Monitoring Juvenile Salmon and Resident Fish within the Matanuska-Susitna Basin

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October 2011

Acknowledgements

This project was conducted with partial support from the Mat-Su Basin Salmon Habitat Partnership under the National Fish Habitat Action Plan. We appreciate the field support provided by Leslie Jensen and Hannah Ramage.

Introduction

The sport and commercial salmon harvest is a major component in the economy of Southcentral Alaska and the Matanuska-Susitna Borough. Salmon abundance depends, in part, on their survival and growth during their fresh-water residency. Juvenile salmon growth and survival is influenced by the quality and quantity of their fresh water habitat. Public support for the protection of water quality in Alaska is largely through desire to protect commercial and recreational salmon fisheries (TNC 2011). The importance of water quality and physical habitat has been recognized by the Mat-Su salmon Partnership as a critical component in the strategy for the protection of salmon (Smith and Anderson 2008). Salmon are one of the target indicators of Mat-Su Salmon Partnership strategic actions; however, the Partnership does not include the abundance of juvenile salmon in evaluating the health of salmon stocks (Smith and Anderson 2008). While water quality and habitat condition are clearly important for rearing juvenile salmon, and salmon production depends, in part, on their growth and survival during fresh-water residency, Alaska does not have a monitoring program in place to measure changes in the abundance of rearing juvenile salmon or tools to evaluate differences in salmon abundance to changes in water quality or physical habitat. The development and implementation of a program to monitor juvenile salmon abundance is a necessary step to track changes in salmon abundance and to determine if those changes are due to habitat conditions during their fresh-water residency.

The use of biological indicators is an integral part of many states' water quality standards. However, Alaska's water quality standards do not include biocriteria or measures of juvenile salmon abundance to assess water quality (ADEC 2011). The concept of biocriteria is not new, and many states began developing biological assessment programs in the late 1980s and early 1990s after a new body of knowledge supported that biotic monitoring of water quality overcomes many of the limitations related to measures of compliance with water quality standards (Davis and Simon 1995). Direct measures of the biotic community are necessary to accurately assess the condition of aquatic ecosystems (Karr and Chu 1999).

The health of the biotic community integrates the effects of different environmental stressors, such as increased sediment loading, direct habitat alterations, temperature fluctuations, and changes in flow regime. For example, the effects of suspended sediment on juvenile salmon are greater at higher temperatures. The influence of high water temperatures on salmon is modified by acclimation and available food resources. The use of biocriteria in regulatory programs therefore provides a more comprehensive and effective monitoring strategy than simply monitoring for changes in physical chemistry or habitat (Barbour et al 2000). Furthermore, biological integrity has become an important focus within the EPA for assessing the condition of our nation's surface waters, and documenting the success of aquatic resource protection (USEPA 1990).

Monitoring the relative juvenile salmon abundance could be used to evaluate Strategic Action Plan effectiveness. Evaluating the effectiveness of implementing the Strategic Action Plan of the Mat-Su Basin Habitat Partnership and monitoring water quality are key components to the successful protection of salmon. Salmon are one of the conservation targets of the Mat-Su Salmon Partnership's Strategic Action Plan; however, the Key Attribute 2 used to evaluate this target is based upon adult escapement. This attribute has some limitations as an indicator because adult returns reflect fresh water conditions 3 to 5 years previously, and are affected by ocean conditions and the impacts of the commercial fishery.

Juvenile coho, Chinook, and sockeye salmon spend from 1 to 3 years rearing in freshwater lakes and streams prior to migrating to the ocean as smolt. Monitoring juvenile salmon abundance would provide a direct evaluation of water quality changes including increasing water temperatures, and other physical and biotic impacts such as reduced instream flows, habitat modification, and the proliferation of invasive northern pike. The problem we face is that there is no direct link between plan indicators and salmon. We can measure change in ecological attributes and their indicators, but in order to get public support for land management or permitting decisions, we need to show how these changes affect salmon. Similarly, we can monitor changes to water quality or flow volume, however, before we can have the public and political support to deny a water use permit application or require treatment of stormwater runoff, we need to show a direct connection to the abundance of salmon.

ARRI has used the fish community as a component of water quality monitoring within the Mat-Su Basin since 2001. Using these methods we have measured differences in juvenile salmon abundance relative to migration barriers (Davis and Davis 2011), the presence of pike, and increases in turbidity (Davis and Davis 2010, 2011b). We have also measured differences in growth rates due to increased water temperatures, and consistent catch rates over multiple years in pristine un-impacted streams. It may therefore be useful to use juvenile salmon as indicators of change when monitoring human impacts to freshwater salmon habitat.

The objective of this study is to refine methods and to initiate the monitoring of juvenile salmon and resident fish communities in Matanuska-Susitna are streams. Fish community composition can vary between sites and over time due to sampling collection methods, natural spatial and temporal variability in stream physical and chemical characteristics, and numbers of returning adult spawners. Methods must be refined so that we can tell the difference between natural and human-induced differences in fish community composition and fitness. Juvenile fish sampling methods must be refined to reduce the variability due to sample collection. This will increase the sensitivity of monitoring results to reflect changes in fish habitat. Fish community metrics also can vary naturally among sites due to differences in stream classification types. That is, streams that have different channel form, water velocities, substrates, etc. Therefore, sampling locations should be distributed among sites based upon geomorphic classification. We will test for differences in fish community metrics and among stream that very in physical and chemical characteristics. Fish community metrics will be compared to previously collected samples to investigate factors influencing temporal variability.

Methods

Sampling Locations

Sampling in 2010 and 2011 was conducted at 16 stream locations that represent three stream types (lake-stream complex, wetland, and upland). Nine sites were in upland streams, 3 in lake-stream complexes, and 4 in wetland streams. Streams included Buddy Creek, Caswell Creek, Colter Creek, Cottonwood Creek, Greys Creek, Iron Creek, Meadow Creek, Queer Creek, Swiftwater Creek, Wasilla Creek, Kroto Creek, and Moose Creek (Table 1, Figure 1).

Table 1: Site names, coordinates, locations, and stream types.

Site	Latitude	Longitude	Stream type	Location
Buddy Creek	62.13410	-150.00537	Upland	At Anaconda Road crossing
Caswell Creek	61.94748	-150.05572	Lake-stream complex	Downstream of Parks Highway crossing
Colter Creek	61.65583	-149.49877	Upland	At Seize Road crossing
Cottonwood Creek 3	61.57481	-149.41104	Lake-stream complex	Downstream of Old Matanuska Road crossing

Cottonwood Creek 4	61.52517	-149.52959	Lake-stream complex	At Surrey Road crossing
Greys Creek	61.89685	-150.07726	Wetland	At Parks Highway crossing
Iron Creek 1	61.83594	-149.84396	Upland	South Fork Iron Creek upstream of Willer Kash Road
Iron Creek 2	61.83450	-149.83515	Upland	North Fork Iron Creek upstream of Willer Kash Road
Meadow Creek 1	61.59078	-149.66707	Wetland	Downstream of Meadow Lakes Loop crossing of Little Meadow Creek
Meadow Creek 3	61.56252	-149.82607	Wetland	Downstream of Beaver Lake Road crossing
Queer Creek	62.19256	-150.21750	Wetland	West of Parks Highway
Swiftwater Creek	61.49730	-149.51248	Upland	At Softwind Road crossing
Wasilla Creek 3	61.58759	-149.25203	Upland	At Tributary Road crossing
Wasilla Creek 4	61.56721	-149.31371	Upland	Downstream of Fireweed Road crossing
Kroto Creek	62.13268	-150.53889	Upland	Downstream of Oilwell Road crossing
Moose Creek	62.22802	-150.44332	Upland	At Oilwell Road crossing

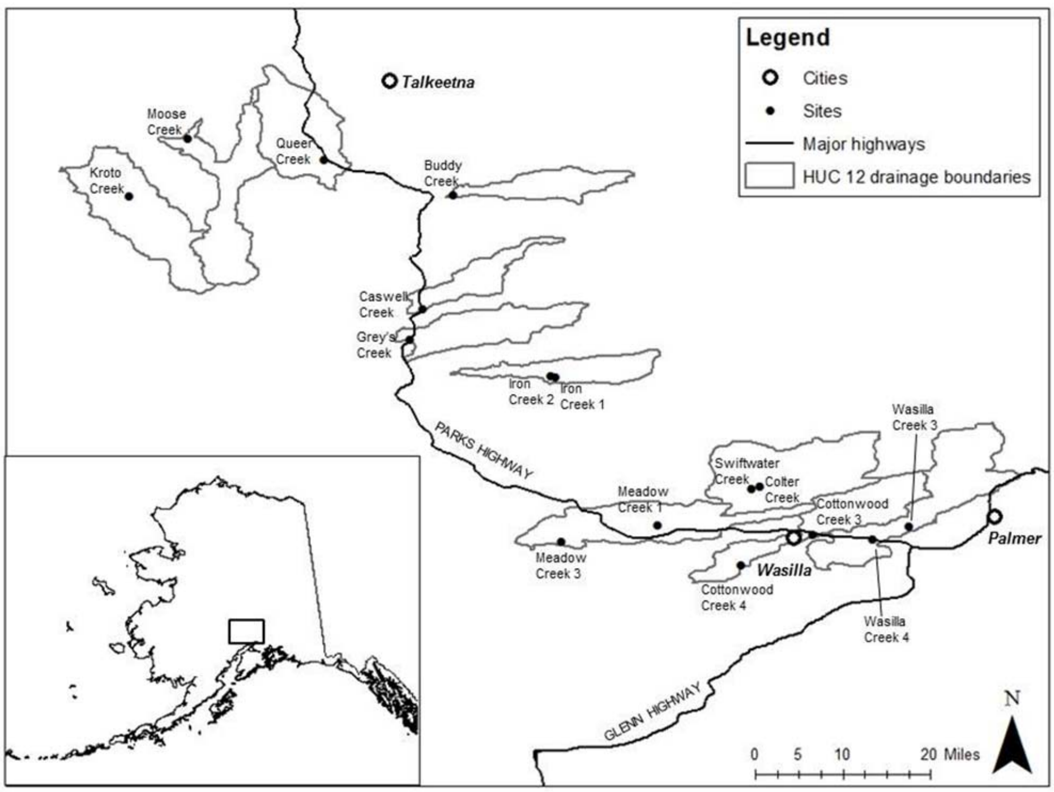

Figure 1: Map of sampling locations.

Trapping Efficiency

A series of experiments were conducted to evaluate the use of minnow trapping as a method to sample rearing juvenile salmon and resident fish. These experiments included the evaluation of (1) the number of traps necessary to obtain consistent measures of catch per unit trap (CPUT), (2) the variability in individual trap catch rate over time, (3) the repeatability of CPUT measures, and (4) downstream immigration of fish into the sampling reach due to the odor released from salmon roe.

Experiment 1. The objective of this experiment was to determine the total number of traps necessary to obtain consistent measures of CPUT. In order to make this determination, we compared the cumulative mean CPUT of all salmonids, with an increasing number of traps from 1 to 20, from the 16 sampling sites in 2011. The stabilization point was considered to be the trap at which the difference between the cumulative mean of CPUT of that trap and the previous trap reached a value less than one. The difference in cumulative mean was calculated as:

$$\frac{n_1 + n_2 + n_3 \ldots + n_x}{x} - \frac{n_1 + n_2 + n_3 \ldots + n_{x+1}}{x+1}$$

Where n is CPUT for a given trap and x is the trap number. The stabilization point of the mean and standard deviation of the difference in cumulative mean of salmonid CPUT at all sites was determined in order to obtain a generalization for all streams. However, we also evaluated whether the number of fish within a sampling reach affected the number of traps necessary to reach a stabilization point.

Experiment 2. The objective of this test was to determine how long a trap should be fished to maximize catch. That is, we hypothesized that there is some minimum amount of time necessary for fish to move into the trap and the number of fish moving into the trap should increase over time. However, fish also can escape from the trap and so fish loss could also increase the longer a trap remains in the stream. Ten traps were placed within backwater or slow moving water areas protected by cover from overhanging banks or woody debris. Each trap was fished for intervals of 3 hours, 6 hours, and overnight for 12 hours and 24 hours. After each fishing interval, all fish were counted and identified, then returned to their same trap and location in the stream. After 24 hours all fish were counted, identified, and measured to fork length. Mean and standard deviation of salmonid CPUT/time was compared across time intervals to assess whether there was a constant, linear relationship between CPUT and time. Loss of fish per unit trap was also compared over time, in order to determine if there is a relationship between losses and the density of fish already in the trap. We used paired T-tests to test for significant differences in CPUT of coho and Chinook salmon between each catch interval (alpha 0.05).

Experiment 3. Replicate sampling was conducted in the fall of 2011 in order to analyze the repeatability of CPUT measures. Sampling was replicated at 6 sites. Repeat sampling was conducted within one week of initial sampling, in order to assess the fish community under the same environmental conditions. Chinook salmon and coho salmon abundance (CPUT) was compared from initial sampling to replicate sampling using paired t-tests.

Experiment 4. The objective of this experiment was to determine if the downstream flow of the odor from salmon roe used as bait in the minnow traps enticed fish to migrate into the sampling reach. We hypothesized that if fish were migrating into the sampling reach from downstream, then catch rates in the traps farthest downstream should be consistently higher. In order to assess whether more fish were captured in the furthest downstream trap, a paired t-test was used to test whether the most downstream trap had a significantly higher catch than the next trap upstream. This test was conducted using salmonid CPUT at all 16 sites. We also ranked the catch from all of the traps within each sampling reach based upon the number of fish in each trap and then compared the ranked catches among site based on trap location to see if the highest ranked catches were occurring in the traps farthest downstream.

Measures of the Fish Community

The fish community was sampled in late August or early September to integrate the effects of summer rearing condition on emerging fry. Fish sampling was conducted using baited Gee minnow traps (1/4 inch mesh, Memphis Net and Twine). Traps were baited with salmon roe enclosed in perforated whirl-pak bags. Twenty minnow traps were fished within each sampling reach for 20 to 24 hours. Traps were placed within backwater or slow moving water areas protected by cover from overhanging banks or woody debris. A separation distance of at least 10 m was maintained between traps. Fish were transferred from the traps to plastic buckets filled with stream water, anesthetized using MS222, identified to species, and measured to fork length (FL). The first 50 salmonids within each sampling trip were weighed to the nearest 10^{-2} grams (Scout Pro Scale). All fish from each trap were identified separately providing 20 replicate CPUT values.

Fish community metrics were calculated for each stream sampling location to allow for comparisons among sites. Metrics included CPUT, juvenile salmon condition factors, ratios of anadromous to resident fish, ratios of salmonids to sticklebacks, and ratios of salmonids to sculpin. Resident fish included rainbow trout, Dolly Varden char, sculpin species, and three-spine sticklebacks. CPUT was calculated at each site for coho salmon, Chinook salmon, and total salmonids. Age classes were determined from length frequency distributions, and age-0 coho salmon CPUT was calculated for each site. Condition factor was calculated for each individual fish using the formula

$$(W/L^3) \times 10000$$

where *W* is weight in grams and *L* is fork length in millimeters.

Stream Classification and Habitat Assessment

Streams were classified based on their physical properties using the Rosgen method (Rosgen 1994). Physical properties include characteristics of channel cross section, longitudinal profile, and plan-form features. Cross section measurements include entrenchment ratio. Entrenchment ratio is the width of the flood prone area (width at 2 x bankfull depth) to channel width at bankfull depth, width to depth ratio, and dominant channel substrate. Longitudinal profile measurements include water surface slope and bed features (delineative criteria describing channel configuration in terms of riffle/pools, rapids, step/pools, cascades and convergence/divergence features). Plan-form feature measurements included sinuosity (stream length/valley length) and meander width ratio (meander belt width/bankfull width).

Habitat assessments for all sites were conducted in the spring of 2011 using AK SOP Method 003 (Major and Barbour 2001). This method ranks 5 parameters within the sampling reach, and 3 parameters for each stream segment. The 5 parameters within the sampling reach are epifaunal substrate and available cover, embeddedness, velocity-depth combinations, sediment deposition, and channel flow status. The 3 parameters for each stream segment are channel alteration, frequency of riffles or bends (for riffle/run streams)/channel sinuosity (for glide/pool streams), and bank stability. Each parameter is based on biological relationships that the observer evaluates qualitatively and ranks on a scale from 0 to 20. The habitat assessment provides a comprehensive picture of the habitat available to fish, macroinvertebrates, and periphyton. The method equates qualitative evaluations for each parameter to quantitative values from 0 to 20. The overall habitat assessment value is calculated as the sum of all 8 parameters.

Water Quality

Stream water turbidity, specific conductivity, pH, dissolved oxygen, temperature, and discharge were measured at each location concurrent with fish sampling in 2010 and 2011. Turbidity (NTU) and true color (CU) were measured using a LaMotte 2020we/wi Turbidimeter. Specific conductivity (µS/cm) and pH were measured using a handheld meter (YSI Model 63). Dissolved oxygen (mg/L and percent saturation) was measured using a handheld YSI 550A dissolved oxygen meter. Discharge (cfs) was measured using a Swoffer Model 3000 current meter. Water temperature at the initiation of fish trapping (^{o}C) was calculated as the average of measurements taken with the YSI Model 63 and YSI 550A meters. Water temperature at 9 of the 16 sites also was measured using Onset Pro V2 loggers, recording every 15 minutes from May through September.

Temporal Variability

A subset of these streams were sampled from 2008 through 2011 (Colter Creek, Iron Creek, Queer Creek, Buddy Creek, and Swiftwater Creek), allowing for evaluation of temporal variability in CPUT, condition factors, and community metrics. Annual variability was evaluated relative to differences in water physical characteristics (temperature, pH, specific conductance, dissolved oxygen, and turbidity) and adult salmon escapement in index streams the previous year. Coho salmon escapement data for the Little Susitna River, Cottonwood Creek, Wasilla Creek, Rabideux Creek, and Deshka River for 2007, 2008, and 2009 was obtained from the Alaska Department of Fish and Game.

Data analysis

Coho salmon CPUT, coho YOY CPUT, mode of coho FL, coho YOY FL max, and coho salmon condition factors were compared within 2010 and 2011 across stream types using ANOVA. Streams were categorized into two stream types, as upland or lowland. Lowland streams were considered to be both wetland streams and lake-stream complexes. This test was conducted in order to assess if there are differences in the abundance and biomass of the juvenile salmon community across stream types, and if there is a preference for specific habitat characteristics between the two different species.

Correlation analysis was used to test for relationships between salmonid CPUT, Chinook salmon CPUT, coho salmon CPUT, coho YOY CPUT, mode of coho FL, coho YOY FL max, coho salmon condition factors, seasonal maximum temperatures, physical chemistry measurements, and habitat assessment for 2010. These tests were conducted in order to evaluate if there were impacts of water quality and habitat quality on fish abundance and biomass. The abundance and mode FL of coho salmon and Chinook salmon were compared within each year using ANOVA, in order to test for differences in abundance and size between these two species.

Biometrics were compared across all years for the 6 sites with consistent data using ANOVA in order to assess if there have been fluctuations in the fish community over the past 4 years. These biometrics included coho salmon CPUT, Chinook salmon CPUT, salmonid CPUT, coho YOY CPUT, mode of coho FL, coho YOY FL max, coho salmon condition factors, and the community composition ratios. ANOVA was also used to test for differences in these variables across all 14 sites from 2010 to 2011. Paired t-tests were conducted on escapement data and seasonal maximum temperatures across years to explain any changes in abundance.

Results

Trapping efficiency

Experiment 1. The relationship between the difference in mean CPUT with the total number of traps used sorted by mean salmonid CPUT is shown in Table 2. For most sites, the difference in CPUT is less than 1 fish when 12 to 13 traps are used. All of the sites had a difference of <1 mean CPUT when 20 traps were used. Mean CPUT stabilizes with fewer traps at sites with fewer fish, and takes more traps to stabilize at sites with higher fish abundance (Table 2). For example, at sites with up to a mean of 8 CPUT, using more than 8 traps did not result in a different mean. On average, mean difference in cumulative mean of salmonid CPUT decreases to less than one between traps 6 and 7 (Figure 2). The standard deviation of the difference in cumulative mean of salmonid CPUT across sites decreases to less than one between traps 6 and 7.

Table 2: Difference in cumulative mean of salmonid CPUT between traps. Cells highlighted in red indicate a difference of greater than one salmonid between subsequent traps. Sites are sorted from greatest to least mean salmonid CPUT.

Trap interval	Swiftwater Creek	Wasilla Creek 4	Colter Creek	Wasilla Creek 3	Meadow Creek 1	Buddy Creek	Queer Creek	Caswell Creek	Moose Creek	Cottonwood Creek 3	Greys Creek	Iron Creek 1	Iron Creek 2	Cottonwood Creek 4	Meadow Creek 3	Kroto Creek
Mean salmonid CPUT	22.65	14.90	14.30	12.95	12.85	12.50	11.80	9.60	8.65	8.05	7.20	6.95	6.30	6.10	3.60	0.20
2 to 3	1.67	5.00	6.17	2.83	4.33	2.17	0.83	1.50	3.17	0.67	3.50	2.83	1.17	0.67	3.83	0.67
3 to 4	4.08	2.25	2.92	0.42	3.67	2.67	2.83	1.00	1.08	3.08	2.75	2.58	1.17	0.58	0.08	0.08
4 to 5	5.05	3.65	3.05	1.25	1.00	1.20	0.30	0.80	1.35	0.45	1.55	1.55	0.50	0.55	1.25	0.15
5 to 6	0.30	2.07	1.20	0.50	0.83	0.20	3.13	0.97	0.90	0.47	4.47	0.30	0.00	0.63	0.83	0.10
6 to 7	2.50	1.48	0.29	0.64	1.45	0.71	0.95	0.40	0.21	0.33	1.52	0.36	0.43	0.26	0.26	0.07
7 to 8	0.75	1.02	0.54	0.02	0.34	1.04	0.46	0.68	0.04	1.50	0.61	0.98	0.05	0.32	0.05	0.05
8 to 9	0.92	1.57	0.53	1.24	1.15	0.53	1.08	0.19	0.19	1.83	0.81	0.65	0.29	0.31	0.74	0.04
9 to 10	0.23	1.26	0.58	0.11	0.92	0.82	0.87	1.34	0.44	2.07	0.16	0.32	0.93	0.26	0.69	0.03
10 to 11	0.72	0.75	1.07	0.73	0.57	0.95	1.75	0.55	1.09	0.22	0.05	0.63	0.04	0.34	0.16	0.06
11 to 12	0.65	1.20	0.56	0.14	0.73	0.13	0.70	0.13	1.91	0.85	0.54	0.02	0.20	0.22	0.05	0.03
12 to 13	0.32	0.29	0.86	0.43	0.31	0.58	0.94	0.19	0.92	0.10	0.46	0.06	0.78	0.19	0.35	0.03
13 to 14	0.35	0.53	0.45	0.35	0.34	0.36	0.95	0.23	0.07	0.73	0.32	0.19	0.03	0.30	0.37	0.02
14 to 15	0.10	0.06	0.34	0.03	1.64	0.29	0.18	0.80	0.14	0.37	0.14	0.97	0.02	0.20	0.32	0.02
15 to 16	0.04	0.07	0.49	0.10	0.06	0.25	0.47	0.68	0.44	0.57	0.31	0.34	0.23	0.02	0.22	0.02
16 to 17	0.86	0.65	0.31	0.38	0.47	0.63	0.47	0.30	1.15	0.44	0.51	0.23	0.14	0.96	0.25	0.01
17 to 18	3.13	0.81	0.11	1.50	1.03	0.44	0.09	0.49	0.20	0.33	0.40	0.19	0.07	0.15	0.17	0.01
18 to 19	1.17	1.01	0.26	0.29	0.87	0.34	0.03	0.56	0.34	0.34	0.30	0.04	0.12	0.19	0.10	0.01
19 to 20	0.35	0.11	0.67	0.31	0.48	0.34	0.27	0.29	0.35	0.06	0.27	0.26	0.19	0.27	0.19	0.01

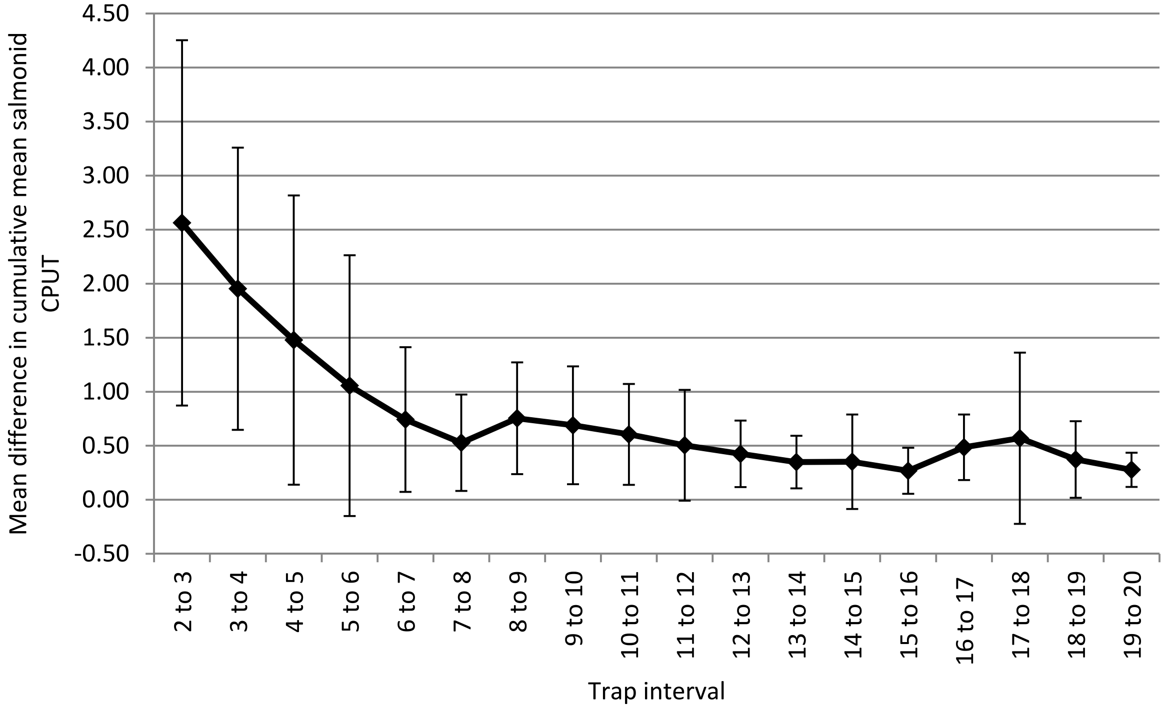

Figure 2: Mean difference in cumulative mean of salmonid CPUT between traps at all sites. Error bars represent one standard deviation from the mean.

Experiment 2. The use of salmon roe in 20 traps within a sampling reach did not result in an increase in CPUT in the downstream traps. This supports the hypothesis that there is no increase in migration due to the use of salmon roe and that fish were not drawn into the sampling reach. Mean CPUT for trap number 19 (the next to the last downstream trap) was t12.3 and 9.0 for trap 20 (the farthest downstream trap). Using paired tests, there was no significant difference in catch between the bottom trap and the trap next upstream for all 16 sites ($t(10) = 2.13$, $p = 0.258$). There was no relationship between CPUT and trap number (distance downstream) for mean CPUT or ranked CPUT. Using all sites, there was no difference in ranked CPUT between trap numbers. That is, the position in the stream, from upstream to downstream, did not affect CPUT.

Experiment 3. The numbers of species captured and mean CPUT increased with fishing time up to 24 hours. Within the first 3 hours, coho salmon, Chinook salmon, and stickleback were present in traps. After 12 hours sculpin were present and after 24 hours rainbow trout. Mean CPUT for all salmonids increased from 6.2 after 3 hours to 11.9 after 24 hours. For coho salmon, CPUT increased from 4.2 to 7.9 from 3 to 24 hours. However, there was little change between 12 and 24 hours. The difference in coho salmon CPUT and Chinook salmon CPUT was not significantly different between 12 and 24 hours ($t(9) = -1.71$, $p = 0.121$; $t(8) = -1.58$, $p = 0.154$). However, the difference in catch between 12 and 24 hours was significant when using all species combined ($t(9) = -4.15$, $p = 0.002$).

The rate of fish capture and the variability in CPUT per hour decreased up to 24 hours (Figure 3). Mean CPUT per time for all salmonids decreases as traps are fished for longer periods of time. During the first 3 hours on average 2 salmonids were captured per hour; however, CPUT per hour was highly variable, with a range of 0 to 5 salmonids captured per hour. The rate of capture decreased to 1 CPUT per hour after 6 hours and to 0.5 CPUT per hour after 24 hours. At 24 hours the CPUT per hour ranged from 0.3

to 0.9. Since catch rates varied over time, CPUT cannot be corrected for differences in sampling time by dividing by hours fished. However, catch rate did fit an exponential decay model (r= 0.99)

$$y = Bx^{-0.686}$$

Where *y* is the catch rate in salmonids per hour, *B* is a constant, and *x* is time fished in hours. Catch rate varies from 0.5 fish per hour at 20 hours to 0.3 fish per hour at 40 hours. Therefore, CPUT can be modified by 1 fish every 2 hours to correct for difference in fishing time between 20 and 24 hours.

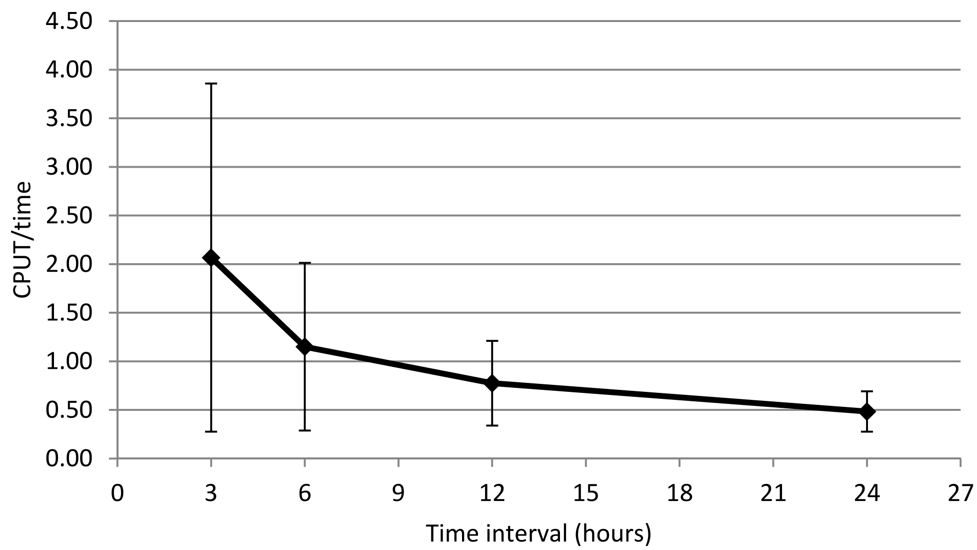

Figure 3: Mean CPUT per hour at each trapping interval. Error bars represent one standard deviation from the mean.

Six salmonids were lost from the 10 traps between each time interval but losses were not related to the number of fish in each trap. Since each time interval is longer than the previous, losses decrease the longer the trap is set. (Between 3 to 6 hours, 1 salmonid was lost per hour. Between 6 to 12 hours, 0.5 salmonids were lost per hour. Between 12 to 24 hours, 0.25 salmonids were lost per hour. Total salmonid, coho salmon, and Chinook salmon losses at each time interval are not correlated with the number of fish already in the trap.

<u>Experiment 4</u>. Replicate measures of coho salmon CPUT were significantly different at 2 of the 5 sampling sites, and Chinook salmon CPUT was significantly different at 1 of the 5 sites (Table 3). Mean coho CPUT decreased between sampling events at Moose Creek and Queer Creek and Chinook salmon CPUT decreased between sampling events at Moose Creek. A storm event occurred between initial and replicate Moose Creek sampling which may have affected CPUT. Alternatively, Queer Creek sampling was conducted on two consecutive days. Lower CPUT in replicate samples may have been due to poor catch rates of fish just released from the traps.

Table 3: Mean CPUT of coho salmon and Chinook salmon at initial sampling and replicate sampling in 2011. Asterisks denote significant differences in means, p < 0.05.

	Initial sampling		Replicate sampling	
	Coho salmon CPUT	Chinook salmon CPUT	Coho salmon CPUT	Chinook salmon CPUT
Moose Creek	4.05	4.60	1.19*	1.15*
Caswell Creek	9.45	0.05	7.80	0.10
Queer Creek	12.95	0.05	6.75*	0.00
Iron Creek 1	4.10	0.40	5.10	1.35
Iron Creek 2	1.50	3.45	0.90	4.70

Juvenile Salmon Abundance

Five fish species were collected during fall sampling. Species included juvenile coho salmon (*Onchorynchus kisutch*), and Chinook salmon (*Onchorynchus tshawytscha*),, Dolly Varden char (*Salvelinus malma*), rainbow trout (*O. mykiss*), three-spine stickleback (*Gasterosteus aculeatus*), burbot (*Lota lota*), and slimy sculpin (*Cottus cognatus*). Juvenile coho salmon were the only species present in catches at all sampling locations in every year. Chinook salmon were present at all sites except Meadow Creek, Cottonwood Creek, and Iron Creek 2 in 2010, and Meadow Creek, Queer Creek, Cottonwood Creek 3, and Kroto Creek in 2011.

Juvenile salmon CPUT for the 16 sampling locations in 2010 and 2011 is shown in Table 4. In 2010 only 2 fish were caught in Kroto Creek (one rainbow trout and one sculpin) and 4 fish at Moose Creek (3 Chinook salmon and one sculpin). In both 2010 and 2011, Meadow Creek sites and Cottonwood Creek sites had the lowest CPUT of coho salmon in lowland streams (wetland and lake-stream complex types). Wasilla Creek and Swiftwater Creek had the highest abundance of coho salmon for upland streams in both years. In 2010, total salmonid CPUT ranged from 1.10 at Meadow Creek 1 to 26.00 at Wasilla Creek 4, and in 2011 from 0.20 at Kroto Creek to 22.65 in Swiftwater Creek (Table 5). Coho salmon CPUT ranged from 0.80 at Meadow Creek, 1 to 18.95 at Queer Creek in 2010, and from 0.20 at Kroto Creek to 14.45 at Wasilla Creek 4 in 2011 (Table 5). Chinook salmon CPUT in 2010 ranged from 0 at several sites to 10.60 at Wasilla Creek 4, and from 0 at several sites to 4.60 at Moose Creek in 2011 (Table 5). The relative abundance of coho salmon was significantly higher than Chinook salmon at all sites in 2010 and 2011 (ANOVA: $F_{1, 26} = 14.67$ $p < 0.001$; $F_{1, 30} = 23.08$, $p < 0.001$).

Mean CPUT for Chinook salmon by site is shown in Figure 3. Juvenile Chinook salmon were more abundant in upland streams as expected. Chinook juveniles were present in Wasilla Creek, tributaries to the Little Susitna River, Little Willow Creek, and Montana Creek. There were no apparent differences in the abundance of coho salmon among stream types (Figure 4). Coho YOY CPUT is not different between stream types in both years (ANOVA: 2010: $F_{1, 13} = 0.03$, $p = 0.862$; 2011: $F_{1, 13} = 2.72$, $p = 0.123$). CPUT was over 10 in Wasilla Creek and Swiftwater Creek, classified as upland streams, but also in the wetland streams, Queer Creek and Caswell Creek.

Fork lengths for Chinook and coho salmon are shown in Table 7. Only one age class of Chinook salmon was present and two or more age-classes of coho salmon. There was a large difference in the mode of fork lengths for age-0 coho and Chinook salmon among sampling streams. For example, coho salmon age-0 fork lengths in 2010 ranged from 50 mm in Colter Creek to 80 mm in Meadow Creek. Similarly in 2011, fork lengths ranged from 45 in Swiftwater Creek to 69 in Meadow Creek. In 2010, coho salmon YOY FL maximum ranged from 66 mm at Buddy Creek to 98 mm at Meadow Creek 3. In 2011, coho salmon YOY FL maximum ranged from 58 mm at Iron Creek 2 to 96 mm at Meadow Creek 3. At sites where Chinook salmon were present, the mode of the distribution of FL for Chinook salmon was significantly higher than the mode of the distribution of FL for coho salmon in both 2010 and 2011 (Table 7, $p < 0.001$). The mode of coho FL and coho YOY FL maximum is greater in wetland streams and lake-stream complexes than in upland streams in 2010 and 2011 (ANOVA: 2010: $F_{1, 12} = 9.98$, $p = 0.008$; $F_{1, 14} = 8.19$, $p = 0.014$; 2011: $F_{1, 13} = 8.95$, $p = 0.010$; $F_{1, 13} = 6.83$, $p = 0.021$).

Table 5: Total salmonid, coho salmon, and Chinook salmon CPUT for 2010 and 2011.

			2010			2011		
	Stream type	Rosgen classification	Salmonid abundance (CPUT)	Coho abundance (CPUT)	Chinook abundance (CPUT)	Salmonid abundance (CPUT)	Coho abundance (CPUT)	Chinook abundance (CPUT)
Buddy Creek	Upland	B4	4.30	2.70	1.25	12.50	9.75	2.00
Caswell Creek	Lake-stream	E5	11.90	11.0	0.45	9.60	9.45	0.05
Colter Creek	Upland	B4	6.45	3.00	1.65	14.30	9.90	0.95
Cottonwood Creek 3	Lake-stream	B5	14.15	10.65	0.00	8.05	5.25	0.00
Cottonwood Creek 4	Lake-stream	B6	8.05	5.95	0.00	6.10	4.20	0.05
Greys Creek	Wetland	E5	13.50	13.05	0.45	7.20	7.00	0.15
Iron Creek 1	Upland	B3	6.00	3.35	0.15	6.95	4.10	0.40
Iron Creek 2	Upland	B3	5.85	3.60	0.00	6.30	1.50	3.45
Kroto Creek	Upland	C3	NA	NA	NA	0.20	0.20	0.00
Meadow Creek 1	Wetland	E4	1.10	0.80	0.00	12.85	1.15	0.00
Meadow Creek 3	Wetland	C5	5.50	3.95	0.00	3.60	2.45	0.00
Moose Creek	Upland	C4	NA	NA	NA	8.65	4.05	4.60
Queer Creek	Wetland	E4	19.10	18.95	0.15	11.80	11.80	0.00
Swiftwater Creek	Upland	B4	8.70	4.70	2.30	22.65	13.40	3.25
Wasilla Creek 3	Upland	B4	19.00	15.20	2.50	12.95	10.30	1.60
Wasilla Creek 4	Upland	B4	26.00	13.15	10.60	14.90	14.45	0.30

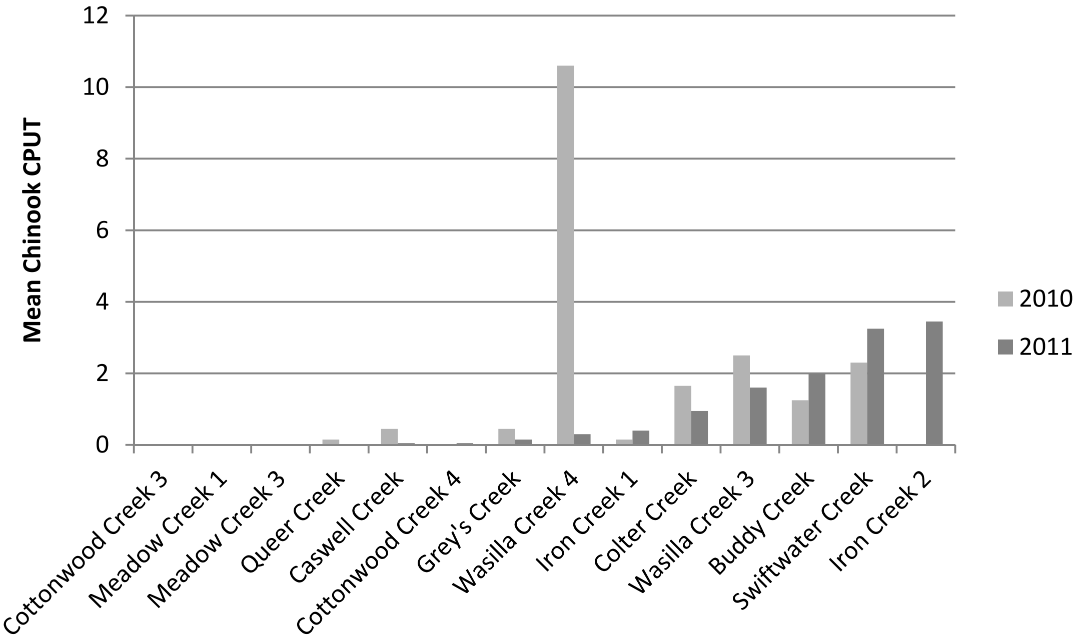

Figure 3. Mean Chinook CPUT at the sampling locations in 2010 and 2011 from lowest to highest 2011 values.

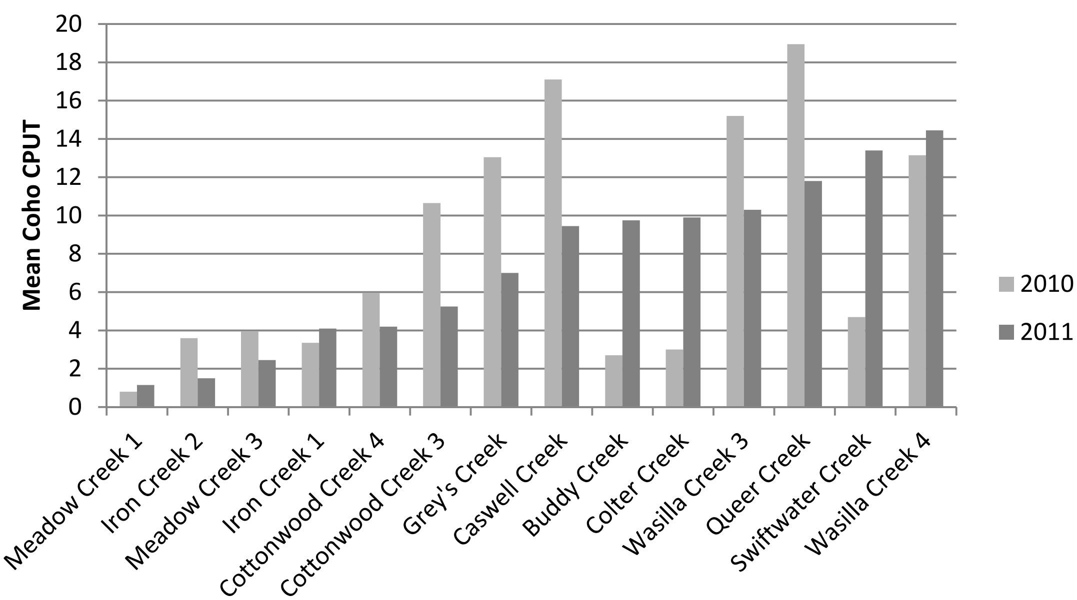

Figure 4. Mean coho salmon CPUT for 2010 and 2011 sorted by 2011 values.

Table 7: Chinook and coho salmon mode FL, coho YOY FL maximum and coho YOY CPUT for all sites in 2010 and 2011.

	2010				2011			
	Chinook mode FL (mm)	Coho mode FL (mm)	Coho YOY FL maximum (mm)	Coho YOY mean CPUT	Chinook mode FL (mm)	Coho mode FL (mm)	Coho YOY FL maximum (mm)	Coho YOY mean CPUT
Buddy Creek	65	54	66	2.35	65	55	75	8.05
Caswell Creek	68	60	75	7.95	NA	96	85	3.95
Colter Creek	66	50	71	2.90	76	60	76	9.80
Cottonwood Creek 3	NA	65	75	6.90	NA	62	75	3.10
Cottonwood Creek 4	NA	63	75	4.60	NA	64	81	3.15
Greys Creek	60	58	73	0.45	NA	55	79	6.00
Iron Creek 1	69	60	72	2.70	61	46	61	2.65
Iron Creek 2	NA	56	69	3.50	64	45	58	1.45
Kroto Creek	NA	NA	NA	NA	NA	NA	NA	NA
Meadow Creek 1	NA	70	91	0.80	NA	69	88	0.65
Meadow Creek 3	NA	83	98	2.70	NA	69	96	2.20
Moose Creek	NA	NA	NA	NA	65	54	88	3.15
Queer Creek	68	60	75	17.30	NA	54	83	9.80
Swiftwater Creek	67	53	68	4.55	74	45	70	13.15
Wasilla Creek 3	65	53	71	12.70	65	50	78	8.85
Wasilla Creek 4	65	56	68	8.70	NA	50	74	12.40

Condition factors for coho salmon are shown in Table 9. Condition factors were variable but did not show consistent differences between stream types. Condition factors ranged from 0.090 to 0.116. Condition factors were lowest both years in Greys Creek and Queer Creek, two wetland stream systems. However, condition factors also were low in 4 upland streams: the two Iron Creek sites, Swiftwater Creek, and Colter Creek. Condition factors were consistently high (>1.0) in Wasilla Creek, Cottonwood Creek, and Meadow Creek.

The fish community metrics are shown in Table 10. The ratio of anadromous to resident fish was consistent between years, but ratios of salmonids to stickleback and salmonids to sculpin were highly variable. The ratio of anadromous to resident fish at all sites in 2010 ranged from 0.11 at Meadow Creek 3 to 67.50 at Grey's Creek (Table 10). The ratio of anadromous to resident fish at all sites in 2011 ranged from 0.01 at Meadow Creek 3 to 32.78 at Wasilla Creek 4 (Table 10). The lowest ratio of anadromous to resident fish in 2010 and 2011 was in Meadow Creek. Low ratios at the upper Meadow Creek site (Meadow Creek 1) were due to large numbers of resident rainbow trout, whereas at the lower Meadow Creek site, low ratios were due to high numbers of sticklebacks. Kroto Creek had a low ratio of anadromous to resident fish primarily due to a very low catch of salmon and higher catch of resident burbot.

The wetland or lake/stream complex streams (Meadow Creek, Cottonwood Creek, Kroto Creek, and Queer Creek) had low ratios of anadromous to resident fish in both years. Whereas upland streams, Wasilla Creek, Iron Creek, and Buddy Creek tended to have higher ratios of anadromous to resident fish. The exception to this was Greys Creek, which is a wetland stream with high anadromous to resident ratios for both years.

Table 9: Condition factors for coho salmon at all sites in 2010 and 2011, and select sites in 2008 and 2009. Condition factors were not obtained for Kroto Creek and Moose Creek in 2011 because there is no weight data for the fish caught at these sites.

	2008	2009	2010	2011
Greys Creek	-	-	0.090	0.091
Queer Creek	0.099	0.100	0.097	0.093
Iron Creek 1	0.101	0.171	0.099	0.096
Iron Creek 2	0.094	0.120	0.097	0.097
Swiftwater Creek	0.130	0.124	0.102	0.098
Colter Creek	0.105	0.125	0.113	0.099
Cottonwood Creek 4	-	-	0.102	0.102
Caswell Creek	-	-	0.095	0.102
Meadow Creek 1	-	-	0.108	0.103
Wasilla Creek 3	-	-	0.100	0.103
Buddy Creek	0.104	0.115	0.098	0.105
Meadow Creek 3	-	-	0.122	0.106
Wasilla Creek 4	-	-	0.114	0.109
Cottonwood Creek 3	-	-	0.107	0.116

Table 10: Ratios of anadromous to resident fish, salmonids to stickleback, and salmonids to sculpin for all sites in 2010 and 2011. Sites where data is not available (NA) is due to absence of stickleback and/or sculpin at that site.

	2010			2011		
	Anadromous to resident (ratio)	Salmonids to stickleback (ratio)	Salmonids to sculpin (ratio)	Anadromous to resident (ratio)	Salmonids to stickleback (ratio)	Salmonids to sculpin (ratio)
Meadow Creek 3	0.11	0.13	0.83	0.08	0.16	0.79
Meadow Creek 1	0.46	1.45	0.94	0.09	11.68	42.83
Kroto Creek	NA	NA	NA	0.14	NA	4.00
Queer Creek	2.18	2.69	11.94	1.01	1.01	236.00
Cottonwood Creek 3	0.61	1.03	94.33	1.15	5.75	23.00
Cottonwood Creek 4	2.70	161.00	161.00	1.33	6.78	13.56
Caswell Creek	8.48	17.00	59.50	1.34	1.39	96.00
Iron Creek 1	1.37	NA	70.00	1.73	NA	46.33
Swiftwater Creek	3.41	NA	20.00	2.73	NA	226.50
Colter Creek	2.27	NA	25.80	3.01	NA	95.33
Iron Creek 2	1.56	NA	72.00	3.41	NA	63.00
Wasilla Creek 3	10.70	NA	2.71	10.35	NA	129.50
Buddy Creek	9.88	NA	86.00	11.75	83.33	125.00
Moose Creek	NA	NA	NA	15.73	NA	87.00
Greys Creek	67.50	NA	135.00	23.83	NA	72.00
Wasilla Creek 4	8.48	3.73	13.05	32.78	298.00	59.60

Stream classification

Stream types ranged from B, C, and E streams under Rosgen classification (Table 5). Most of the streams used in this study were B3 and B4 types, which are moderately entrenched streams characterized by high width to depth ratios and moderate sinuosity. B streams are in narrow and moderately sloping basins, and have a bed morphology dominated by riffles. B3 types are cobble dominant, and B4 types are gravel dominant.

Moose Creek and Kroto Creek are the only upland streams that are C types. C type streams are similar to B type streams, although they are less entrenched and are located in wider valleys constructed by alluvial deposition. They have bed morphology indicative of a riffle/pool configuration. The characteristic morphological features of C type streams in this study are point bars within the active channel. Meadow Creek 3 is also a C type stream. Kroto Creek is cobble dominant (C3), Moose Creek is gravel dominant (C4), and Meadow Creek 3 is sand dominant (C5).

The remainder of the streams used in this analysis are E types. E type streams are slightly entrenched, have low width to depth ratios, and have very high sinuosity. Bed morphology is dominated by a riffle/pool configuration with a higher number of pools per unit distance of channel than C type streams. E streams occur in alluvial valleys of low elevation relief characteristics.

Several sites used in this analysis are located at road crossings. Often, culverts appeared to cause a change in stream type due to obstruction of flow and increased sediment deposition upstream of the culvert. At Meadow Creek 3, fish sampling was conducted downstream of the culvert where the stream was a C5 type. Upstream of the culvert is more characteristic of an E type stream. There are still characteristics of an E type stream farther downstream from our sampling reach. However, just downstream of the culvert the stream has a high width to depth ratio and characteristic point bars which make it more representative of a C type stream.

At Meadow Creek 1, fish sampling occurs both up and downstream of the culvert at Meadow Lakes Road. It is an E stream type both upstream and downstream of the culvert. However, the substrate is dominated by sand downstream and gravel upstream. At Cottonwood Creek 3 (below Wasilla Lake and the Parks Highway) the substrate changes from sand to gravel and cobble through the majority of the reach.

Physical Chemistry and Habitat Assessment

Physical chemistry data for 2010 is in Table 12. Different sites on the same creek were highly correlated for physical chemistry data (Cottonwood Creek, Iron Creek, Meadow Creek, and Wasilla Creek; $r \geq 0.981$, $p < 0.001$). Swiftwater Creek and Colter Creek were also highly correlated for physical chemistry data ($r > .999$, $p < 0.001$).

Seasonal maximum temperatures ranged from 10.30°C at Swiftwater Creek to 20.31°C at Cottonwood Creek 3 in 2008, from 13.17°C at Iron Creek 2 to 25.77°C at Cottonwood Creek 3 in 2009, and from 12.78°C at Swiftwater Creek to 21.84°C at Cottonwood Creek 3 in 2009 (Table 13). Days above 20°C were a total of 1 in 2008, 66 in 2009, and 12 in 2010.

Lake-stream complex types and wetland stream types had significantly higher temperatures and lower dissolved oxygen levels than upland streams in 2010 (Table 19; ANOVA: $F_{1, 12} = 20.36$, $p < 0.001$; $F_{1, 12} = 51.96$, $p < 0.001$).

Table 12: Physical chemistry data for all sites in 2010. Values with an asterisk (*) may have been recorded incorrectly. Physical chemistry data was collected in 2011 at the time of fish sampling for Kroto Creek and Moose Creek. Discharge measurements are not available for Kroto Creek and Moose Creek due to their depth and power.

	Date of fish data collection	Stream type	Temperature (on day of fish sampling, °C)	Discharge (cfs)	Dissolved oxygen (mg/L)	Percent dissolved oxygen (percent saturation)	pH	Specific conductivity (µS/cm)	True Color (CU)	Turbidity (NTU)
Caswell Creek	8/17/10	Lake-stream	11.70	17.56	8.51	79.20	5.88	54.50	28.40	1.88
Cottonwood Creek 3	9/1/10	Lake-stream	15.70	14.76	9.22	91.90	7.91	214.90	15.23	2.06
Cottonwood Creek 4	9/1/10	Lake-stream	14.25	10.10	9.80*	96.80	8.09	223.00	10.93	2.92
Buddy Creek	9/14/10	Upland	8.50	22.99	13.06	100.90	6.35	23.50	30.17	1.52
Colter Creek	9/2/10	Upland	8.40	6.67	12.72	100.40	7.17	65.20	8.27	0.69
Iron Creek 1	9/22/10	Upland	6.13	11.40	13.56	101.70	6.89	42.90	24.57	2.11
Iron Creek 2	9/22/10	Upland	4.95	15.35	14.04	103.30	6.71	42.40	18.63	2.55
Kroto Creek	8/23/11	Upland	11.20	NA	10.78	97.20	5.51	36.80	40.60	2.43
Moose Creek	8/23/11	Upland	10.85	NA	10.57	95.20	5.76	51.30	37.00	3.50
Swiftwater Creek	9/2/10	Upland	7.40	7.93	13.08	102.00	7.22	66.80	7.10	1.07
Wasilla Creek 3	8/31/10	Upland	10.35	23.09	11.84	106.30	8.01	149.30	13.63	8.04
Wasilla Creek 4	8/31/10	Upland	10.15	25.00	12.15	110.40	7.71	179.90	20.03	10.06
Greys Creek	9/7/10	Wetland	11.20	10.40	9.72	89.10	6.41	45.40	56.77	3.14
Meadow Creek 1	9/3/10	Wetland	10.80	3.79	10.34	98.00	6.38	155.60	22.43	1.67
Meadow Creek 3	9/3/10	Wetland	11.55	18.53	10.63*	98.80	7.56	208.90	8.37	1.26
Queer Creek	9/14/10	Wetland	12.70	37.65	10.84	93.50	6.02	13.40	54.80	0.52

Table 13: Seasonal maximum temperature and number of days above 20 °C for 9 sites in 2008, 2009, and 2010.

	2008		2009		2010	
	Seasonal maximum temperature (°C)	Days above 20 °C	Seasonal maximum temperature (°C)	Days above 20 °C	Seasonal maximum temperature (°C)	Days above 20 °C
Buddy Creek	17.61	0	21.31	7	17.61	0
Colter Creek	10.74	0	15.94	0	13.62	1
Cottonwood Creek 3	20.31	1	25.77	34	21.84	11
Cottonwood Creek 4	18.75	0	21.96	7	18.75	0
Iron Creek 1	13.65	0	16.24	0	13.46	0
Iron Creek 2	10.94	0	13.17	0	11.92	0
Meadow Creek 1	18.13	0	21.65	5	18.44	0
Meadow Creek 3	18.91	0	22.68	13	19.89	0
Swiftwater Creek	10.30	0	15.15	0	12.78	0
Mean	15.48	0.11	19.32	7.33	16.48	1.33

Habitat assessment values ranged from a low of 134 at Cottonwood Creek 3 to a high of 189 at Buddy Creek (Table 14). Cottonwood Creek 3 scored low for habitat assessment primarily due to lack of a diversity of velocity and depth combinations. As a glide-pool stream type, the site was dominated by small, shallow glides and entirely lacked large or small pools. Streams with many pool types support a wide variety of aquatic species, while streams with monotonous pool characteristics do not have sufficient quantities or types of habitat to support a diverse community (Ball 1982, Gore and Judy 1981, Osborne and Hendricks 1983, Oswood and Barber 1982). Cottonwood Creek 3 also scored marginal due to lack of epifaunal substrate and available instream cover, increased sediment deposition, and low channel sinuosity.

Also scoring lower on habitat assessment were the Wasilla Creek sites, specifically due to high embeddedness and sediment deposition. Wasilla Creek 4 had gravel, cobble, and boulder particles 50% surrounded by fine sediment, and new bar formation from gravel, sand, and fine sediment deposition. Wasilla Creek 3 had gravel, cobble, and boulder particles 60% surrounded by fine sediment, and moderate deposition of new gravel with sand on old and new point bars.

Table 14: Habitat assessment scores for all sites.

	Epifaunal substrate/ available instream cover	Riffle/run: embeddedness Glide/pool: pool substrate characteristics	Riffle/run: velocity-depth combinations Glide/pool: pool variability	Sediment deposition	Channel flow status	Channel alteration	Riffle/run: frequency of riffles or bends Glide/pool: channel sinuosity	Bank stability	Bank vegetative protection	Riparian vegetative zone width	Sum
Buddy Creek	18	18	17	20	20	20	16	20	20	20	189
Caswell Creek	10	15	12	14	20	20	8	20	20	20	159
Colter Creek	19	20	14	19	16	20	19	15	19	20	181
Cottonwood Creek 3	9	13	3	9	18	20	9	20	20	13	134
Cottonwood Creek 4	19	19	14	19	17	20	20	20	20	20	188
Greys Creek	12	17	16	14	17	20	9	19	20	20	164
Iron Creek 1	19	17	19	13	18	20	18	20	20	20	184
Iron Creek 2	18	18	14	15	19	20	20	20	20	20	184
Kroto Creek	14	19	14	20	19	20	18	11	17	20	172
Meadow Creek 1	14	13	8	9	15	20	19	20	20	20	158
Meadow Creek 3	11	15	10	18	20	20	20	20	20	19	173
Moose Creek	11	12	11	8	15	20	13	14	18	18	140
Queer Creek	15	17	14	18	20	20	20	20	20	20	184
Swiftwater Cr	18	19	15	17	19	20	19	20	18	18	183
Wasilla Creek 3	20	9	20	8	19	18	19	14	18	20	165
Wasilla Creek 4	19	11	19	13	18	19	19	17	18	15	168

Temporal Variability

The variability in juvenile salmon CPUT, fork lengths, and fish community metrics was evaluated using data from 6 locations that have been sampled using the same methods from 2008 through 2011. Differences were evaluated relative to changes in water temperature and adult salmon returns. Coho salmon and salmonid CPUT, Chinook juvenile CPUT, and condition factors were all highest in 2009. This increase in juvenile salmon abundance and condition coincided with higher seasonal water temperatures. Average juvenile Chinook CPUT in 2009 was 9.0, 2 times higher than the next highest value of 4.0 in 2008. Average juvenile Chinook CPUT was significantly different between years ($p = 0.002$). Similarly, average juvenile coho CPUT among the 6 locations was 16.7, twice as high as the next highest years 7.3 in 2008 and 8.4 in 2011 (Figure 5). Annual mean coho CPUT was also significantly different ($p = 0.008$).

Coho condition factors also were higher in 2009 (Figure 6). Average coho condition factors in 2009 were 0.11 in 2009. The next highest average was 0.10 in 2010. Difference in annual coho condition factors were significantly different ($p = 0.01$)

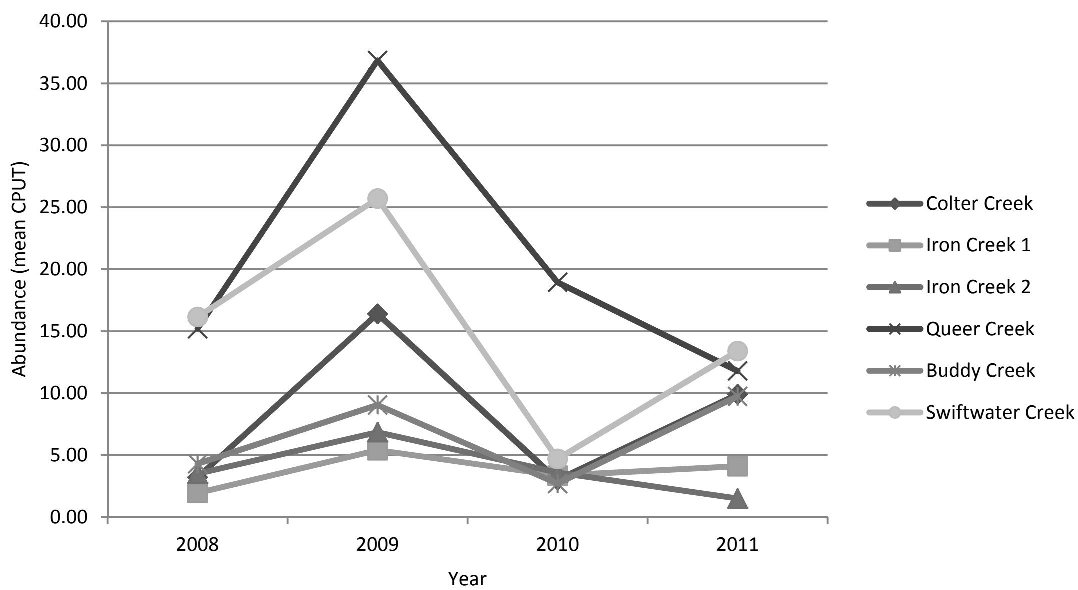

Figure 5. Change in coho salmon abundance in mean CPUT from 2008 to 2011 at sites where data is available for all years.

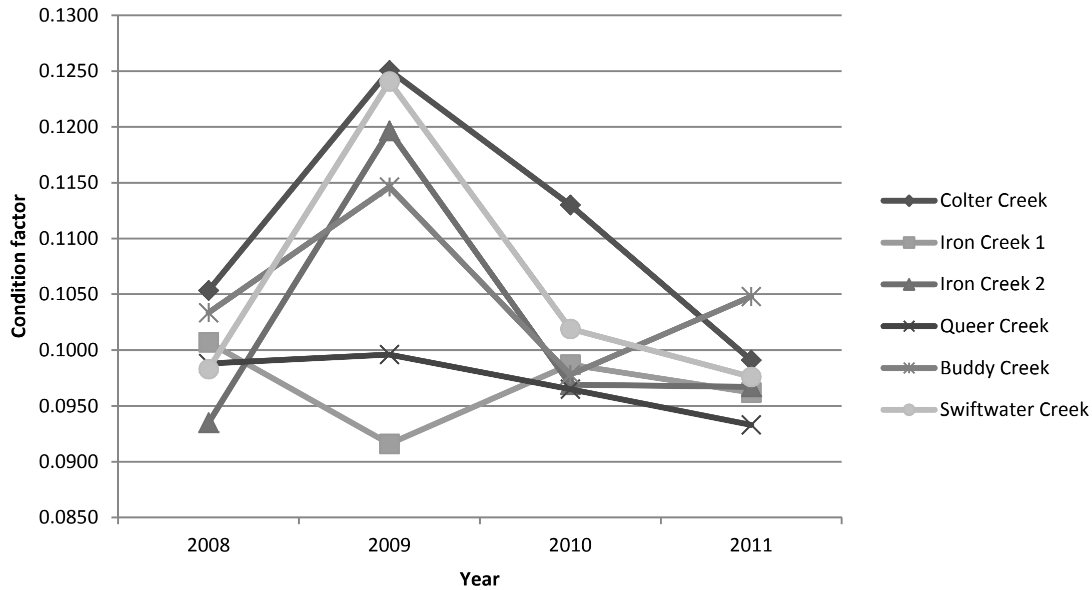

Figure 6. Change in condition factor values for coho salmon from 2008 to 2011 at sites where data is available for all years.

Coho salmon escapement was slightly higher at most Susitna River index sites in 2008, which could have resulted in the higher coho CPUT in 2009 (Table 15). Coho salmon escapement increased from 2007 to 2008, and decreased at all sites except the Deshka River from 2008 to 2009. However, differences were not significant ($p = 0.863$). Differences in adult escapement the previous year would not explain differences in juvenile coho condition factors.

Seasonal water temperatures in these 6 streams showed the same pattern as juvenile salmonid CPUT and coho condition factors. For example, season maximum temperatures significantly increased from 2008 to 2009 and significantly decreased from 2009 to 2010 ($t(9) = -10.20$, $p < 0.001$, $t(9) = 10.56$, $p < 0.001$) (Figure 7).

Ratios of anadromous to resident fish also increased at some of the locations in 2009, likely due to higher rearing salmon CPUT; however, differences were not consistent among sites (Figure 8). Anadromous to resident ratios increased in Iron Creek 2 (North Fork) and Buddy Creek. Both of these sites saw large increases in total salmonid CPUT in this same year.

Table 15: Coho salmon escapement data for 2007-2009 for select sites within the Mat-Su Basin (ADF&G 2010, Oslund and Ivey 2010).

	Collection Type	2007	2008	2009
Little Susitna River	Weir	17573	18485	9523
Cottonwood Creek	Foot Survey	1024	1821	942
Wasilla Creek	Foot Survey	380	1461	936
Rabideux Creek	Foot Survey		10043	345
Deshka River	Weir	10575	12724	27348

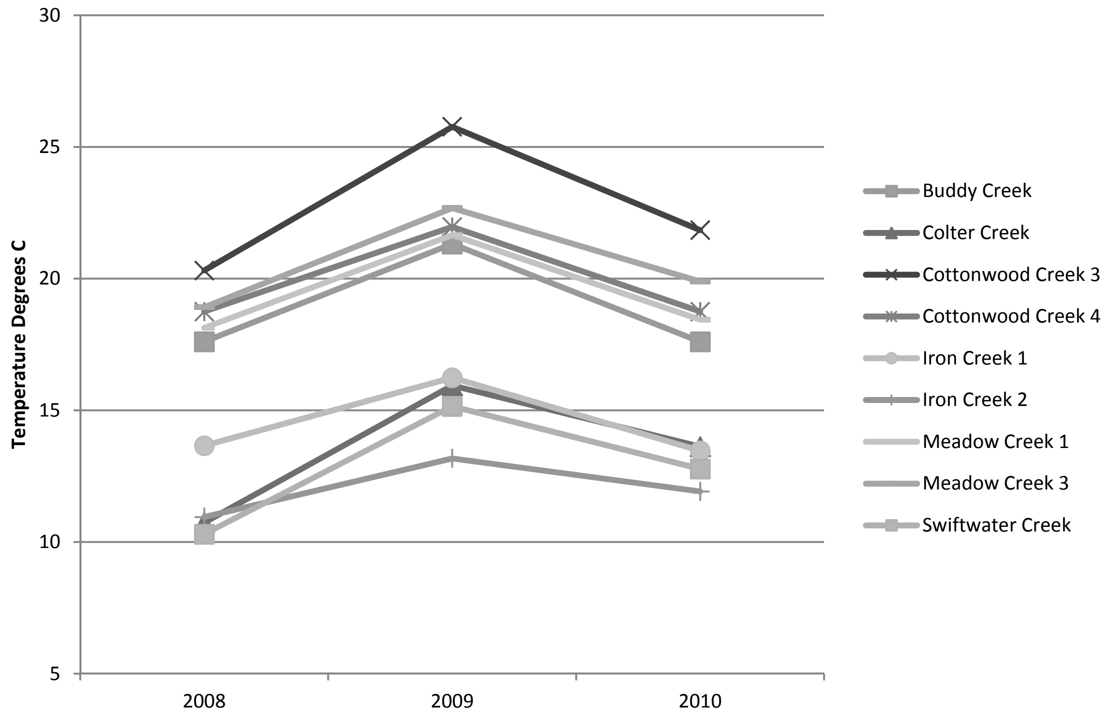

Figure 7. Change in seasonal maximum temperature at 9 sites from 2008 to 2010.

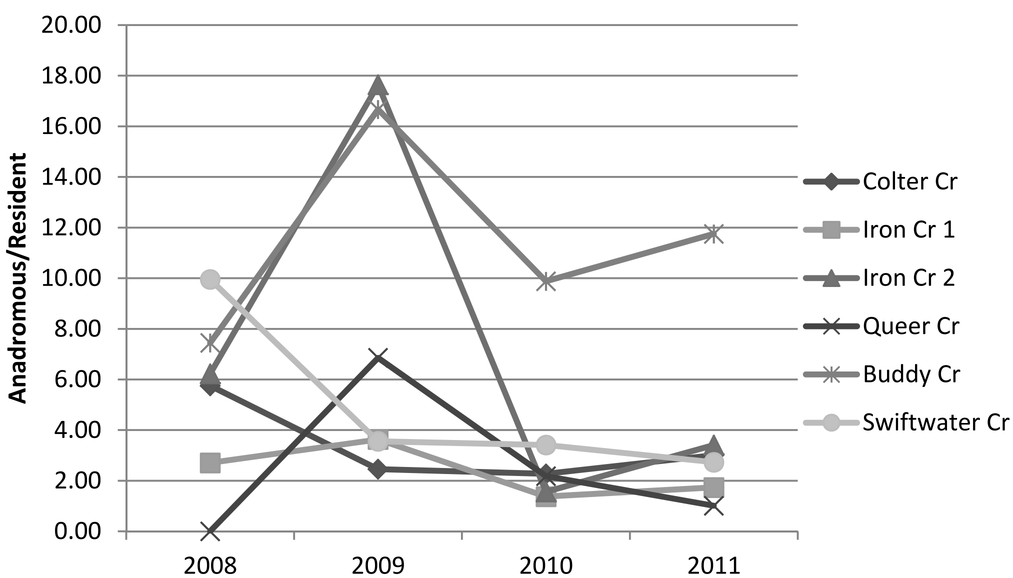

Figure 8. Ratios of anadromous to resident fish in 6 sites from 2008 to 2011 showing an increase at 2 of the sites in 2009.

Relationships between the fish community, water chemistry, and habitat assessment

Correlations between juvenile salmon metrics, water physical characteristics, and habitat assessment scores are shown in Table. 16. Juvenile salmon CPUT was correlated with a number of stream characteristics but not to habitat assessments. Chinook salmon CPUT was significantly correlated with turbidity ($r = 0.79$, $p < 0.001$) and percent dissolved oxygen ($r = 0.55$, $p = 0.041$). These correlations reflect the higher Chinook salmon abundance in upland streams, particularly Wasilla Creek, which also had relatively high turbidity (8 to 10 NTU) during fall sampling.

Juvenile coho CPUT was positively correlated with discharge (r = 0.65, p = 0.012), and fork lengths were positively correlated with seasonal maximum temperatures (r = 0.67, p = 0.047; Figure 9) and negatively correlated with dissolved oxygen (r = -0.50, p = 0.017) and habitat assessment scores (r = -0.61, p = 0.020). These relationships suggest that rearing coho salmon were more abundant in larger streams and wetland streams including stream/lake complexes which tended to have higher temperatures and lower percent dissolved oxygen. The negative relationship with habitat assessment is probably because assessment scores were negatively correlated with seasonal maximum temperatures (r = -0.72, p = 0.030).

Table 16: Correlation coefficients for physical chemistry, habitat assessment, and fish abundance and biomass at all sites in 2010. Values with an asterisk (*) are significant to an alpha level of 0.05, values with two asterisk (**) are significant to an alpha level of 0.01.

	Salmonid abundance (mean CPUT)	Chinook salmon abundance (mean CPUT)	Coho salmon abundance (mean CPUT)	Coho YOY abundance (mean CPUT)	Coho FL mode (mm)	Coho YOY FL maximum (mm)	Coho condition factor	Discharge (cfs)	Temperature (on day of fish sampling, ^{0}C)	Dissolved oxygen (mg/L)	Percent dissolved oxygen (percent saturation)	pH	Specific conductivity (microS/cm)	Color (CU)	Turbidity (NTU)	Seasonal maximum temperature(ºC)	Habitat assessment
Salmonid abundance (mean CPUT)	1.00																
Chinook abundance (mean CPUT)	0.66*	1.00															
Coho abundance (mean CPUT)	0.84**	0.23	1.00														
Coho YOY abundance (mean CPUT)	0.74**	0.23	0.79**	1.00													
Coho FL mode (mm)	-0.28	-0.33	-0.17	-0.19	1.00												
Coho YOY FL maximum (mm)	-0.35	-0.35	-0.21	-0.21	0.93**	1.00											
Coho condition factor	-0.07	0.31	-0.36	-0.14	0.50	0.55*	1.00										
Discharge (cfs)	0.64*	0.27	0.65*	0.80**	-0.05	-0.16	-0.12	1.00									
Temperature (on day of fish sampling, ^{0}C)	0.33	-0.11	0.47	0.33	0.43	0.36	0.14	0.19	1.00								
Dissolved oxygen (mg/L)	-0.18	0.24	-0.49*	-0.14	-0.48*	-0.45*	0.02	0.00	-0.88**	1.00							
Dissolved oxygen (% Saturatio)	0.10	0.55*	-0.39	-0.01	-0.23	-0.21	0.39	0.06	-0.49	0.76**	1.00						
pH	0.24	0.32	-0.12	0.05	0.09	0.01	0.51	-0.14	0.25	0.04	0.51	1.00					
Specific conductivity (microS/cm)	0.13	0.20	-0.08	-0.03	0.55*	0.48	0.64*	-0.16	0.59*	-0.42	0.18	0.78**	1.00				
Color (CU)	0.28	-0.14	0.52	0.23	-0.10	-0.12	-0.64*	0.42	0.14	-0.25	-0.44	-0.69**	-0.56*	1.00			
Turbidity (NTU)	0.70**	0.79**	0.37	0.30	-0.24	-0.28	0.10	0.27	0.02	0.08	0.50	0.48	0.37	-0.10	1.00		
Seasonal maximum temperature (ºC)	0.24	-0.48	0.46	0.23	0.67*	0.55	0.44	0.26	0.91**	-0.90**	-0.87**	0.43	0.81**	0.02	0.15	1.00	
Habitat assessment	-0.13	0.05	-0.19	0.03	-0.64*	-0.61*	-0.43	0.06	-0.55*	0.62	0.31	-0.23	-0.59	0.13	-0.09	-0.72*	1.00

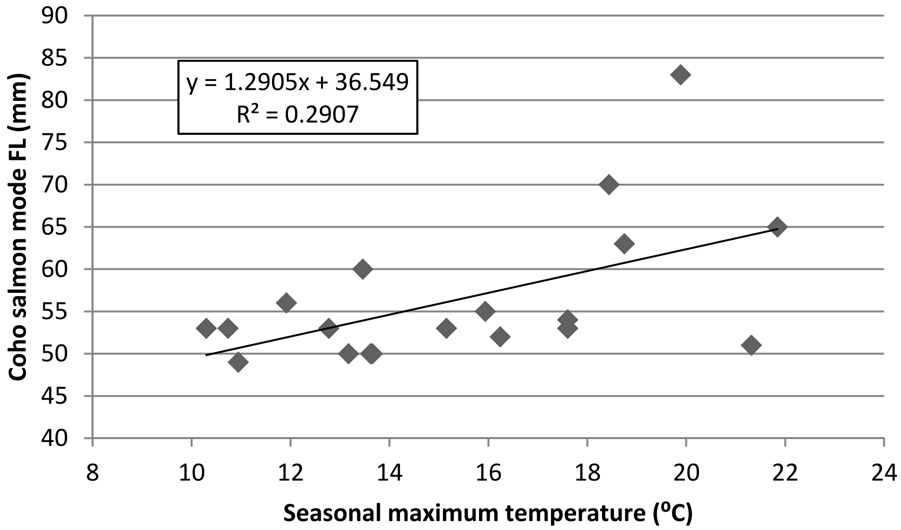

Figure 9. Relationship between seasonal maximum temperature and age-0 coho FL mode for all sites in 2008, 2009, and 2010 with available seasonal temperature data.

Discussion

The use of baited minnow traps provides a useful method for sampling the juvenile fish community within Southcentral Alaskan streams. The within-stream relative abundance and condition of rearing juvenile coho and Chinook salmon were relatively consistent over time providing a measure that could be used to monitor stream condition. A long-term (5 year) monitoring program should be initiated to provide a baseline of juvenile salmon abundance that can be used to identify effects of declining water quality and physical habitat conditions.

The use of 20-baited minnow traps fished overnight for 20 to 24 hours reduced the variability in juvenile coho and Chinook salmon CPUT and provided an effective sampling method. Minnow traps can be size and species selective (Jackson and Harvey 1997, Lapointe et al. 2006), and trap efficiency can vary because of water temperatures (Stott 1970) and fishing time (Culp and Glozier 1989). Catch rates varied within this study; however, these differences can be minimized when traps are left overnight for at least 20 hours and, if necessary, CPUT can be corrected for differences in fishing time. Minnow trapping has been found to be effective for monitoring relative abundance of some species (He and Lodge 1990, MacRae and Jackson 2006) and we found that juvenile coho and Chinook salmon are readily captured. Juvenile sockeye salmon are occasionally found in minnow traps; however, we do not believe that they are attracted to the salmon roe, and their relative abundance is likely underestimated. Rearing juvenile salmon generally are <100 mm fork length and, therefore, should not be affected by size selectivity. Larger resident Dolly Varden char and rainbow trout are excluded from minnow traps. In addition, the influence of these predators on catch rates has not been evaluated. Dolly Varden and rainbow trout have been observed to consume juvenile salmon within traps and their presence may result in reduced CPUT number due to trap avoidance or predation. The downstream scent released from salmon roe did not increase migration into the sampling reach; therefore, blocking the downstream end of the sampling reach is unnecessary.

The fish community composition and juvenile salmon relative abundance is not consistent among all streams or different stream types. This prevents the broad application of metrics and supports the alternative use of index streams. The index of biological integrity and other fish community metrics used to assess water quality generally used consistent values for water quality assessment (Simon 1999). For example, the relative abundance of pollution intolerant species or the ratio of intolerant to pollution tolerant species. These metrics may vary by stream geomorphic classification type. However, development of fish community metrics is limited by the low diversity of fish found in Southcentral Alaska Streams. The relative abundance of juvenile salmon and resident fish and the fish community composition were highly variable among streams or stream types in this study preventing the development of regional metrics. Coho condition factor was the only value that was consistent among streams. However, this metric displays a low range and, therefore may not be suitable for monitoring. The monitoring of the fish community in index streams along with measures of basic water quality parameters is suggested as an alternative to regional metrics.

There was relatively low within-stream variability in coho and Chinook CPUT, fork length of age-0 salmon, and ratios of anadromous to resident fish. A portion of this variability is explained by differences in water temperatures. For example, in 2010 coho CPUT ranged from < 1 to 20; however, within Meadow Creek coho CPUT ranged from 3.95 in 2010 to 2.45 in 2011. Therefore, differences in salmon abundance within a stream can be used to assess changing conditions over time. Within stream differences in CPUT, fork lengths, condition factors, and ratios of anadromous to resident fish should reflect differences in salmon spawning and rearing habitat conditions. Measures of trends in juvenile salmon abundance or condition could be used as an indicator in changing stream conditions.

Long-term monitoring of juvenile salmon and resident fish should be conducted in a select number of area streams along with measures of water temperature and basic water physical characteristics. Index streams should include replicates of upland and wetland streams in both urban and rural settings. Chinook salmon were more abundant in upland streams. Juvenile coho salmon were present in all stream types, but lengths and condition factors were higher in wetland streams. In addition, the influence of urban development on hydrology, channel form, water quality, temperature, and physical habitat conditions may vary between these stream types (Davis and Davis 2012). A minimum of 5 streams in each category over a 5 year period will allow for statistical evaluation of between streams and trends in juvenile salmon abundance relative to stream characteristics and development impacts.

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