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Fish Assemblage, Density, and Growth in Lateral Habitats within Natural and Regulated Sections of Washington's Elwha River Prior to Dam Removal

Abstract

We characterized seasonal fish assemblage, relative density, and growth in river margins above and between two Elwha River dams scheduled for removal. Fish assemblage and relative density differed in the lateral habitats of the middle-regulated and upper-unregulated sections of the Elwha River. Rainbow trout was the numerically dominant salmonid in both sections, with bull trout present in low numbers. Sculpin were common in the middle section, but not detected in the upper section. In 2004, mean length and biomass of age-0 rainbow trout were significantly smaller in the middle section than in the upper section by the end of the growing season (September). In 2005, an earlier emergence of rainbow trout in the middle section (July) compared to the upper section (August) corresponded with warmer water temperatures in the middle section. Despite lower growth, the margins of mainstem units in the middle section supported higher mean areal densities and biomass of age-0 rainbow trout than the upper section. These results suggest that growth performance of age-0 rainbow trout was lower in the middle section than in the upper section, which could have been a density-dependent response, or a result of poor food production in the sediment-starved regulated section, or both. Based on our findings, we believe that seasonal sampling of river margins within reference reaches is a cost effective and repeatable method for detection of biologically important short- and long-term changes in emergence timing, density, and growth of rainbow trout before and after dam removals in the Elwha River.

Introduction

The juxtaposition of two dams in the Elwha River, Glines Canyon Dam at rkm 21.7 and Elwha Dam at rkm 7.9, present differing conditions for fish production. The river above the upper dam is free flowing, with natural supplies of habitat-forming wood and sediment, but the middle section between the dams has been starved of wood and sediment recruitment, resulting in a less dynamic habitat (Kloehn et al. 2008). Because these river sections have been void of anadromous fish influence for 95 years, contrasts between the two sections present a unique opportunity to understand the current effects of the dams' existence and operations without the potential confounding effects of ocean productivity.

Given the fluvial and geomorphic characteristics of the river between the dams (Pess et al. 2008), this section of regulated river is likely to be particularly important for production of recolonizing anadromous fish species after the dams are removed (Brenkman et al. 2008). This section may experience an extensive change owing to the reconnection with nutrient inputs from downstream (especially via upstream migrating anadromous salmonids) and to the hydrologic inputs of sediment and wood from upstream. The physical influence from changes in flow, sediment, and wood will likely alter habitat that the river margins afford juvenile salmonids and other vertebrate and invertebrate species. Interactions of flow, sediment, and wood serve to intensify floodplain dynamics (Gregory et al. 2002), and alter the type and amount of habitat available along mainstem river margins, including side channels (Rabeni and Jacobson 1993). These lateral habitats can be highly important rearing areas for juvenile salmonids (Moore and Gregory 1988, Murphy et al. 1989, Hubert at al. 1994) and many other fish and aquatic species (Rabeni and Jacobson 1993, Schiemer et al. 1995). The change in amount, type, and location of lateral habitats associated with dam removal will likely have a major influence on assemblage structure, fish density, and individual growth of existing fish populations and those fish that colonize after dam removal.

The purpose of our study was to characterize the existing fish populations in lateral habitats above

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and between the Elwha River dams. Our approach was much driven by the need to fill information gaps and the need to keep costs low. We wanted to test if our approach could be an effective and low cost method to measure response of a particularly sensitive portion of the fish community to the likely biotic (e.g., introduction of other fish species) and abiotic (e.g., flow, sediment, and temperature) changes expected with dam removal. With removal of the Elwha dams, we considered it likely that fish populations in the river margins will experience change depending on the success of fish species available to colonize the reconnected and possibly reshaped habitat. We reasoned that existing fish species in the regulated portion of river between the dams will not only interact with the colonizing species for space and food, but will also need to adjust to substantial changes in habitat conditions and river temperature. Specific objectives of our study were to: 1) characterize assemblage of fish in river margins during summer months, 2) document growth, relative density, and biomass of young-of-the-year salmonids, and 3) determine if there were differences in the assemblage and population metrics between the upper and middle Elwha River prior to dam removal.

Study Area

The Elwha River flows 72 km to its confluence with the Strait of Juan de Fuca. Of the 72 rkm, there are 8 rkm below Elwha Dam and 45 rkm upstream of Glines Canyon Dam. Between Glines Canyon Dam and the upstream end of Lake Aldwell is a 9.5 km section of river that is not impounded.

For this study, we selected two reference sites located in unconstrained portions of the Elwha River. One reference site was located at rkm 19, between Glines Canyon Dam and Elwha Dam, which we refer to as the "middle section." This section of river is generally within a low gradient alluvial valley with substrate dominated by large cobble and boulder (Kloehn et al. 2008). The east bank of the river is highly armored with rip-rap serving to protect a road throughout most of its length. Glines Canyon Dam, the upstream border of the middle section, is operated as a run-of-the-river dam where daily flows are not altered, but daily hydrological regimes are modified by the dam (Gregory et al. 2002). Fish that inhabit the middle section and its tributaries include rainbow trout (*Oncorhynchus mykiss*), federally-listed "threatened" bull trout (*Salvelinus confluentus*), cutthroat trout (*O. clarkii*), non-native brook trout *(S. fontinalis),* and sculpin (*Cottus spp*.). Additionally, kokanee (*O. nerka*) inhabit Lake Sutherland, which drains into the middle section of the Elwha River (Table 1). Fish that inhabit the middle section cannot access the river upstream of Glines Canyon Dam, but entrainment can occur downstream at Elwha Dam. While we use the terms "rainbow trout" and "cutthroat trout", we do not mean to infer that these are purely "resident" forms, for they may well have been derived from the anadromous forms of *O. mykiss* (steelhead) or *O. clarkii* (sea-run cutthroat trout). This is also the case for bull trout, which may have exhibited anadromy prior to construction of the dams (Brenkman et al. 2007).

A second sample site was located near rkm 28 in a portion of river immediately upstream of Rica Canyon. The sample site was in an unregulated section of river that exists in nearly pristine habitat in Olympic National Park. This section of river, which we refer to as the "upper section", is within a low gradient alluvial valley bottom with a pool-riffle channel type and substrates dominated by gravel and cobble (Pess et al. 2008). While our site was small relative to the entirety of the upper Elwha system, it was located in the area that Gilbert

TABLE 1. Summary of salmonid species known to inhabit the lower, middle, and upper Elwha River. Based on Brenkman et al. (2008).

Elwha River	Anadromous salmonids[a]	Rainbow trout	Bull trout	Cutthroat trout	Brook trout	Kokanee salmon
Lower	Yes	Yes	Yes	Yes	Yes	No
Middle	No	Yes	Yes	Yes	Yes	Yes[b]
Upper	No	Yes	Yes	Yes[c]	No	No

[a] Includes salmon (Chinook, coho, pink, and chum) and steelhead.
[b] Present only in Lake Sutherland.
[c] Present only in Long Creek.

and Link (1995) described as the best example of pre-dam geomorphology for the area inundated by the upper dam. Potamodromous forms of rainbow trout and bull trout inhabit this section of river, and cutthroat trout are present, but potentially limited to a single tributary (Long Creek).

Methods

We characterized the juvenile fish assemblage and examined changes in relative densities and growth of young-of-the-year rainbow trout in river margins (including mainstem lateral habitats and side-channels) of the middle and upper Elwha River during summer months in 2004 and 2005. We sampled the upper and middle sites during the same week on a monthly basis. The allocation of sampling effort represented a balance between ecological impacts and practical limitations caused by logistical constraints and funding.

Habitat Units Sampled

We identified three pools and three non-pools in mainstem and side-channel habitats in each of the upper and middle sections. We attempted to sample these habitat units during each sampling period in 2004 and 2005. The units were contiguous to the maximum degree possible for the sake of sampling efficiency. Contrary to 2004, we achieved a completely balanced sampling design in 2005, with three pools and three non-pools sampled in both mainstem and side channels in both the upper and middle sections of the river during four sampling months (June, July, August, and September).

Backpack Electrofishing

We deemed backpack electrofishing as the most effective and feasible method to sample river margins in the logistically difficult to sample terrain. Snorkel methods were not feasible due to low water visibility during summer run-off, and boat electrofishing was not possible due to lack of road access to the upper site.

We conducted monthly backpack electrofishing surveys (using Smith-Root model 12B set at 60 Hz, 6 ms, 400-600 v) in the middle section during July-September 2004 and June-September 2005, and in the upper section during August-September 2004 and June-September 2005. Within each section, we attempted to sample a series of six habitat units (three pools and three non-pools) in both mainstem and side channel habitats. Because of equipment problems, we did not sample side-channel units in the middle section in September 2004. Electrofishing was limited to a single pass within the wadeable 4.5-m margin of the right river bank (when looking downstream). The electrofishing crew of three or more proceeded upstream without block-nets throughout the length of the pool and non-pool habitats. We attempted to capture all fish turned. Although effort was held consistent as possible among sampled units, capture efficiency was not estimated and largely unknown. From field observations, we surmised that capture efficiency was relatively high for young-of-year salmonids, but low for age-1 or older salmonids. In 2005, we carefully documented the actual length and width of the area sampled (Table 2) by subtracting those areas within the 4.5-m wide swath where the

TABLE 2. Lengths of habitat units selected for sampling and the sampled area for each month in 2005.

Site Channel type	Habitat type	n	Length of individual units (m)[a]	Mean sampled area (m^2) Jun	 Jul	 Aug	 Sep
Middle							
Mainstem	Pool	3	79, 61, 193	515	456[b]	457[b]	491[b]
	Non-pool	3	43, 84, 49	250	264[b]	291[b]	251[b]
Side Channel	Pool	3	53, 28, 20	110	131[b]	144[b]	189
	Non-pool	3	89, 57, 15	155	231[b]	217[b]	243
Upper							
Mainstem	Pool	3	90, 91, 50	302	316	340[b]	341[b]
	Non-pool	3	210, 53, 55	423	422	469[b]	472[b]
Side Channel	Pool	3	43, 7, 48	146	147[b]	128[b]	154[b]
	Non-pool	3	64, 33, 21	145	177[b]	183[b]	180[b]

[a] Lengths of units are those measured in July 2005, proceeding downstream to upstream. Upstream and downstream boundaries of the middle (5318056 N, 0455731 E; 5318345 N, 0445850 E) and upper (5311098 N, 0457458E; 5311318 N, 0457286 E) were determined by GPS using NAD27.

[b]Also sampled in 2004.

water was too deep, too fast, or too debris filled to sample effectively or safely.

Fish Handling

All fish collected were immediately placed in five gallon buckets that were regularly monitored to minimize stressful conditions. Each fish was lightly anesthetized with 50 mg/L MS-222 buffered with an equal amount of sodium bicarbonate, weighed to the nearest 0.1 g, and measured for fork length to the nearest mm. All fish were held in ambient temperature river water and released near their point of capture.

Water Temperature

To examine differences in water temperatures between river sections, we monitored water temperature within reference sites from August to September 2004 and from June to September 2005 using StowAway TidbiT units by Onset. These thermographs were set to record a value every 30 minutes. They were attached to a flow-through PVC pipe with pre-drilled holes and secured to a metal fence post with plastic zip ties.

Results

Fish Assemblage

We observed rainbow trout, bull trout, and sculpin in the middle section, but only rainbow trout and bull trout in the upper section of the Elwha River (Table 3). During most sampling months, both river sections were largely dominated by rainbow trout, but sculpin were especially numerous in side channels of the middle section (Figure 1). Bull trout occurred in both river sections, but comprised a low percentage of the fish assemblage (Figure 1). Bull trout were largely limited to mainstem habitats in both river sections. Although previously documented in the middle section, we did not capture brook trout in 2004 or 2005 (Table 1).

Growth of Rainbow Trout

Length-frequency analysis showed a clear distinction of the size distribution and growth of age-0 rainbow trout during summer months in 2004 and 2005 in both the middle and upper sections (Figure 2). Length and weight achieved by individual fish varied between year and section (ANOVA, interaction term year*section, $P < 0.001$; Table 4). In September 2004, mean length and biomass of age-0 rainbow trout were greater in the upper section than in the middle section (t-tests, $P < 0.001$). September likely represented the near end of the growing season as fish became subjected to cooler temperatures in fall and winter. In 2005, emergence date of age-0 rainbow trout appeared to be earlier (July) in the middle section, compared to the upper section (August; Figure 3). In September 2005, the mean length and biomass were larger than those in the upper section (t-tests: length, $P = 0.042$; biomass, $P = 0.054$; Table 4), which was reversed from 2004 but with smaller differences.

We rarely captured salmonids between 150-200 mm (e.g., rainbow trout: Figures 2 and 3), and we caught only 11 fish over 200 mm (8 rainbow trout, 3 bull trout) throughout the duration of the study. Older and larger salmonids were probably less vulnerable to our capture methods than age-0 and age-1 salmonids, and they may not have been as prevalent as younger salmonids in the lateral river margins (Figure 3, see next section).

Relative Density and Biomass

Based on our 2005 sample, the middle section supported higher relative density (number per 100 m^2) of age-0 rainbow trout in July, August, and September than the upper section (Figure 3). Differences in relative density between pool and non-pool habitats for both age-0 and age-1 or older rainbow trout were not significant (Table 5; ANOVA, $P > 0.05$). Significant interaction terms ($P < 0.05$) in the

TABLE 3. Species and number (% age-0) of fish observed during electrofishing surveys in our upper and middle sites of the Elwha River, 2004-2005.

Site	Channel type	Rainbow trout	Sculpin	Bull trout
Middle Elwha River	Mainstem	576 (80%)	230 (12%)	59 (86%)
	Side channel	192 (60%)	171 (6%)	1 (0%)
Upper Elwha River	Mainstem	106 (75%)	0	5 (60%)
	Side channel	71 (54%)	0	3 (67%)

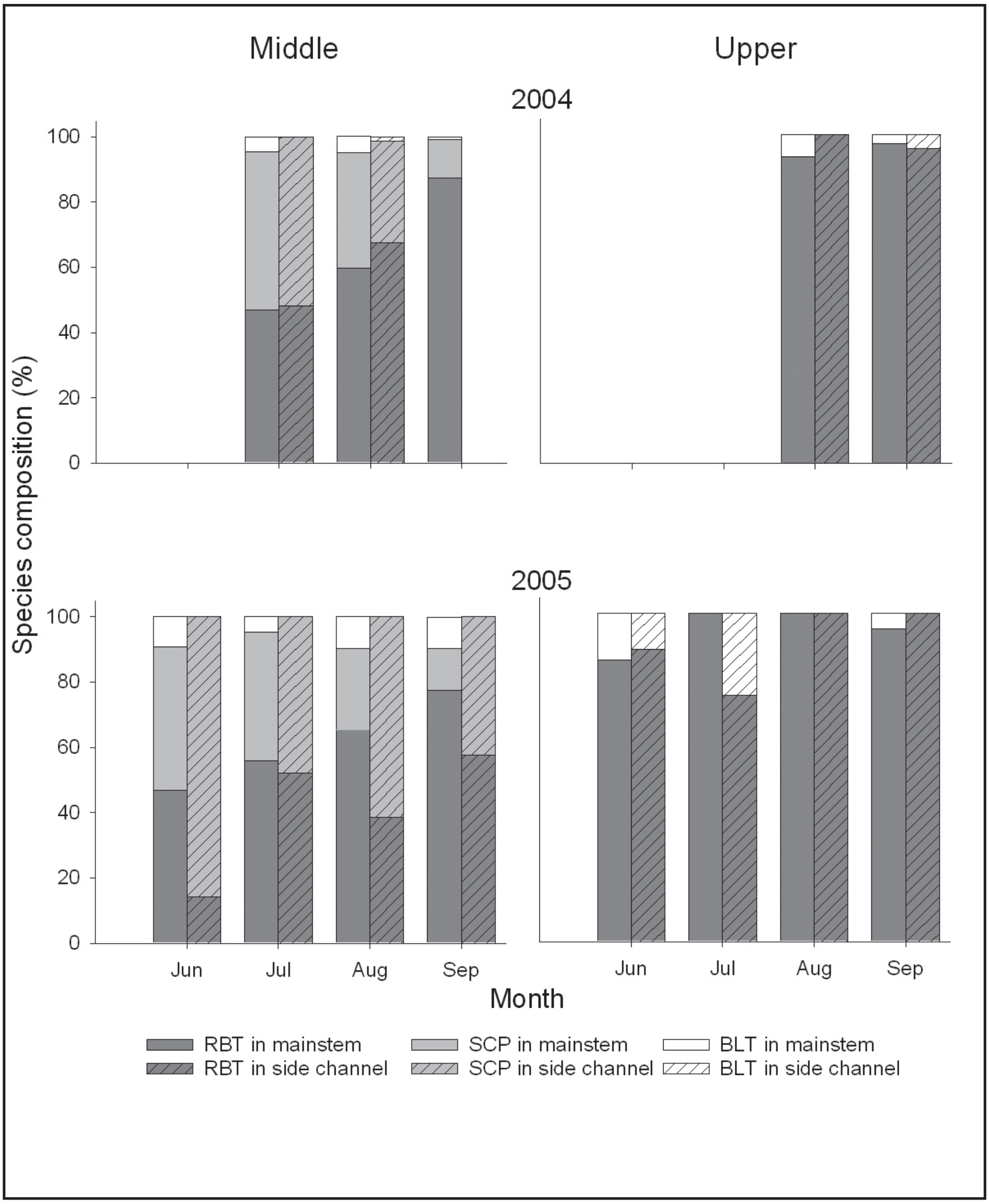

Figure 1. Percent composition of fish species in the middle and upper Elwha River by habitat type, month, and year. Absence of a bar indicates when and where no sampling occurred.

ANOVA (among main effects: section, channel type, and month) prevented clear isolation of the contribution of these individual main effects for differences in age-0 densities. Relative density of age-1 or older rainbow trout generally increased with sampling month, but the increasing trend was not significant (ANOVA, P = 0.116). Side channel habitats had significantly higher densities of age-1 or older rainbow trout than mainstem habitats (ANOVA, P = 0.030).

Relative biomass (g per 100 m^2) of rainbow trout had some similar, and some differing, patterns than that for relative density. Differences in mean biomass between pool and non-pool habitats for

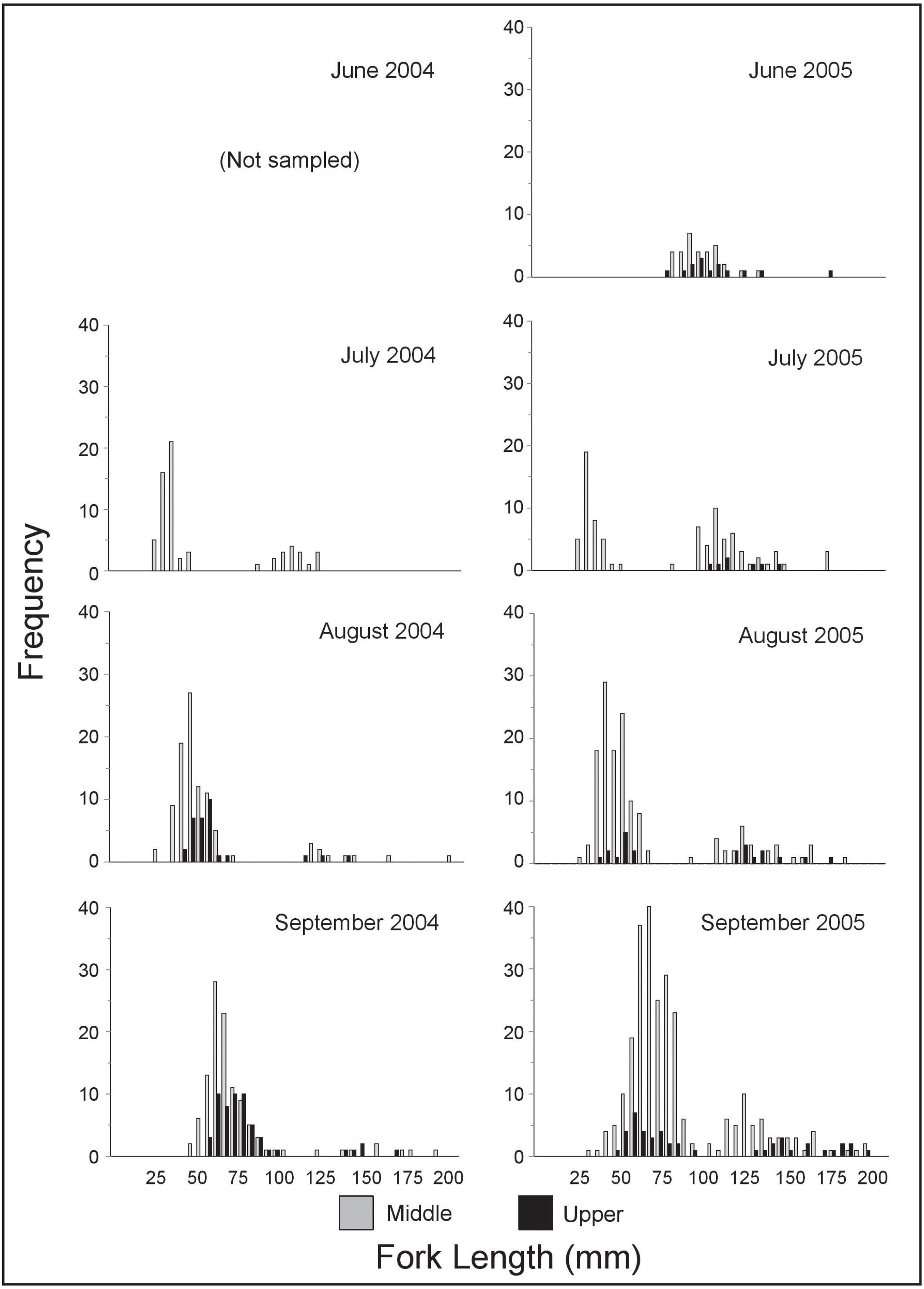

Figure 2. Length-frequency histograms for rainbow trout in the middle and upper Elwha River in June, July, August, and September 2004 and 2005. Data were limited to those fish with fork lengths 200 mm or shorter.

TABLE 4. Fork length and weight of age-0 rainbow trout in the middle and upper Elwha River, 2004 and 2005.

Section	Year	Sample date	n	Fork length (mm) Min	Mean	Max	Weight (g)[1] Min	Mean	Max
Middle	2004	20 Jul	47	23	31	41	0.1	0.3	0.7
		17 Aug	86	22	43	68	0.1	1.0	3.0
		28 Sep	100	44	62	84	0.7	2.7	6.6
Upper	2004	16 Aug	28	39	49	61	0.7	1.6	2.5
		27 Sep	51	53	68	92	1.4	3.8	7.5
Middle	2005	22 Jun[2]	0	---	---	---	---	---	---
		19 Jul	34	22	30	50	0.1	0.3	0.9
		17 Aug	113	25	43	64	0.1	1.0	2.8
		28 Sep	202	27	64	88	0.1	3.5	9.6
Upper	2005	23 Jun[2]	0	---	---	---	---	---	---
		20 Jul[2]	0	---	---	---	---	---	---
		16 Aug	11	35	46	55	0.3	1.0	2.0
		27 Sep	29	29	60	87	0.2	2.8	6.8

[1] Weight not available on four fish.

[2] No age-0 rainbow trout were captured.

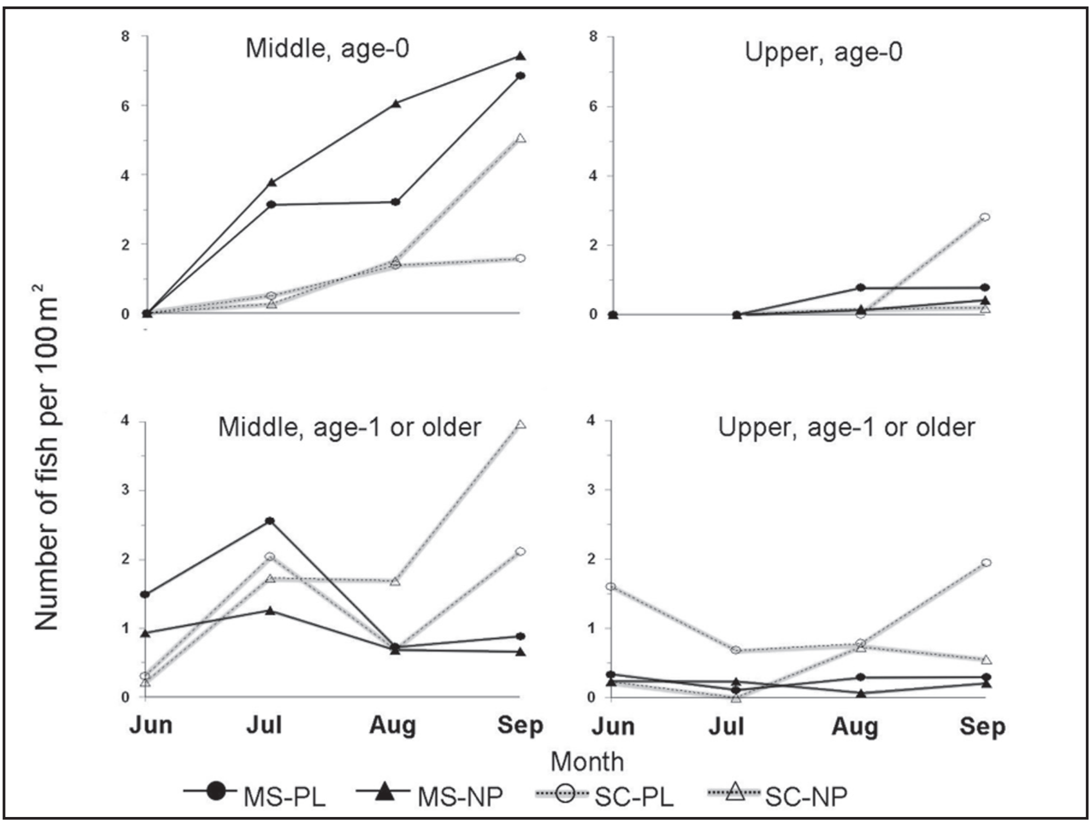

Figure 3. Relative density of age -0 and age-1 or older rainbow trout in mainstem pools (MS-PL), mainstem non-pools (MS-NP), side channel pools (SC-PL), and side channel non-pools (SC-NP) in the middle and upper Elwha River, 2005.

TABLE 5. Relative density of rainbow trout in 2005 for site, habitat type, month, and age class.

Site / Channel type	n	Month	Mean number of fish per 100^2 m (SD): Age-0 Pool	Age-0 Non-pool	Age-1 or older Pool	Age-1 or older Non-pool
Middle Elwha River						
Mainstem	3	June	0.00 (0.00)	0.00 (0.00)	1.64 (0.47)	0.80 (0.71)
	3	July	0.93 (0.69)	1.75 (1.51)	0.69 (0.18)	0.53 (0.53)
	3	August	4.42 (3.38)	6.84 (5.38)	0.81 (0.59)	0.64 (0.39)
	3	September	8.35 (4.43)	7.87 (4.56)	0.90 (0.10)	0.72 (0.83)
Side channel	3	June	0.00 (0.00)	0.00 (0.00)	0.25 (0.43)	0.13 (0.23)
	3	July	0.19 (0.33)	0.09 (0.16)	1.08 (0.51)	0.62 (0.56)
	3	August	1.17 (1.44)	1.23 (1.19)	0.74 (1.28)	1.88 (1.29)
	3	September	1.27 (0.80)	4.36 (1.51)	1.57 (1.57)	3.11 (2.77)
Upper Elwha River						
Mainstem	3	June	0.00 (0.00)	0.00 (0.00)	0.53 (0.69)	0.19 (0.18)
	3	July	0.00 (0.00)	0.00 (0.00)	0.08 (0.14)	0.47 (0.65)
	3	August	0.86 (0.40)	0.07 (0.12)	0.44 (0.76)	0.12 (0.20)
	3	September	0.71 (0.37)	0.46 (0.55)	0.43 (0.75)	0.19 (0.18)
Side channel	3	June	0.00 (0.00)	0.00 (0.00)	1.20 (1.28)	0.14 (0.24)
	3	July	0.00 (0.00)	0.00 (0.00)	1.41 (1.71)	0.00 (0.00)
	3	August	0.00 (0.00)	0.11 (0.19)	1.35 (1.39)	0.63 (0.55)
	3	September	3.26 (1.30)	0.44 (0.76)	3.66 (5.13)	0.63 (0.66)

both age classes were not significant (ANOVA, $P >$ 0.05). As with density, significant interaction terms ($P < 0.05$) in the ANOVA (among main effects: section, channel type, and month) prevented clear isolation of the contribution of other individual main effects for differences in age-0 biomass. Areal biomass of age-0 rainbow trout generally increased with time, and by September, their mean biomass was significantly higher than other months in the upper section (ANOVA by section, significant month effect, $P < 0.001$; Tukey's multiple range test, $P < 0.05$). Mean biomass was higher in side channels than in mainstem habitats (ANOVA by channel type, significant month effect, $P < 0.0001$; Tukey's multiple range test, $P < 0.05$). Across all locations and habitat types, mean biomass per 100 m^2 of age-1 or older rainbow trout increased with sampling month (ANOVA, $P = 0.016$), but mean biomass in September was similar to that of preceding months, August and July (Tukey's multiple range test, $P > 0.05$). Mean areal biomass of age-1 or older rainbow trout was significantly higher in side channel than mainstem habitats (ANOVA, $P = 0.011$).

Water Temperature

Water temperatures in the middle, regulated section of river were consistently higher than those in the upstream, unregulated section of river (Figure 4). In August and September, 2004 and 2005, maximum daily temperatures in the upper section did not overlap with the minimum daily temperatures in the middle section (Figure 4). In the middle section, maximum daily water temperatures reached up to 17.2°C in 2004 and 18.5°C in 2005, but in the upper section, these temperatures were lower: 12.5°C in 2004 and 16.0°C in 2005. Differences in minimum, mean, and maximum water temperatures between the two sites generally were small from June into August 2005 (Figure 4), but thermal regimes were well differentiated by late summer.

Diel temperature differences were not consistent between years for the months when both river sections were monitored (August-September 2004 and 2005). There were minimal differences in diel temperatures between our middle and upper sites in 2004 (Figure 5). In 2005, differences in diel water temperatures between the sites were more pronounced. At both sites, relatively high variation in day-to-day diel temperatures occurred from June through August 2005. The middle section exhibited consistently greater diel temperatures than the upper section in late August through September 2005, but in 2004 during this same period, occurrence of high diel temperatures in

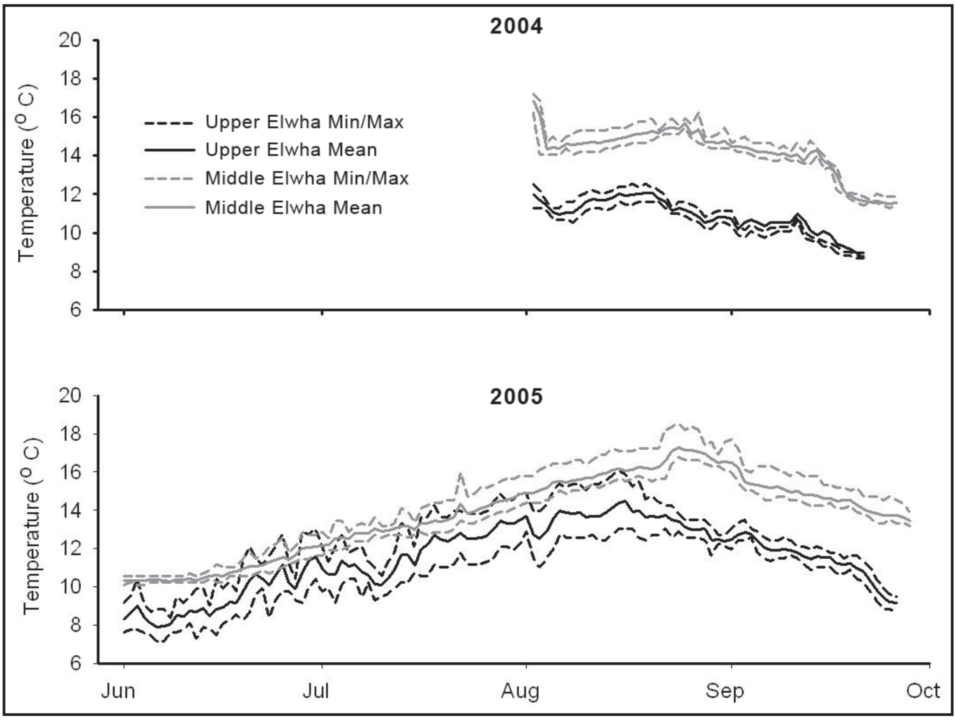

Figure 4. Minimum, mean, and maximum water temperatures (°C) in the middle and upper Elwha River, 2004 and 2005.

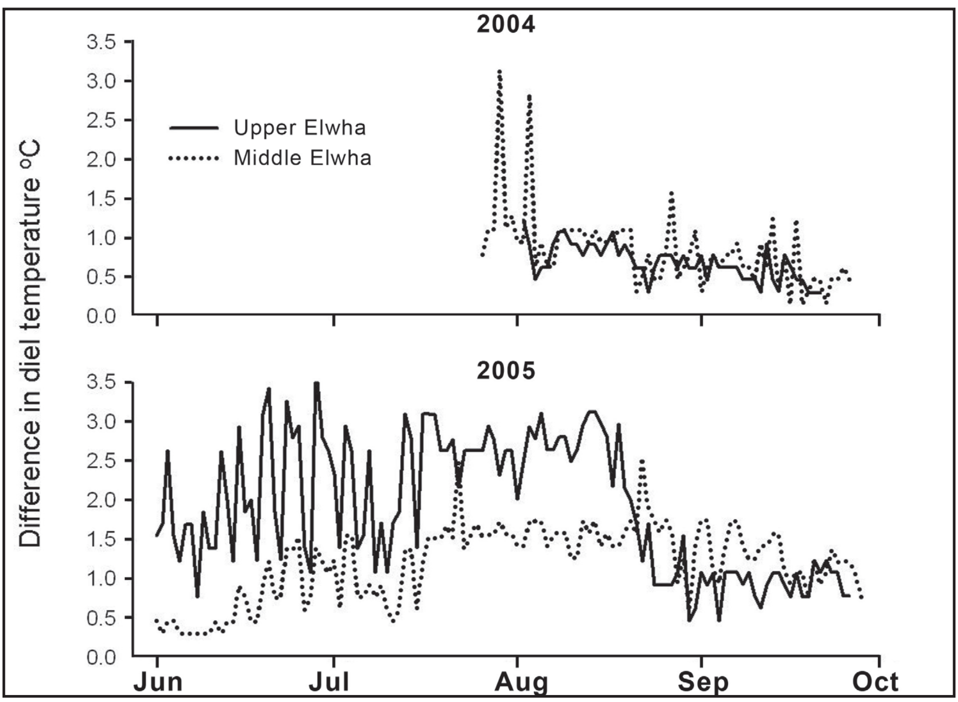

Figure 5. Difference in daily maximum and minimum water temperatures (°C) in the middle and upper Elwha River, 2004 and 2005.

the middle section was limited to multiple peak thermal events.

Discussion

We found definitive differences in fish density in the river margins and in water temperature between the regulated (middle) and unregulated (upper) sections of the Elwha River. The warmer temperatures in the middle section likely contributed to the earlier emergence timing of rainbow trout observed in 2005. During the hottest part of summer, the warmer water temperatures in the middle section are likely more optimal for growth of juvenile rainbow trout than those in the upper section, based on the growth curve developed by Railsback and Rose (1999). This curve predicts that growth of rainbow trout should be highest between 10-22°C, with peak growth occurring at about 15°C. However, growth (length and biomass) achieved by age-0 rainbow trout in the middle section by the end of the growing season was less than (2004) or similar (2005) to the upper sections. The less thermally variable (lower diel differences), albeit warmer, conditions in the regulated section appeared to provide better thermal conditions for rainbow trout growth, but long-term limited transport of sediment and wood from upstream may have limited food production and/or its availability to age-0 rainbow trout.

The lower growth performance in the middle section may be the result of the altered hydrologic transport of wood and sediment important to food production and habitat formation. Another possibility is that growth was density-dependent, whereby the lower growth may have been related to the much higher densities of age-0 rainbow trout in the middle section relative to the upper section. The effects of sharing the space with sculpin, a potential competitor, in the middle but not the upper section cannot be discounted for contributing to the growth pattern observed for rainbow trout. Growth of age-0 rainbow trout has implications for survival over their first winter, with larger sized individuals potentially being more resilient to winter conditions (but see Connolly and Petersen 2003).

No brook trout were captured in the upper or middle section in 2004 and 2005. We did not expect to capture brook trout in the upper section, because they appear to be confined to the areas between the dams and downstream of Elwha Dam (Brenkman et al. 2008). However, we also did not capture brook trout in the middle section despite their documented occurrence in the middle river. This may be because of the limitations of our sampling gear, but our reference site was located just upstream of where brook trout have been detected. Brenkman et al. (2008) suggest that brook trout may not readily colonize upstream areas after dam removal because velocity barriers (e.g., Rica Canyon) could limit upstream movements.

The continuous monitoring of water temperatures in the Elwha River revealed that the warming of the middle section was quite pronounced in late summer and early fall, which may be at least partially attributed to storage of heat in Lake Mills (Wunderlich et al. 1994). Surface releases from the reservoirs can raise temperatures 2 to 4°C in summer months (DOI 1995). The river warming coincides with the prolonged period of low-flows into early October.

Removal of the two dams will reconnect the middle and upper fish populations with anadromous and lower river fish species (Brenkman et al. 2008), and it will reestablish natural temperature, sediment, and flow patterns in the middle section. However, these sections of river will not likely become homogenous with respect to their fish assemblage and productivity. The middle section will likely experience a dramatic short-term disturbance from fine sediment with removal of Glines Canyon Dam (Randle et al. 2004, Pess et al. 2008). These fine sediments could decrease the quality of habitat now afforded to juvenile salmonids in the river margins. In the long-term, because of distance from the Pacific Ocean and high water velocities and hydraulic drops in canyon areas (e.g., Rica Canyon just downstream of our upper section sampling site), the middle section may experience much higher densities of pink and chum salmon than the upper section after the short-term disturbances are dissipated (Pess et al. 2008). Owing to the nutritive benefits of these sometimes prolific salmon species, added to the expected benefits of reestablished natural sediment and wood transport, the middle section may become a highly productive area for fish.

The sampling methods in this study were designed to characterize the fish assemblage in river margins of reference sites in regulated and unregulated sections of the Elwha River during summer months. We documented fish growth, relative density, and biomass of young-of-the-year salmonids, and we examined differences in the fish assemblage between sites in the upper and middle river. Sampling was limited to two index areas, with our upper site not likely to be representative of the long and complex upper Elwha River as a whole. Because we could not install block nets in the river, we were unable to assess sampling efficiency. The Elwha River is inherently difficult to sample, which poses numerous challenges in sampling fish. Areas above Glines Canyon Dam have prolonged periods of high river flows, low water visibility, and poor access. Backpack electrofishing was a low cost method that accommodated many of the challenges inherent in working in a roadless portion of this large river. Our results suggest that the sampling design was adequate to show important differences and within-year changes in fish populations in the margins of the middle and upper river sites.

By sampling the river margins multiple times through the summer months, we were able to gain information on emergence timing, relative density, and growth of age-0 rainbow trout. Although this approach did not allow us the ability to assess the true density or age-structure of rainbow trout or other members of the fish community, we believe it to be a repeatable and cost-effective method for measuring some important aspects of short-term and long-term fish response to dam removal in the Elwha system.

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