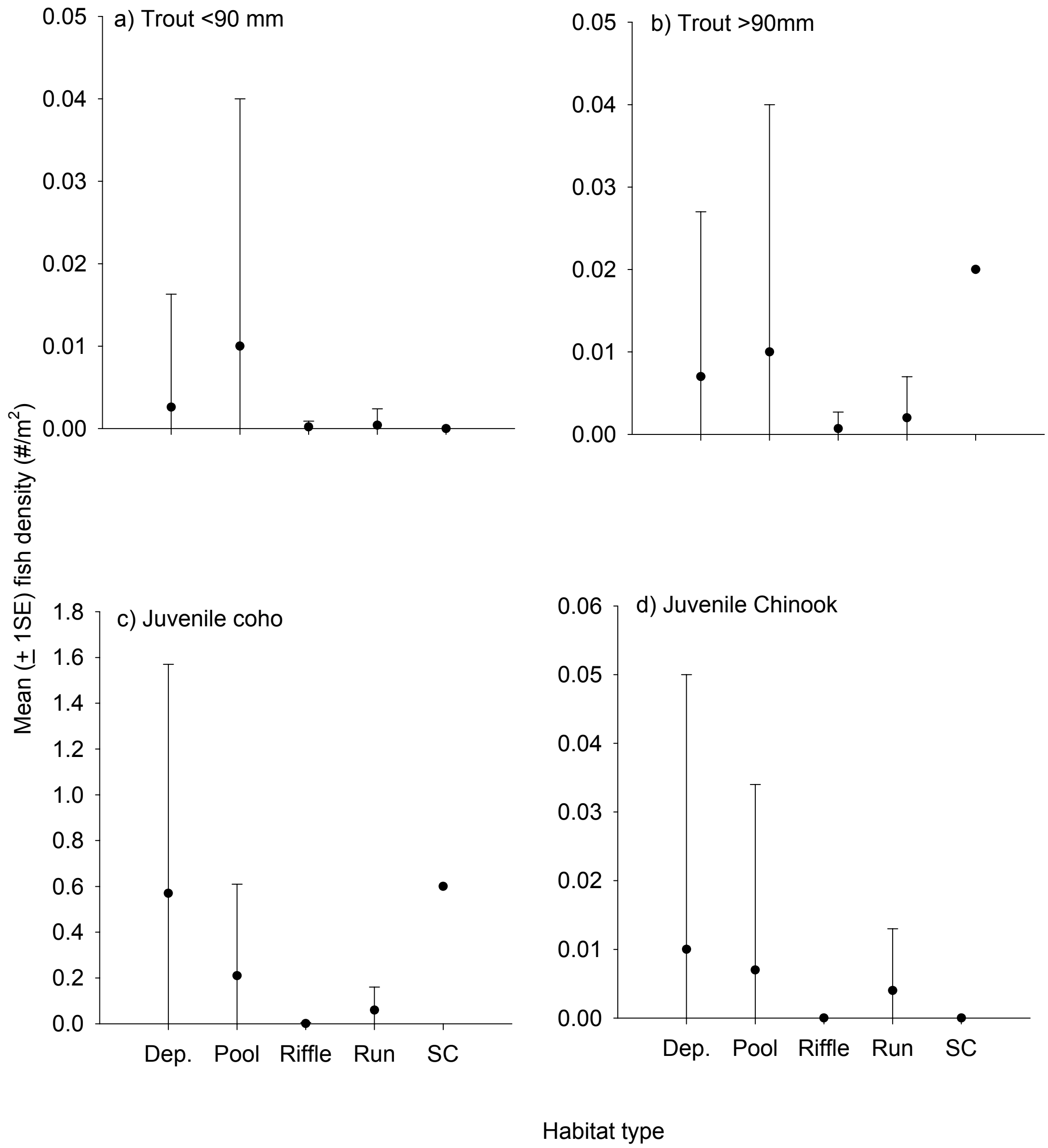

Figure 8. Mean (±1se) density of a) juvenile trout, b) larger trout, c) juvenile coho and d) Chinook by habitat type during April 2007. Dep.= depositional, SC=side channels.

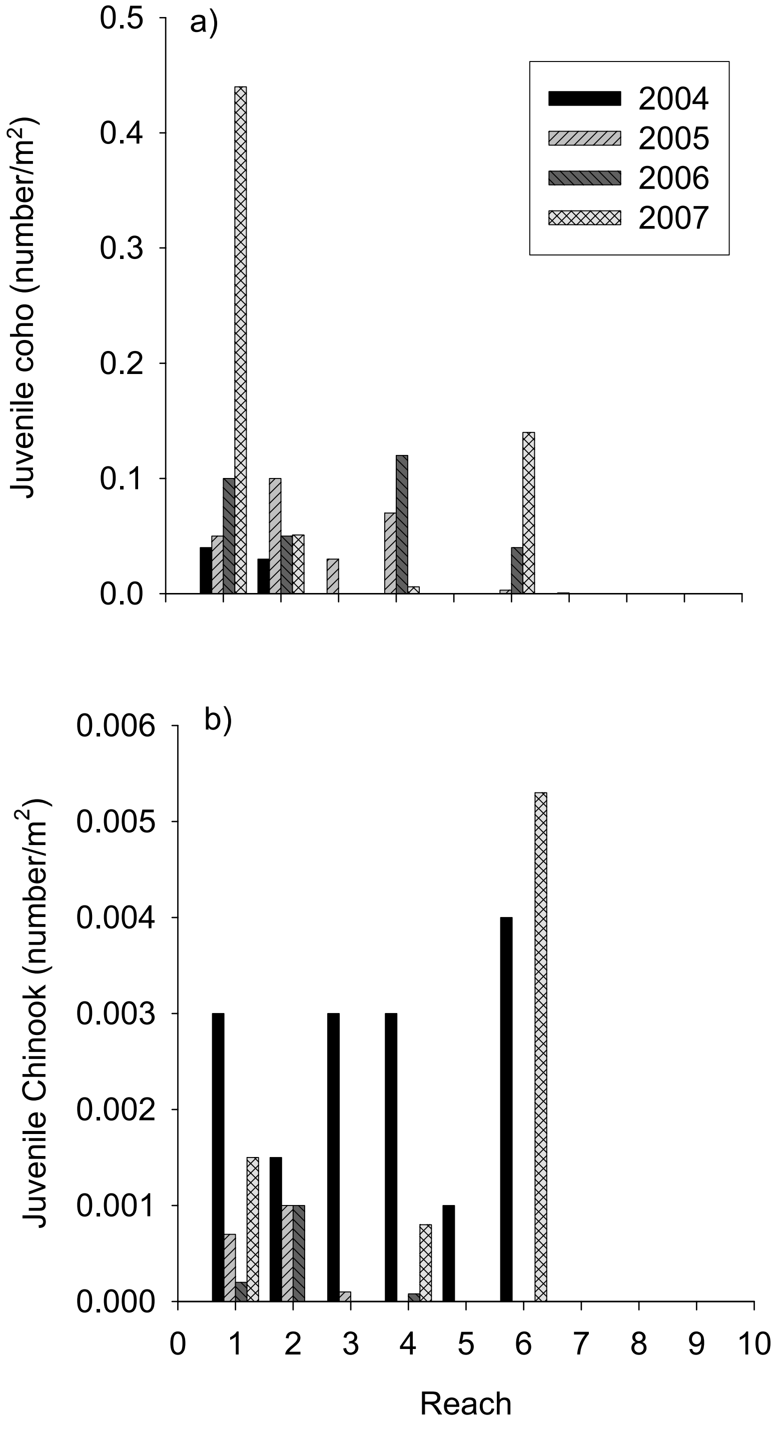

Figure 9. Mean juvenile a) coho and b) Chinook density during August by reach since 2003.

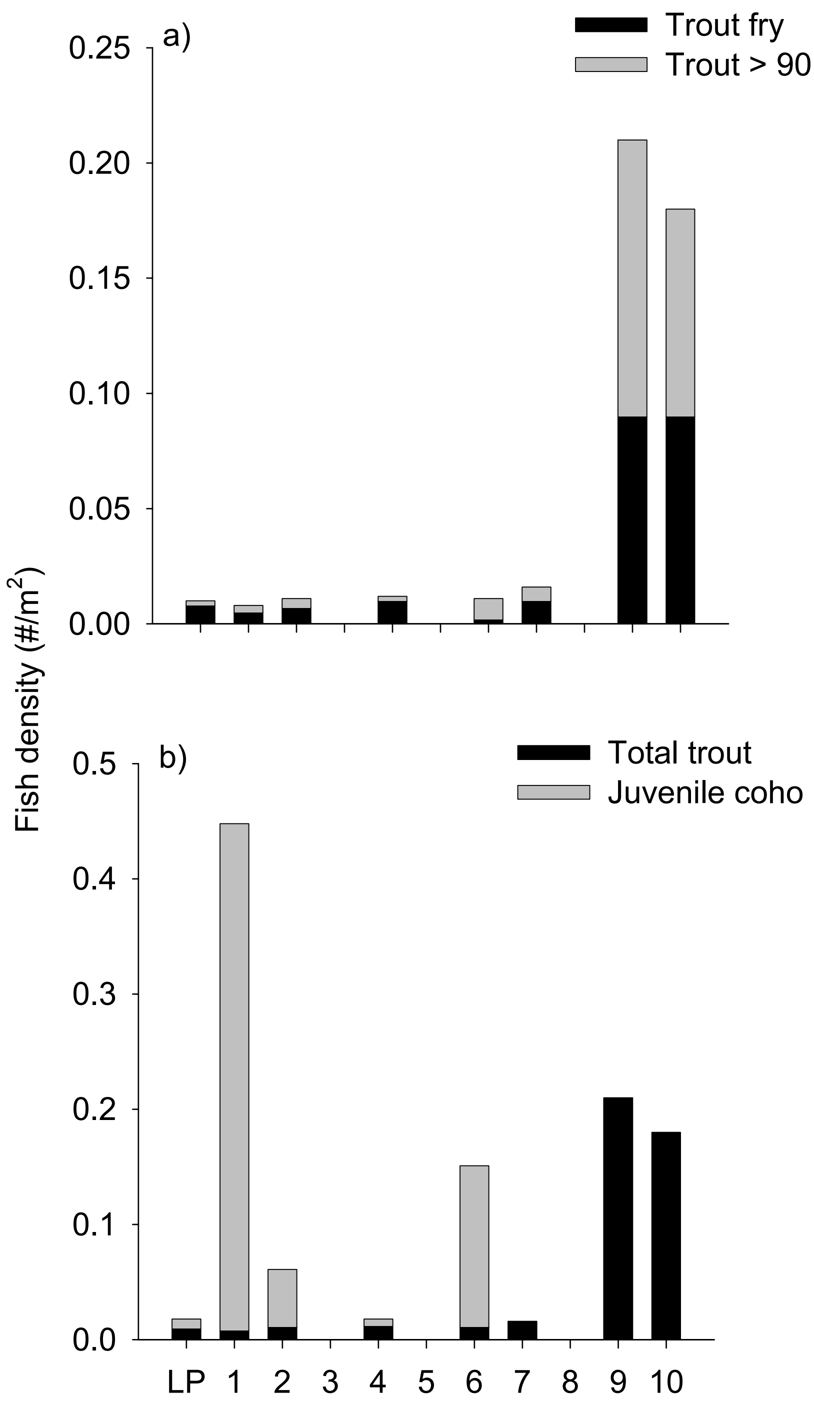

Figure 10. a) Trout fry (<90 mm) and large trout (>90 mm) density and b) total trout and juvenile coho density during summer 2007 from Landsburg Park to reach 10 near Cedar Falls.

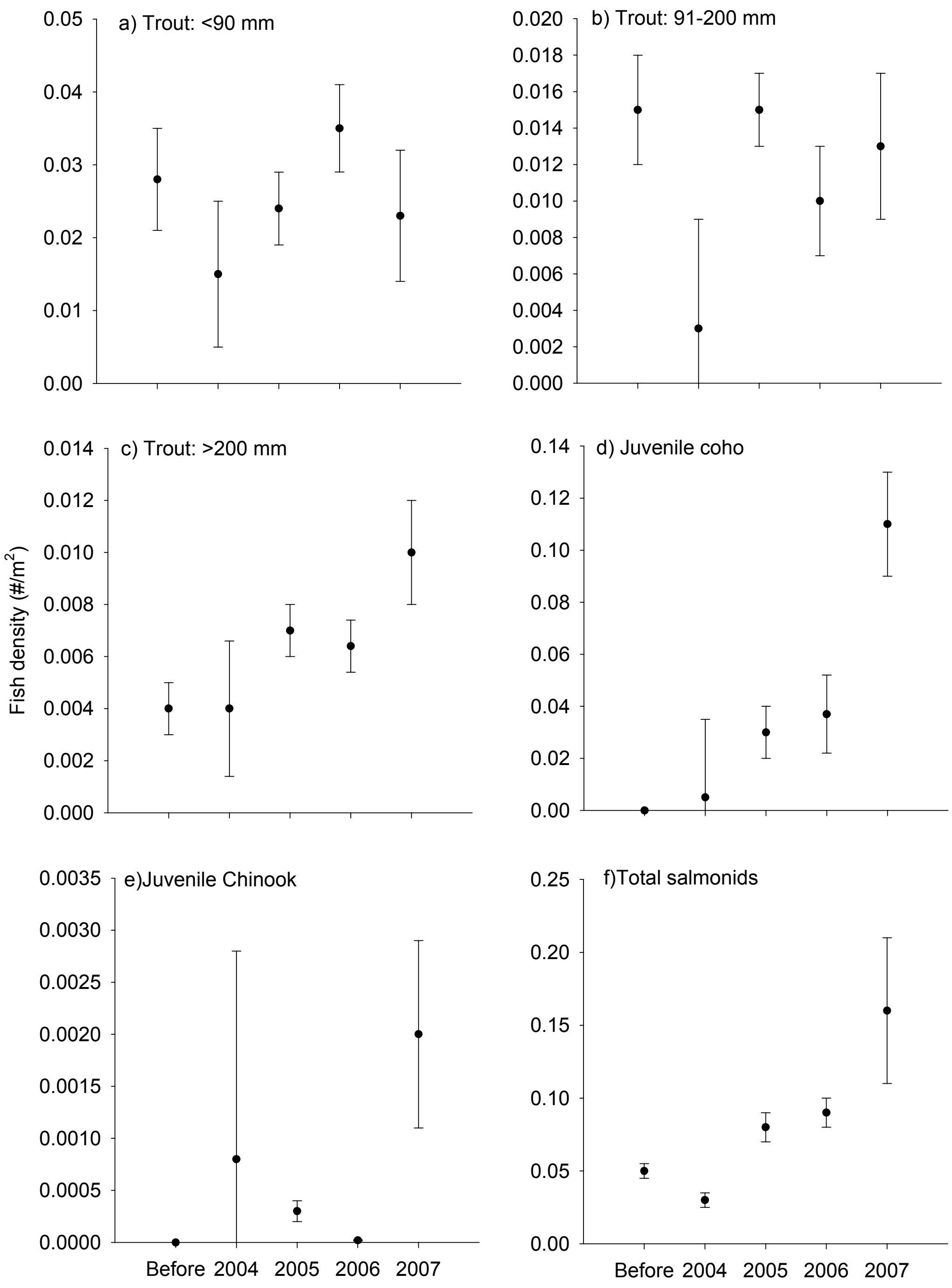

Figure 11. Mean (±1se) density (individuals/m^2) of a) juvenile trout, b) medium trout, c) large trout, d) juvenile coho, e) juvenile Chinook, and d) total salmonids (trout+salmon) during August before (2000-2001) and after (2004-2007) installation of fish passage

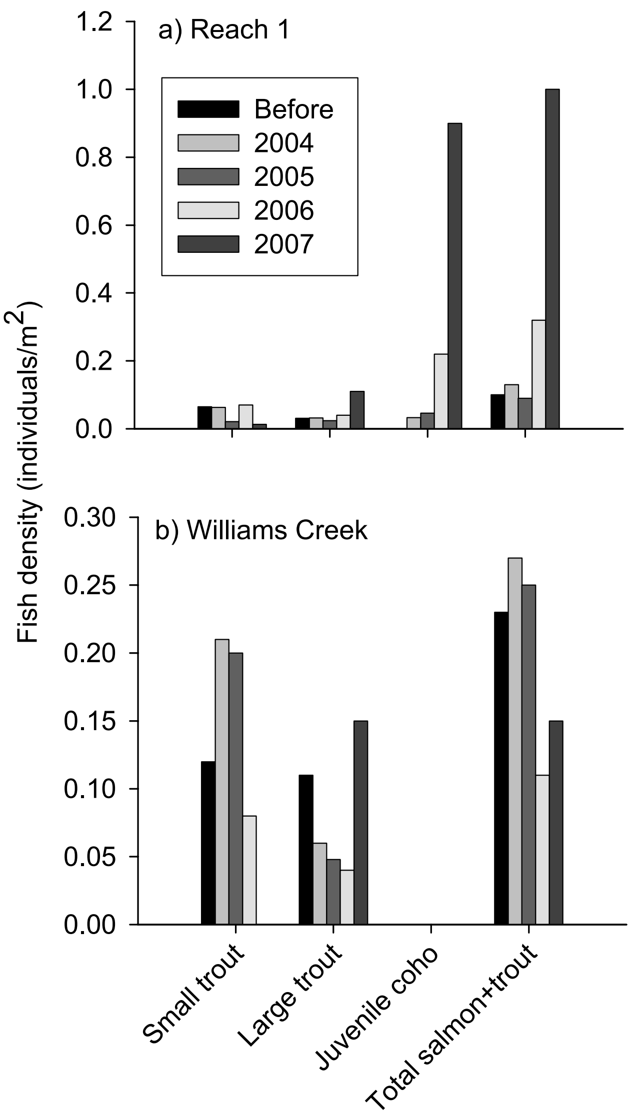

Figure 12. Density of small trout (<90mm), large trout (>90 mm), juvenile coho and total salmon+trout from 2000-2001 (before) to 2007 in a) reach 1 of Rock Creek and b) reach 3 of Williams Creek.

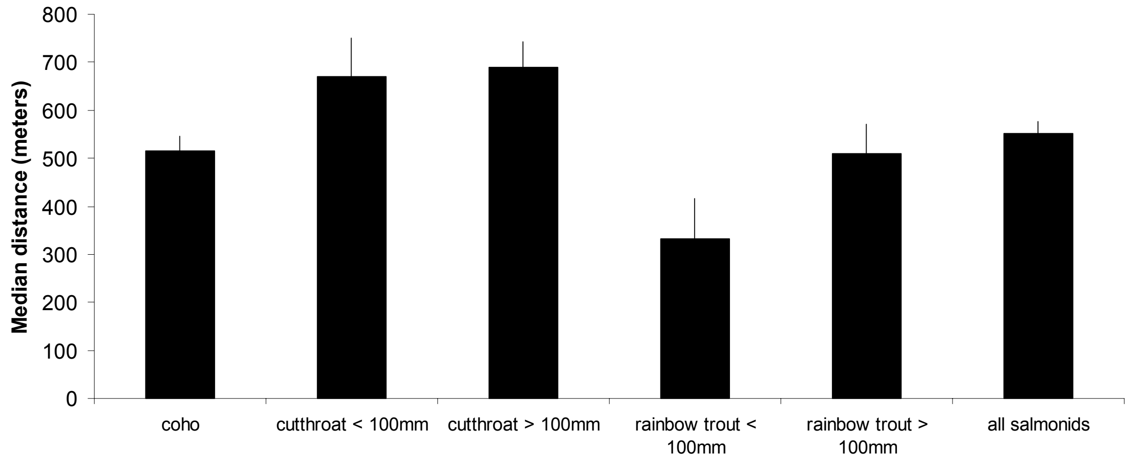

Figure 13. Average distance traveled by salmonids from Fall 2005 to Spring 2008 in Rock Creek.

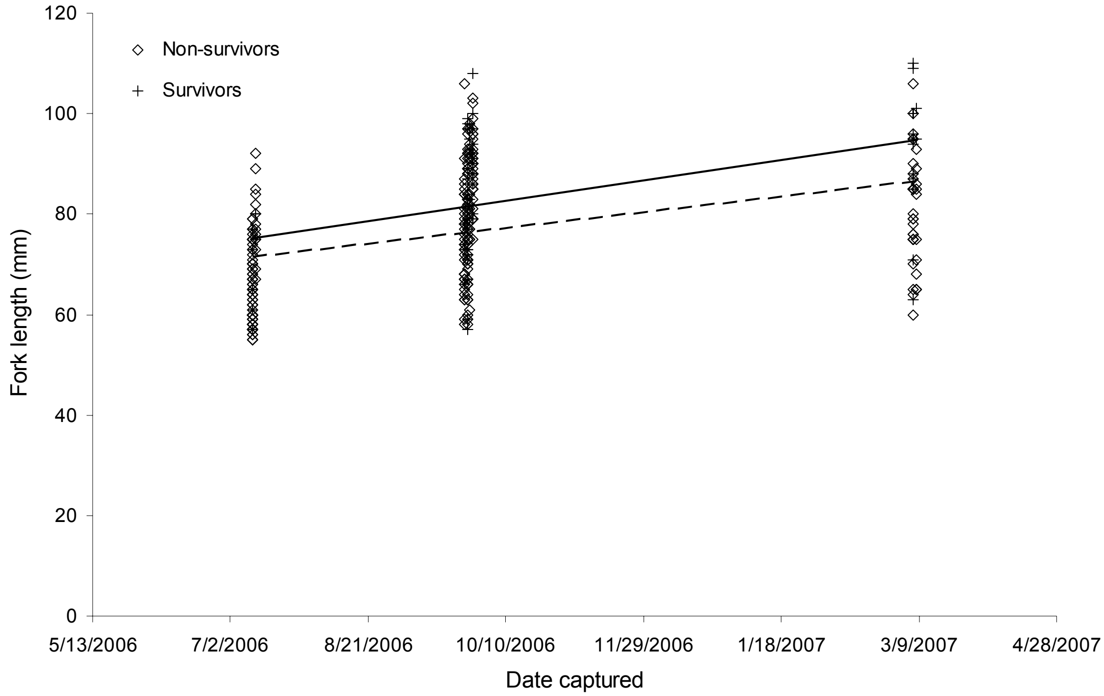

Figure 14. Differences in coho length by date captured between survivors and non-survivors from Rock Creek (BY 2006). Regression for survivors is fork length (mm) = 0.0811(date captured) - 3081.4. R^2 = 0.22. Regression for non-survivors is fork length (mm) = 0.0627(date captured) - 2369.7. R^2 = 0.15. Solid line is survivor regression, hashed line is non-survivor regression. Analysis of covariance means difference p = 0.0002.

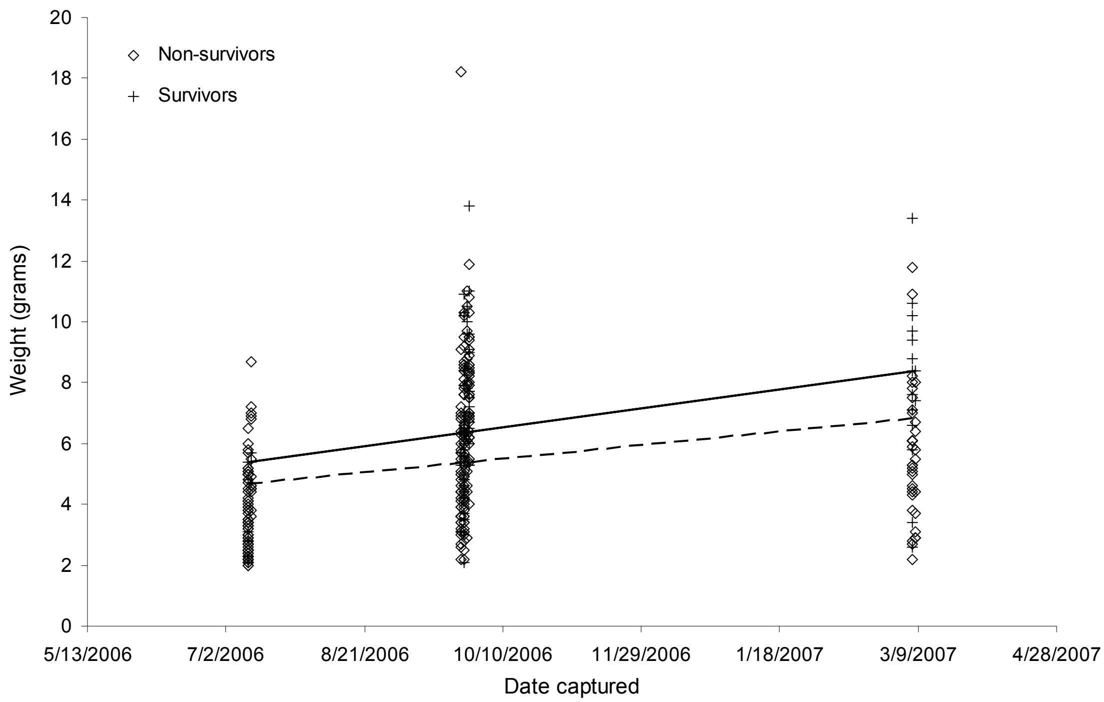

Figure 15. Differences in coho weight by date captured between survivors and non-survivors from Rock Creek (BY 2006). Regression for survivors is weight (grams) = 0.0125(date captured) – 481.08. $R^2 = 0.13$. Regression for non-survivors is weight (grams) = 0.009(date captured) – 343.7. $R^2 = 0.08$. Solid line is survivor regression, hashed line is non-survivor regression. Analysis of covariance means difference $p = 0.0008$.

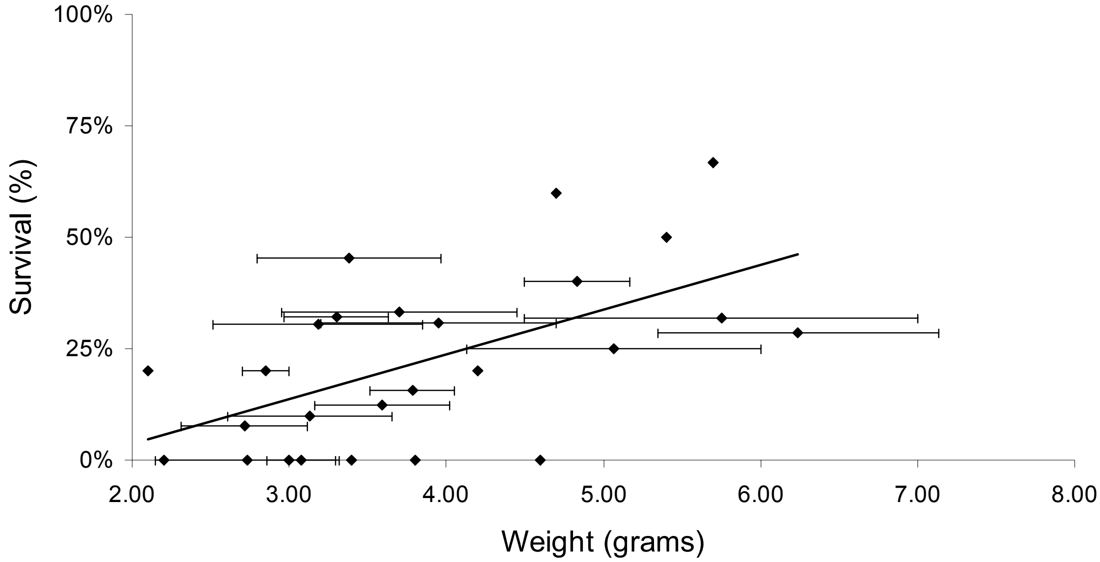

Figure 16. Initial weight at tagging and percent survival within each pool unit sampled in Rock Creek for BY 2006. Each point is a pool unit with standard error bars. Regression is percent survival = -0.164(initial tagging weight) – 0.100. $R^2 = 0.30$, p = 0.002.

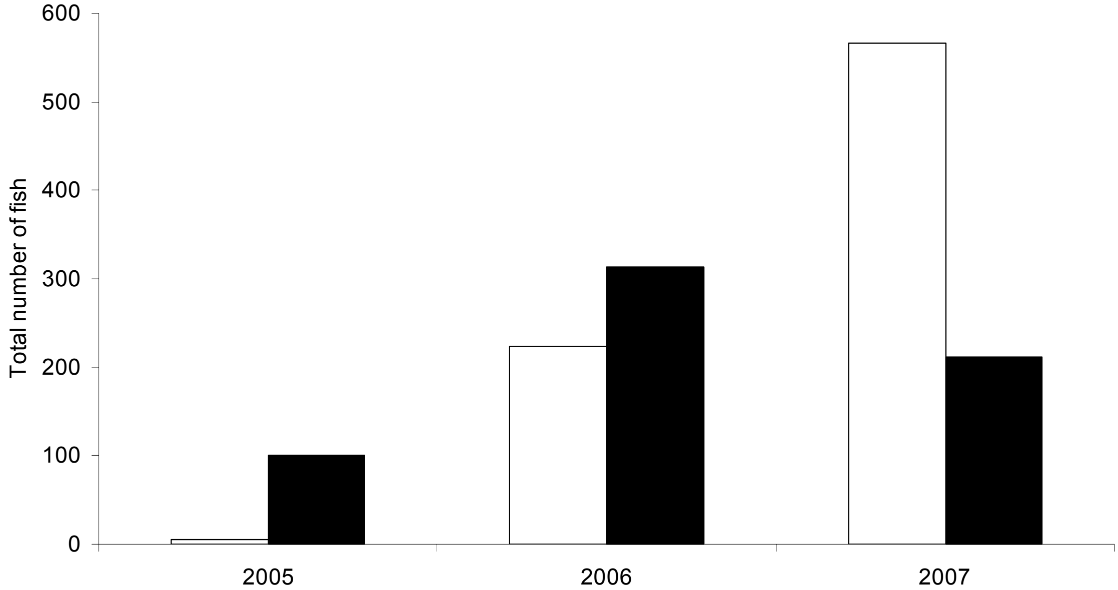

Figure 17. Total number of coho and trout in Rock Creek between 2005 and 2007. Clear bars are coho while black bars are trout.

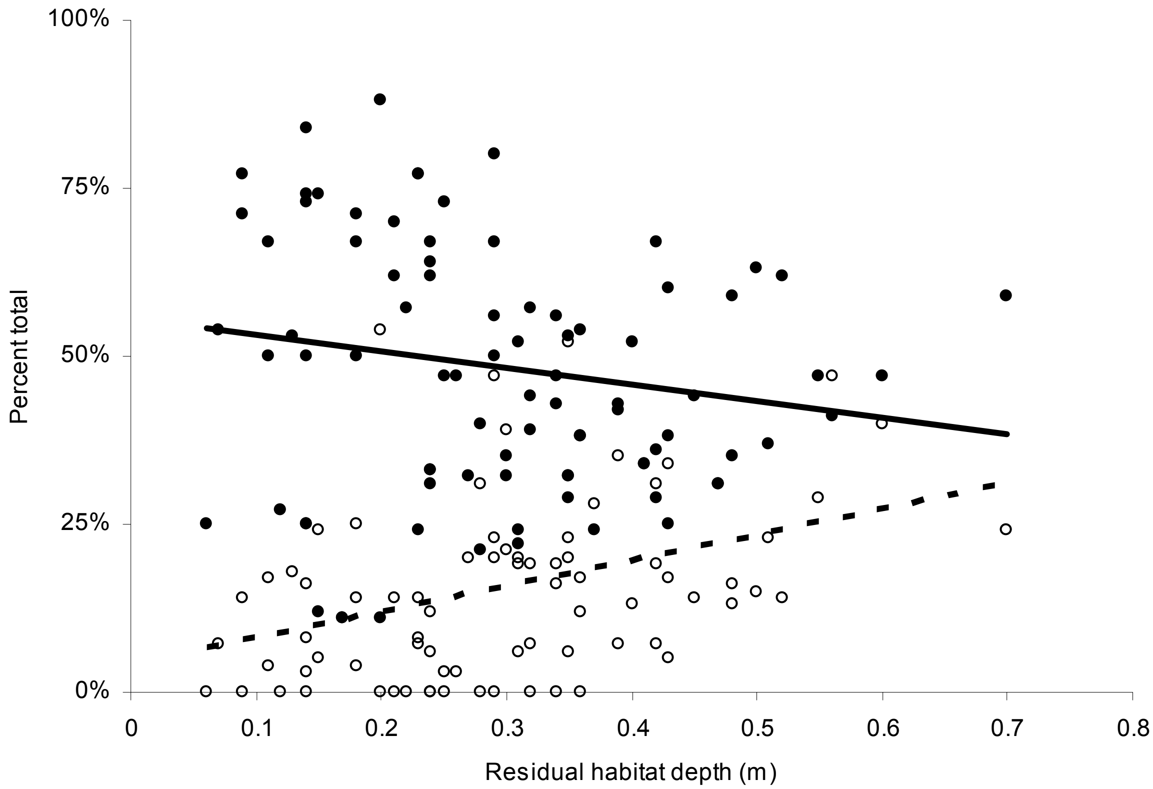

Figure 18. Species composition (%) by residual habitat depth in Rock Creek 2007. Clear circles are coho, while filled circles are trout. Hatched line is regression for % coho (0.38*(residual habitat depth) + 0.042, $r^2 = 0.15$, $p = 0.0004$). Solid line is regression for % trout (-0.24*(residual habitat depth) + 0.56, $r^2 = 0.03$, $p = 0.11$).

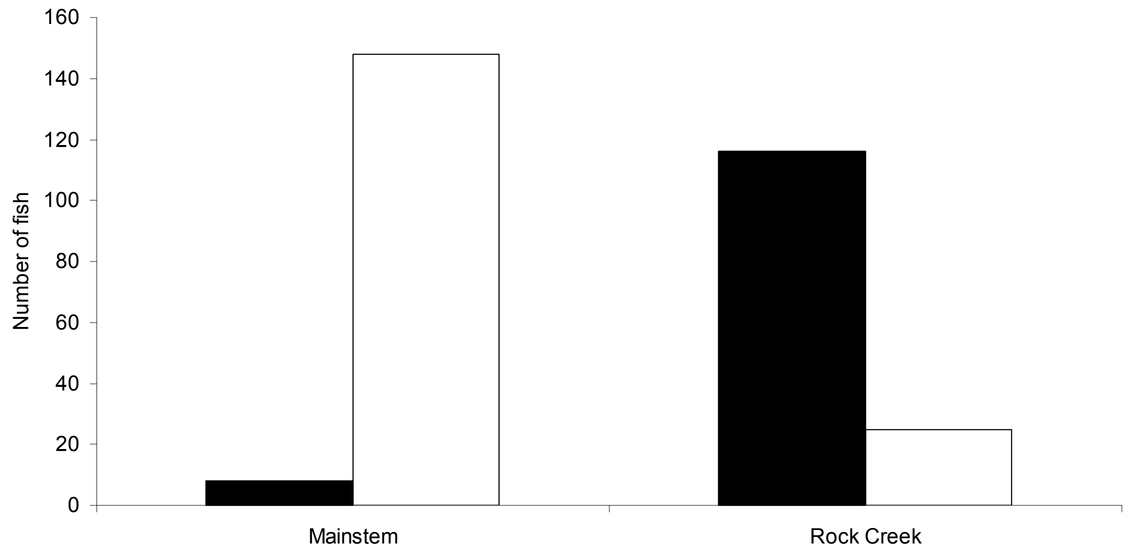

Figure 19. Number of rainbow (clear bars) and cutthroat (black bars) captured in the main stem Cedar and Rock Creek 2007.

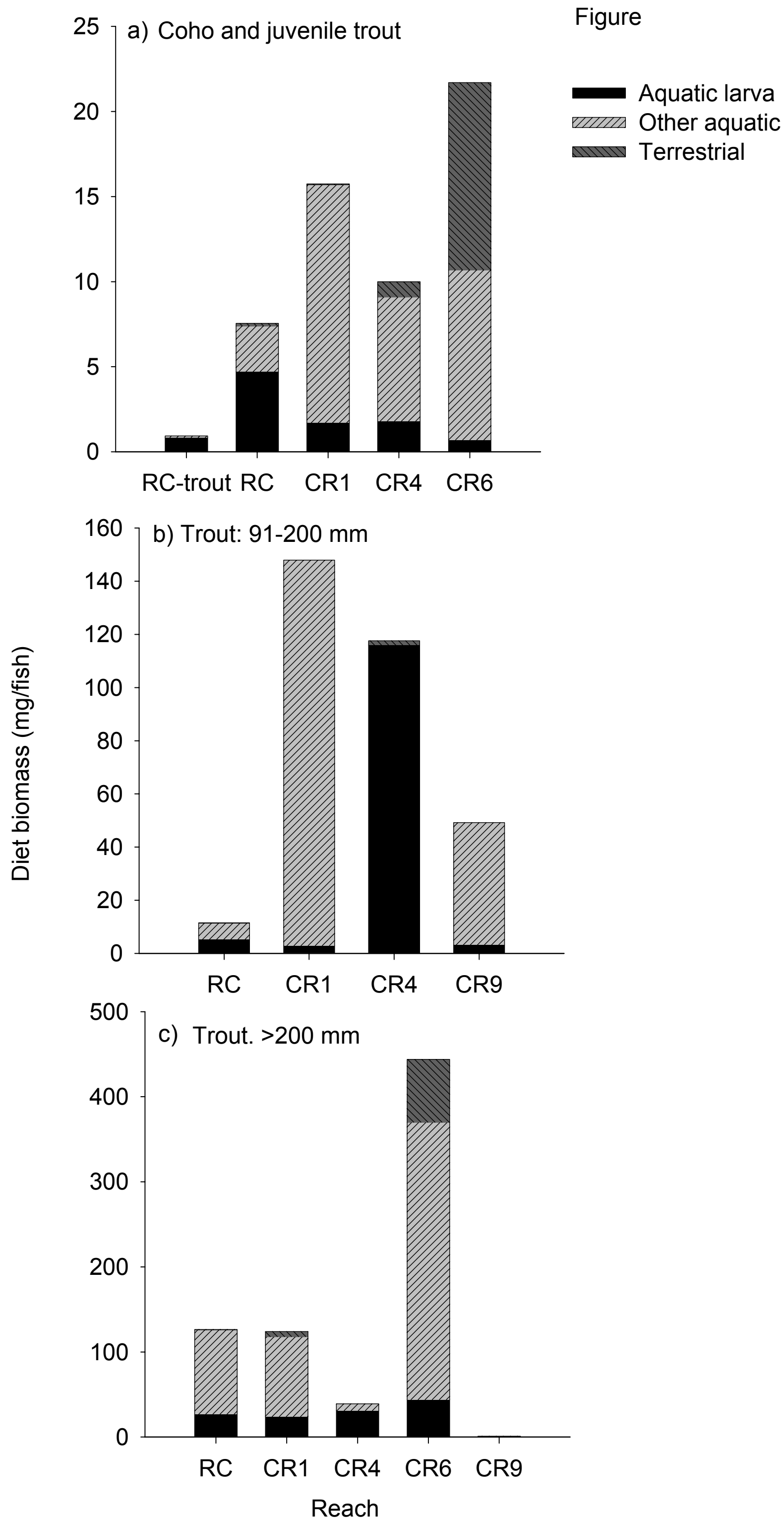

Figure 20. Biomass (mg) of stomach contents of a) juvenile trout and coho, b) medium trout and c) large trout collected from Rock Creek and mainstem reaches during summer 2007. Aquatic larvae include Ephemeroptera, Trichoptera, Diptera and Plecoptera larva; other aquatic includes Coleoptera, Hemiptera and Collembola.