Assessment and Classification of Mat-Su Fish Habitat—Stream Temperatures and Juvenile Fish Distribution

Aquatic Restoration & Research Institute

Jeffrey C. Davis and Gay A. Davis
P.O. Box 923, Talkeetna, AK 9967
(907) 733-5432, arri@mtaonline.net

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Summary

The objective of this project is the continued classification and assessment of fresh-water streams within the Matanuska-Susitna Borough (MSB). Assessment and classification is based upon differences in water temperatures, and the variability in habitat quality and fish use among classification types. The Science and Data Strategy within the NFHAP calls for the classification and assessment of the Nation's fish habitat. The Framework for Assessing the Nation's Fish Habitat, prepared by the National Fish Habitat Science Data Committee, has outlined criteria to be considered in this classification. One of the assessment variables is water temperature. Stream temperatures are an important fish habitat component, often exceed salmonids tolerance values, are variable within and among streams, and can be influenced by human activities. Water temperature is a key variable influencing many components of aquatic ecology and fish physiology. Information regarding the fish distribution among diverse stream types within the MSB is necessary to prioritize restoration efforts and to guide local, state, and federal regulatory actions and planning efforts in order to avoid future fish habitat losses.

In 2007, the Aquatic Restoration and Research Institute (ARRI) summarized stream water temperature data that we collected through a number of different projects within the MSB from 2001 to 2007 and evaluated the range of stream temperatures, the factors influencing variability, and the relationship to state water quality standards. Three groups of streams were identified based upon this summary. These classification types were cold water streams which included small and moderate sized streams draining forested regions of the Talkeetna Mountains; temperate streams, which included the lower portions of larger clear water and semi-glacial streams, and both large and small lowland wetland streams; and warm water streams, which included streams draining small and large lakes. Stream water temperatures in the lowland streams draining the wetlands of the Susitna River Drainage often exceeded the temperature preferences and tolerance limits of rearing juvenile salmonids. However, these wetland streams appear to provide productive juvenile salmon rearing habitat.

To continue the assessment and classification, stream water temperatures were measured at 33 stream locations during the open water season of 2008 within the Cottonwood Creek, Fish Creek, Little Susitna, and Susitna River drainages. Juvenile salmon and other resident fish were sampled seasonally in a subset of these locations including six small cold-water upland streams and six small warm-water lowland streams. All fish were identified, fork length measured, and weighed. Community composition was compared between these two stream types. Measures of stream nutrient concentrations and other chemical characteristics were used to further evaluate differences between stream types.

Stream temperatures in 2008 were consistent with 2007 results. Variation in water temperature among sites could be explained by differences in exposure to solar radiation, stream size, and buffering through groundwater and hyporheic exchange. The subset of small wetland streams were among the warmer sites. In addition, wetland streams were more acidic, with reduced dissolved oxygen and nitrate nitrogen concentrations. Wetland streams were dominated by coho salmon juveniles while upland streams supported near equal numbers of coho and Chinook salmon juveniles, along with resident

rainbow trout and Dolly Varden char. Total salmonid catch rates were higher in the wetland streams during spring and summer. There were no significant differences in total salmonid biomass; however, the biomass of coho salmon in wetland streams was significantly higher than the combined biomass of coho and Chinook salmon in the upland streams. Coho salmon growth rates were higher in wetland streams, but differences were not significant.

Introduction

Multiple different stream types are present within the Susitna and Matanuska River drainages. Common stream types within the MSB are large glacial rivers, clear water rivers, low slope small and large wetland streams, and lake and stream complexes. These stream types differ in slope, hydrology, temperature and production, and likely provide support to different salmon life stages and respond differently to human disturbance.

The ability to protect fish habitat in cooperation with future development will require an extensive understanding of the stream characteristics that provide high fish productivity. Fresh water fish production is often limited by winter survival. Survival through the winter and the number of winters prior to smolt migration has been linked to the size and health of fish in the fall (Ebersole et al. 2006). Different stream types may provide advantages to rearing juvenile fish that can influence fitness and survival. Previous studies have shown that juvenile salmon will migrate to small streams and off-channel habitats for rearing and overwintering (Bramblett et al. 2002). This may be particularly important for fish use associated with glacial rivers where juvenile fish have been shown to migrate long distances to find adequate rearing habitat (Murphy et al. 1997). The differences in water temperature and ameliorated flows during fall storms in small wetland streams may provide ideal wintering habitat for juvenile salmon within the Susitna River drainage.

In 2007, we investigated differences in characteristics among these stream types common throughout the MSB. Water temperature, channel physical characteristics, and basic water chemistry were collected within small upland streams, small wetland streams, large wetland streams, and lake-dominated stream systems. There were significant differences in maximum water temperatures and cumulative degree days among small upland, wetland, and lake-dominated systems; however, there were no significant differences between small and large wetland streams (Davis and Davis 2008). Maximum daily temperatures in small upland streams never exceeded 15° C, while wetland streams exceeded 15 °C, 50% of the time, and lake dominated streams exceeded 15 °C 75 to 90% of the time. Water temperatures were strongly correlated with air temperatures demonstrating limiting buffering capacity and susceptibility to human induced watershed impacts. Water temperatures in the small and large wetland streams of the Susitna River drainage often exceed optimal rearing ranges for juvenile salmonids and may approach values that can result in direct mortality; however, due the large numbers of rearing juveniles, these streams appear to be important for salmon production.

Wetland streams and backwater sloughs provide critical habitat for rearing and overwintering juvenile coho salmon. Wetland streams are characterized by low slopes, deep channels and low water velocities. Beaver dams are common, which further reduce water velocity and result in additional side channels and inundation of the floodplain. These habitats are believed to be beneficial for rearing fish because less energy is needed to maintain position within the water column. However, wetland streams also have metabolic costs associated with warmer water temperatures which require greater food consumption. While considerable work has been done describing the physical characteristics of these habitats, little work has been conducted to determine the factors influencing available food resources which support these productive habitats. This information is needed in order to maintain or restore these critical habitats that are modified through development and resource extraction industries, which, through the regulatory process often address stream physical characteristics but ignore less clearly understood, but perhaps more important, functional processes occurring in wetland streams.

Juvenile salmon migrate from spawning areas to rearing and overwintering habitats. Juvenile salmon within the Taku River migrate from spawning reaches within the upper watershed to rearing and overwintering streams in the lower river and estuary (Murphy et al. 1997). Brown and Hartman (1988) documented the movement of coho salmon to off-channel habitats coincidental with high fall flows in Southeast Alaska. Other studies also have documented the use of these habitats for rearing and overwintering of juvenile coho salmon (Bell 2001, Bennett 2006, Brown and Hartman 1988).

Juvenile salmon that occupy low velocity off-channel or estuarine habitats tend to grow faster than fish that rear or overwinter in other habitats. For example, Bennett (2006), in comparing coho salmon smolt from two different stream reaches found that those emigrating from a low sloped wetland stream were relatively larger than those from higher velocity and steeper reach within the same stream system. Dolloff (1987), in comparing coho production among different stream types found streams through meadows tend to be more productive than forested streams or streams with an open canopy. Larger size leads to increased overwinter and marine survival of juvenile anadromous salmon. For example, juvenile salmon that were larger (based on fork length) or had a higher condition factor (length to weight relationship) in the fall had higher winter survival rates in an Oregon tributary stream (Ebersole et al. 2006). Similarly, Henning et al. (2006) found high growth and survival rates for juvenile coho salmon rearing in emergent floodplain wetlands.

Low water velocity rearing and overwintering habitats may provide an advantage energetically; however, other studies have identified increased stream algal and macroinvertebrate production resulting in increased juvenile fish growth rates. Ebersole et al (2006) hypothesized that the energy derived from adult salmon carcasses and eggs resulted in higher growth rates for juvenile salmon rearing in a spawning tributary. However, others have linked increased growth rates to increases in primary production, potentially related to changes in sunlight following the removal of the riparian canopy (Dolhoff 1987; Bjornn and Reiser 1991). Sommer et al. (2001) reported higher growth rates and survival for Chinook salmon that migrated through a wetland side channel of the Sacramento River which was correlated with greater food resources.

This project continues measurements of stream water temperatures among different stream types within the MSB. We compare differences in juvenile anadromous and resident fish species abundance, community composition, fitness, and growth rates between small upland and small wetland streams. Differences in these measures of the fish community are evaluated relative to measures of stream physical, chemical and biological characteristics.

Methods

Stream water temperatures were measured at 33 stream locations within the Susitna, Little Susitna, Cottonwood and Fish Creek drainages throughout the open water season of 2008 (Table 1). All of these systems flow into the Knik Arm of Cook Inlet in Southcentral Alaska. Measures of the fish community and water chemistry were obtained at a subset of these streams representing cooler upland streams (upland) and warmer streams draining wetlands (wetland). These stream locations were selected based upon 2007 water temperature data (Davis and Davis 2008). The headwaters of upland streams were above 1000 feet and channel slopes ranged from 1 to 8 %. Upland streams included Swiftwater and Colter Creeks (tributaries to the Little Susitna River) Deception Creek (tributary to Willow Creek), the North and South Forks of Iron Creek (tributaries to Little Willow Creek) and Sawyer Creek (also known as Buddy Creek, a tributary to Montana Creek). Wetland streams included Trapper Creek (flows into the Susitna River), Wiggle Creek (flows into the Talkeetna River), Whiskers Creek (a tributary to the Susitna River), Queer Creek (a tributary to Rabideux Creek), Chijik Trib (small tributary near Chijuk Creek), and Lake Creek below Nancy Lake (a tributary to the Little Susitna River). The wetland streams originate at elevations below 1000 ft with channel slopes less than 1%.

Water temperature was measured using HOBO Water Temp Pro V2 temperature data loggers. The loggers were checked for accuracy within a water bath at approximately 0 and 10°C against a NIST standardized thermometer prior to deployment. Loggers were set to record time and water temperature at 15 minute intervals. The temperature loggers were deployed at most sites prior to June 1 and removed at the end of September. Temperature loggers were placed within well mixed portions of the stream adjacent to the dominant flow. Temperature data was downloaded using Hoboware and exported to Microsoft Excel. Daily maximum, minimum and average temperatures were calculated from the 15 minute interval data beginning at 00:15 and ending at 24:00. Daily statistics were used to determine daily ranges, season maximums and temperature exceedances. Monthly cumulative degree days are the sum of daily average values. Air temperature was obtained from the National Weather Service, Palmer and Talkeetna, AK stations. Relationships between air and water temperatures were determined using maximum daily air temperatures from the nearest weather station, and maximum daily water temperatures. Regression slopes, R squared, and Y intercepts were determined using these Excel functions.

The fish community was sampled during the spring (late May to early June), summer (late July to early August), and fall (late September to October). In order to collect fish at similar temperatures among sites, spring sampling was conducted first in the warmer wetland streams and fall sampling was conducted first in the colder upland streams. The fish community was sampled using baited minnow traps. Twenty minnow traps were baited with commercial salmon roe suspended within perforated whirl-pak bags. The traps were placed adjacent to or under cover provided by undercut banks or woody debris within deeper water out of the main flow. Traps were separated by approximately 10 to 20 m, depending upon the availability of cover. The traps were fished for 20 to 24 hours. Upon removal, each trap was emptied into a 5 gallon bucket of water containing dissolved tricaine methanesulfonate (MS-222). All salmonids were identified to species, fork length measured (to nearest millimeter) and weighed (centigram) using a Scout Pro scale. All other fish were identified to genus and counted. Following measurements, all fish were placed in a fresh-water bucket until they recovered from the anesthetic and returned to the stream.

We used individual catch per trap values to calculate average catch per trap for each site for each species individually. We did not adjust catch data based upon the time traps were fished as there is no indication that catch rate increases proportionally with time fished. That is, total catch may peak at 8, 12, or 24 hours (Whitesel et al. 1959). Total catch biomass was calculated as the sum of all fish weights by species. We plotted the size frequency distribution by fork length at 2 mm intervals. Growth rates, as length or weight, were calculated for coho salmon juveniles as the difference in the natural log of the median value for the dominant size class based on the frequency distribution divided by time (days) between summer and fall samples. Weights for the median length coho salmon were determined by the length to weight relationship developed using the entire catch for that date. Coho salmon fitness (weight (g)/length (mm)^{3}x10000) for each stream was calculated as the average of all fish values for each species. T-tests were used to test for statistically significant differences in parameters between upland and wetland streams.

We measured discharge and water chemical and physical characteristics concurrent with summer and fall fish sampling. Discharge was measured using a Swoffer 3000 velocity meter which calculates discharge as the sum of individual components with velocity measured at 0.6 x depth. Turbidity, color, pH, specific conductivity, and dissolved oxygen were measured on site. Water samples were collected and submitted to AM Test, Inc. in Kirkland, Washington for ammonia-N, nitrate+nitrite-N, total phosphorus, and total dissolved phosphorus analyses.

Results

Water Temperature

Stream water temperatures were highly variable among sampling locations (Table 1). Maximum seasonal temperatures ranged from 11 to over 22°C. Stream water temperatures within the Susitna River drainage often exceed Alaska State Water Quality Standards for spawning and incubation (13°C) or rearing and migration (15°C). Stream water temperatures exceeded 13°C greater than 10% of the time at 22 of the 33 sites investigated, and 15°C greater than 10% of the time at 17 of the 33 sites. The coldest streams were the small streams draining the Talkeetna Mountains, and the larger glacially-influenced Little Susitna River in Hatcher Pass. Sawyer Creek (a tributary to Montana Creek) was warmer than the other upland streams, and may be due to a warmer wetland tributary. These were followed by the larger clear-water streams. These streams had low regression slopes between daily air and daily water temperatures. The large and small wetland streams created the next warmer category. The larger wetland streams were generally cooler than the smaller streams with lower regression slopes. Lowland streams downstream from lakes were the warmest among the systems investigated.

TABLE 1. STREAM WATER TEMPERATURE STATISTICS FOR 2008 SAMPLING LOCATIONS SORTED BY AUGUST CUMULATIVE DEGREE DAYS. ASTERISKS INDICATE INCOMPLETE DATA FOR THE SEASON OR STATISTIC.

	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13°C	Percent of Total Days > 13°C	Days Max Temp >15°C	Percent of Total Days >15°C	Days Max Temp >20°C	Jun Cumulative Degree Days	Jul Cumulative Degree Days	Aug Cumulative Degree Days	Sep Cumulative Degree Days	Regression Slope	Regression R^2	Y Intercept
Little Susitna River-Mile 12 Hatcher Pass Road	11.13	6.59	113	0	0	0	0	0	108*	192	204	150	0.46	0.77	0.05
Little Susitna River at Edgerton Park	12.00	6.08	113	0	0	0	0	0	127*	224	234	173	0.47	0.78	0.78
Swiftwater Creek *	10.30	3.53	67	0	0	0	0	0			245	198	0.44	0.84	1.78
Iron Creek Trib North (WK2)	10.94	4.20	128	0	0	0	0	0	198	224	251	188	0.28	0.38	3.24
Colter Creek*	10.74	3.60	68	0	0	0	0	0			252	208	0.44	0.83	2.12
Iron Creek Trib South (WK1)	13.65	5.64	128	1	1	0	0	0	216	294	285	200	0.42	0.40	2.01
Little Susitna River at Miller's Reach	13.06	3.57	122	1	1	0	0	0	169	292	292	216	0.41	0.65	2.72
Willow Creek	14.84	4.80	92	4	4	0	0	0		315	324	231	0.45	0.66	3.33
Nancy Creek above Nancy Lake	15.39	5.27	122	8	7	1	1	0	269	321	325	238	0.52	0.60	2.89
Little Willow Creek at Parks Hwy	15.58	5.03	120	6	5	1	1	0	249	323	325	227	0.45	0.58	3.15
Deception Creek	15.68	5.73	122	13	11	1	1	0	282	330	329	231	0.47	0.61	3.26
Montana Creek	16.51	5.61	122	19	16	2	2	0	268	339	332	242	0.50	0.65	3.15
Whiskers Creek	16.62	6.11	126	34	27	5	4	0	339	365	338	234	0.53	0.61	3.23
Sawyer Creek (aka Buddy Creek) *	17.61	5.62	101	35	35	9	9	0	336	375	351	244	0.55	0.51	2.64
Rabideux at South Parks Highway	16.37	4.78	131	41	31	9	7	0	252	389	358	253	0.52	0.52	3.43
Little Susitna at the Public Use Facility	16.30	5.50	122	52	43	5	4	0	232	373	373	261	0.56	0.61	3.27
Moose Creek at Oilwell Road	19.77	6.19	120	70	58	21	18	0	369	406	381	254	0.61	0.67	3.26
Chijik Trib*	14.51	2.49	64	19	30	0	0	0			383	261	0.63	0.73	1.61
Sawmill Creek at Parks Highway	18.30	5.82	140	76	54	16	11	0	377	402	396	261	0.57	0.58	3.60
Meadow Creek at Beaver Lakes Road	18.91	6.94	122	90	74	41	34	0	391	420	402	267	0.64	0.62	3.48

	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13°C	Percent of Total Days > 13°C	Days Max Temp >15°C	Percent of Total Days >15°C	Days Max Temp >20°C	Jun Cumulative Degree Days	Jul Cumulative Degree Days	Aug Cumulative Degree Days	Sep Cumulative Degree Days	Regression Slope	Regression R^2	Y Intercept
Chijik Creek at Oilwell Road*	20.82	6.31	94	62	66	31	33	2		429	412	269	0.72	0.68	1.99
Kroto Creek at Oilwell Road	20.53	6.66	122	87	71	43	35	2	402	435	412	269	0.74	0.69	2.04
Trapper Creek	19.25	5.06	122	88	72	32	26	0	400	441	414	284	0.60	0.62	4.01
Little Meadow Creek at Meadow Lakes Loop	18.13	6.85	122	82	67	40	33	0	358	412	420	279	0.60	0.68	4.09
Wiggle Creek	20.14	6.24	149	109	73	63	42	1	439	462	423	280	0.80	0.57	1.16
Twister Creek	19.66	4.95	150	111	74	62	41	0	437	457	433	286	0.67	0.65	3.63
Cottonwood Creek at Surrey	18.75	5.13	122	95	78	60	49	0	402	452	439	298	0.70	0.67	3.20
Queer Creek	19.84	5.40	138	112	81	76	55	0	425	459	449	307	0.65	0.61	4.25
Fish Creek at Knik-Goose Bay	19.03	5.61	121	93	77	63	52	0	408	457	449	302	0.69	0.62	3.57
Cottonwood Creek below Wasilla Lake	20.31	6.19	150	111	74	84	56	1	433	493	478	319	0.82	0.65	2.10
Lake Creek below Nancy Lake	22.78	5.67	113	107	95	90	80	6	465	527	510	278*	0.57	0.47	7.72
Question Creek below Question Lake	21.34	3.14	112	110	98	100	89	4	492	541	519	392	0.55	0.62	7.80
Fish Creek Below Big Lake	21.03	4.41	122	110	90	95	78	3	469	525	524	382	0.69	0.62	3.57

TABLE 2. STREAM CHEMICAL CHARACTERISTICS, TURBIDITY, AND COLOR FROM FALL SAMPLES.

	Specific Conductivity (µS/cm)	pH	Turbidity (NTU)	Color (CU)	D.O. Percent Saturation	DOC (mg/L)	Nitrate-N (mg/L)	Ammonia-N (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Molar N:P Ratio
Queer Creek	11.8	6.00	0.47	75.4	87.4	23.0	0.000	0.046	0.012	0.012	8.76
Trapper Creek	26.3	6.64	1.00	41.4	88.8	11.0	0.033	0.130	0.013	0.007	28.66
Wiggle Creek	60.6	7.20	0.00	9.3	72.9	5.7	0.000	0.046	0.008	0.000	13.14
Chijik Trib	20.5	6.85	1.17	79.7	83.1	15.0	0.017	0.180	0.016	0.014	28.14
Nancy Creek	46.5	7.09	0.65	7.8	80.1	9.3	0.000	0.044	0.008	0.010	12.57
Whiskers Creek						6.7	0.045	0.042	0.010	0.007	19.89
Sawyer Creek	30.4	7.13	0.86	27.6	98.3	7.8	0.030	0.087	0.014	0.010	19.10
North Fork Iron Creek	45.0	7.28	2.09	19.5	100.9	7.0	0.120	0.051	0.020	0.011	19.54
South Fork Iron Creek	32.9	7.21	1.34	23.8	99.2	5.9	0.039	0.110	0.028	0.014	12.16
Colter Creek	61.3	7.79	1.46		97.6	1.9	0.077	0.110	0.009	0.000	47.49
Swiftwater Creek	57.0		2.62		100.5	0.0	0.041	0.059	0.016	0.000	14.29
Deception Creek	100.1	7.49	2.64		101.6	7.3	0.014	0.175	0.016	0.007	27.00
Average Wetland	33.1	6.76	0.66	42.7	82.5	11.8	0.016	0.081	0.011	0.008	18.53
Average Upland	54.5	7.38	1.84	23.6	99.7	5.0	0.054	0.099	0.017	0.007	23.26
p value (t-test)	0.34	0.07	0.03	0.42	0.00	0.06	0.07	0.62	0.16	0.76	0.29

Water Chemistry

Water chemical results are shown in Table 2. Wetland streams differed from upland streams in pH, dissolved oxygen concentration, turbidity, dissolved organic carbon, and nitrate+nitrite-nitrogen concentrations. Wetland streams were more acidic, with pH generally below 7.0. This difference is consistent with the high concentrations of dissolved organic matter within these streams. Upland streams were consistently saturated with dissolved oxygen, while dissolved oxygen in wetland stream ranged from 73 to 88 percent saturation. Both stream types contained little inorganic particulate matter with low turbidity values; however, turbidity within the wetland streams was lowest. Average water color was higher in the wetland streams. Nutrient concentrations among the two stream types were similar, with the exception of nitrate + nitrite-nitrogen concentrations which were significantly higher in upland streams. These differences were reflected in ratios of nitrogen to phosphorus, which indicate that nitrogen may be more commonly limiting to primary production within wetland stream systems.

Juvenile Salmon Relative Abundance and Growth

Community Composition

Fish community composition and age classes varied considerably between samples collected from wetland and upland streams. Coho salmon juveniles were captured at all wetland and upland stream sampling sites. Chinook salmon juveniles were captured at 2, 3 and 4 of the 6 wetland stream sampling locations in the spring, summer, and fall, respectively. Chinook salmon were present in catches from all upland streams during mid-summer and fall sampling and from 4 of the 6 sites during spring sampling. Upland streams included tributaries to Montana Creek, Little Willow Creek, Willow Creek, and the Little Susitna River. Resident Dolly Varden char, rainbow trout, or both, also were commonly captured in upland streams. Dolly Varden were captured at all upland stream locations with the exception of Deception Creek. Rainbow trout were captured within all of the streams with the exception of Swiftwater and Colter Creeks, the two Little Susitna River tributaries. Among the upland streams, resident Dolly Varden were common in tributaries to the Little Susitna River and Little Willow Creek, while rainbow trout were more common in tributaries to Willow and Montana Creeks. Dolly Varden char were absent from wetland stream catches and rainbow trout were captured at 4 of the 6 locations. Rainbow trout were not found in catches from Wiggle Creek (a tributary to the Talkeetna River) or Queer Creek (a tributary to Rabideux Creek).

The appearance of assumed age-0 coho salmon varied considerably between wetland and upland streams and among streams of these two classifications. Spring sampling was conducted at three wetland sites on May 20 and May 23 at Trapper Creek, Wiggle Creek, and Queer Creek. Based upon the size frequency distribution, coho salmon fry were not present, or present in very low numbers, in these streams during spring sampling with 1 to 10% of the catch smaller then 55- mm in fork length (Figure 1). Similarly, coho salmon juveniles less than 55 mm in fork length were found in catches from 3 of the 5 upland streams sampled in the spring. At one of these 3 locations (Sawyer Creek), catch rates were very low (12 fish total), and while the portion juvenile salmon less than 55 mm in fork length was high, the overall low number suggested that they did not represent newly emerged fish.

The relative abundance of fish less than 55-mm was highest during the mid-summer samples from wetland streams, but in upland streams, the relative abundance of these smaller fish peaked in fall catches. Among the wetland streams, 4 of the 5 sites sampled had the highest number of small fish during mid-summer samples. Fish less than 55 mm in fork length did not make up a large portion of the catch within the remaining streams on any sampling date, and were not present in samples until the October sampling date. In contrast, smaller coho salmon made up the largest portion of the catch during fall sampling at 3 of the 6 upland sites (Figure 1).

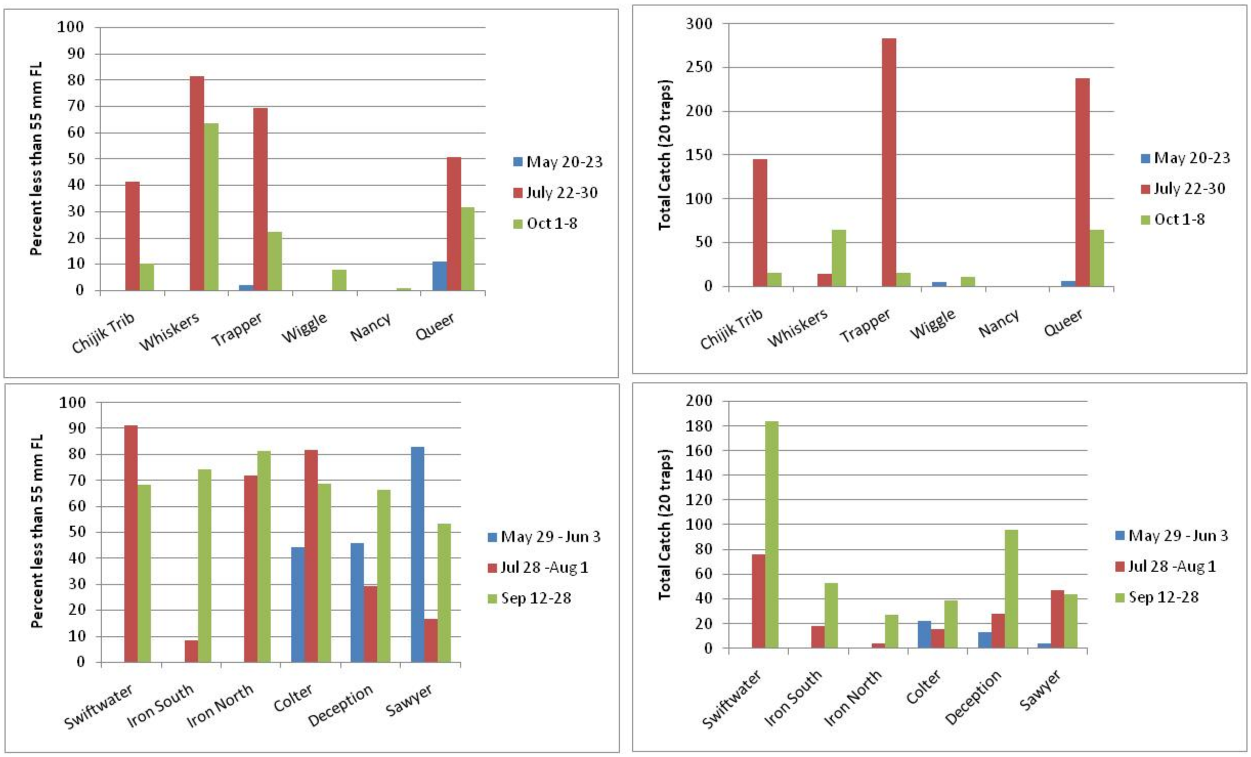


FIGURE 1. RELATIVE PERCENT OF COHO SALMON CATCH COMPOSED OF FISH LESS THAN 55-MM FORK LENGTH (LEFT) AND TOTAL CATCH LESS THAN 55MM (RIGHT) FOR SPRING, SUMMER AND FALL SAMPELS. SMALLER FISH DOMINATED THE CATCH DURING MID-SUMMER IN WETLAND STREAMS BUT OFTEN PEAKED DURING FALL SAMPLES FROM UPLAND STREAMS.

Relative Catch Rate

Total salmonid catch rates were highest in the wetland streams during spring and summer sampling, but similar between the two stream types during fall sampling (Table 2). Differences in catch rates were statistically significant (t-tests, alpha <0.05). On average, we captured 6 more salmonids per trap during the spring and 10 more per trap during the summer in wetland streams. We captured on average 5 more fish per trap in upland streams during fall sampling.

Average catch rates of coho salmon were greater in wetland streams during all seasons; however, differences were only statistically significant during the spring and summer. Coho salmon catch rates decreased significantly in all of the wetland streams between mid-summer and fall sampling in the wetland streams, but remained similar or increased in the upland streams. Coho salmon catch rates increased 5 fold between summer and fall sampling in Swiftwater Creek, one of the upland streams, but decreased to 0.25 of summer catches in the fall sampling at Sawyer Creek, another of the upland sites.

Chinook salmon catch rates were significantly higher in upland streams during all seasons. Chinook salmon were rare in the wetland streams and catch rates never exceeded 1 fish per trap. In contrast, average Chinook salmon catch rates increased from less than 1 fish per trap in the spring to 6 or 7 fish per trap during mid-summer and fall sampling in the upland streams. Differences in Chinook salmon catch rates between summer and fall in the upland or wetland streams were not significant.

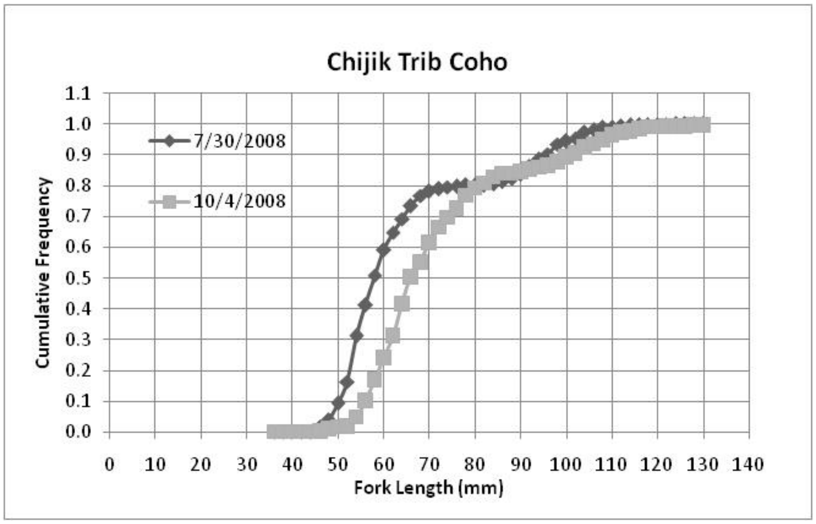
Catch rates of Dolly Varden char ranged from 0.4 to 1.5 fish per trap in catches from the upland streams but were absent in the wetland streams. Similarly, catch rates of rainbow trout ranged from 0.5 to 0.75 fish per trap in the upland streams, but maximum catch rates in the wetland stream during mid-summer were 0.2 fish per trap.

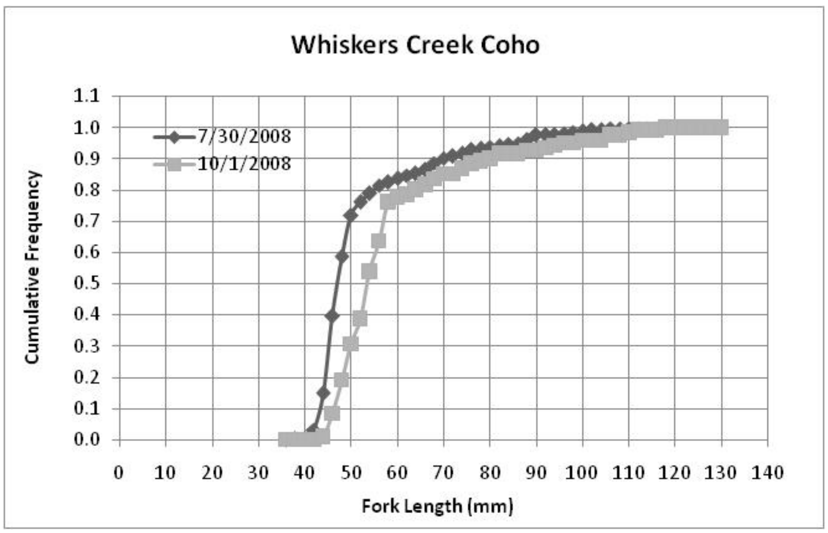
Biomass and Growth Rates

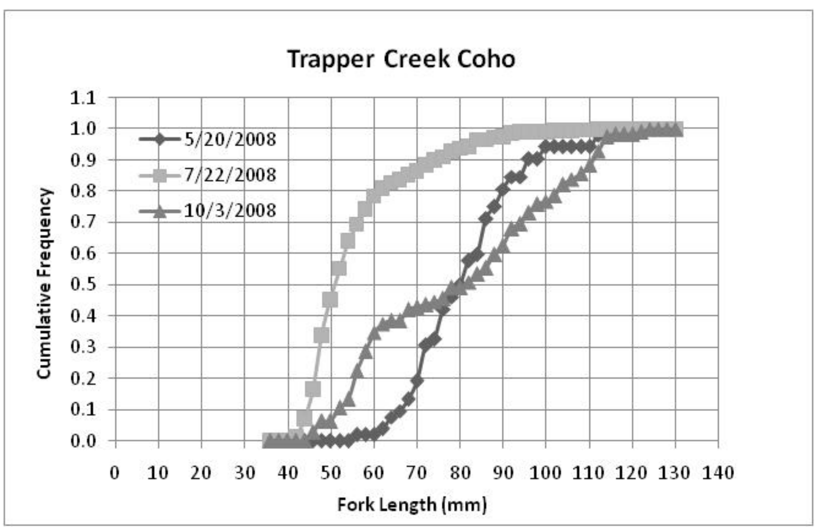
There were no significant differences in the biomass of total salmonids from catches in wetland streams compared to the upland streams for any season; however, average values tended to be higher in the wetland streams (Table 3). As the fish community in the wetland streams was dominated by coho salmon, biomass in catch rates was due to their abundance. Coho salmon biomass was significantly higher in catches from wetland streams, while Chinook salmon biomass was significantly higher in mid-summer and fall catches from upland streams. The average combined biomass of coho and Chinook salmon in catches was higher in the wetland streams for all seasons, but differences were only significant in the fall.

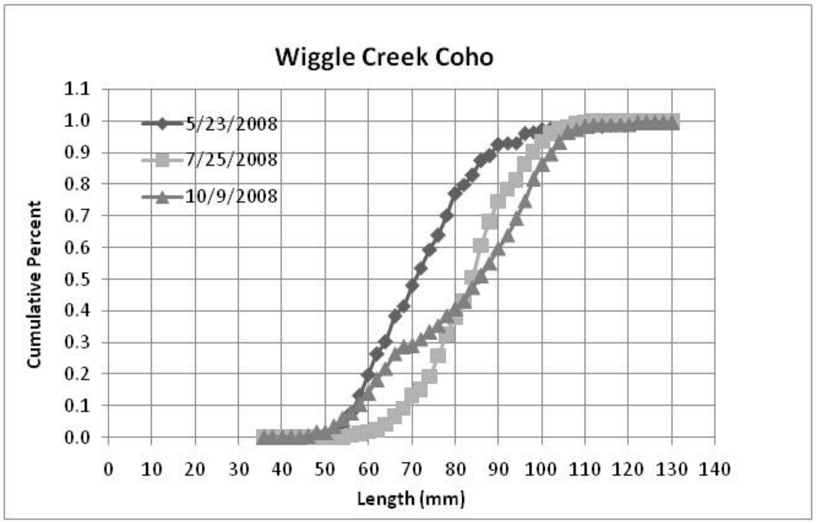
The trends in seasonal catch rates were not the same when using biomass instead of fish numbers. While there was a decrease in the number of coho salmon captured in wetland streams between summer and fall, there were no differences in biomass between these two seasons. While average catch rates of coho salmon juveniles increased in upland stream fall samples, average coho salmon biomass decreased. In contrast, the small decreases in Chinook salmon catch rates between summer and fall in upland streams were associated with a small increase in average biomass.

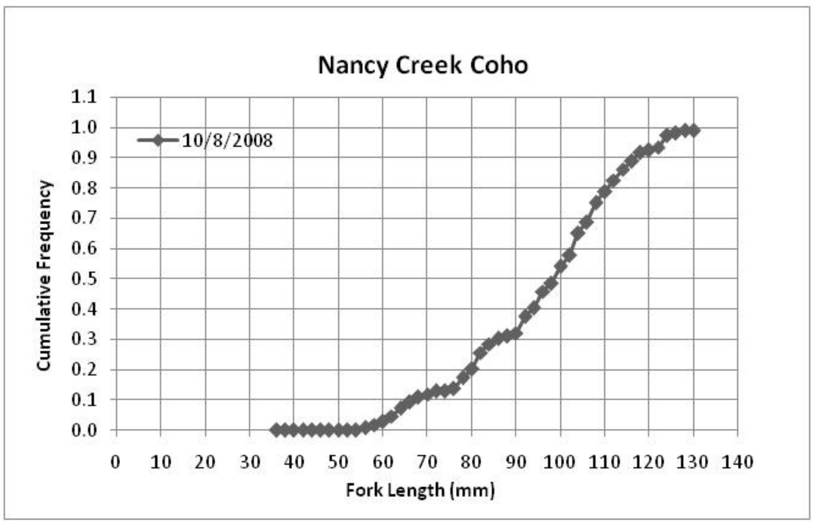
Comparisons between growth rates and condition factors between upland and wetland streams were limited to coho salmon juveniles as they were the only species abundant in both stream types. Calculation of growth rates was further limited by the ability to track a cohort between sampling dates. There were no significant differences in coho salmon condition factors between these two stream types. Average condition factors from all coho salmon captured within a site ranged from 0.10 to 0.11 with the lowest values during the fall within both stream types. Average growth rates as changes in weight between summer and fall sampling dates were 0.26 and 0.10 g/day for wetland and upland streams, respectively; however, differences were not statistically significant. Changes in coho salmon biomass ranged from 0.18 to 0.34 g/day in the wetland streams, and from -0.12 to 0.29 g/day in the upland streams. Average coho salmon growth rates based on fork length increased 0.12 mm/day in the wetland streams and 0.11 mm/day in the upland streams.

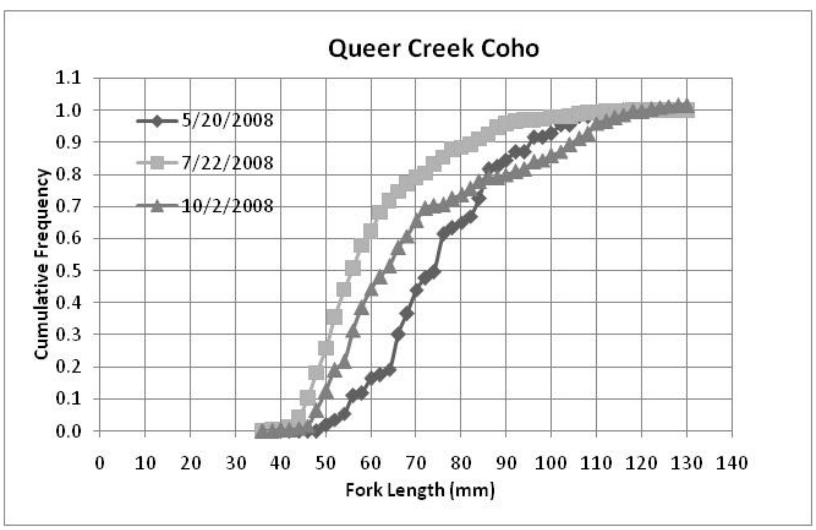

Chijik Trib Coho
Cumulative Frequency
Fork Length (mm)
7/30/2008
10/4/2008
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140

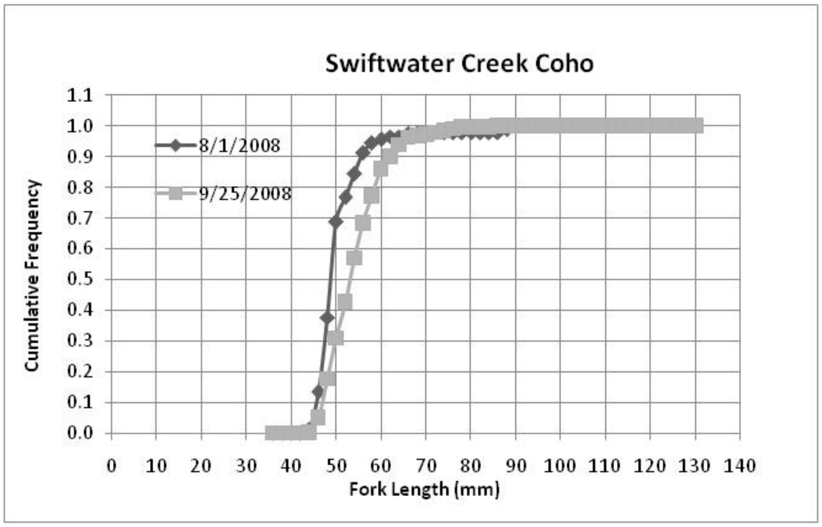

Whiskers Creek Coho
Cumulative Frequency
Fork Length (mm)
7/30/2008
10/1/2008
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140

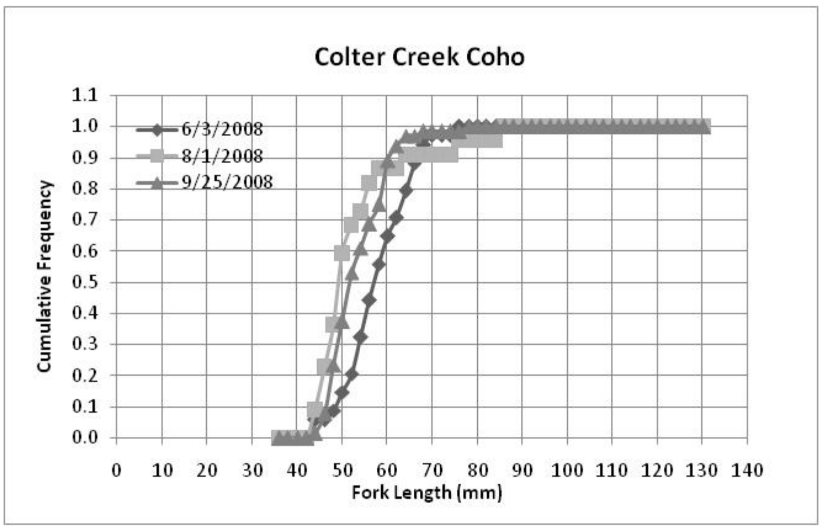

Trapper Creek Coho
Cumulative Frequency
Fork Length (mm)
5/20/2008
7/22/2008
10/3/2008
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140

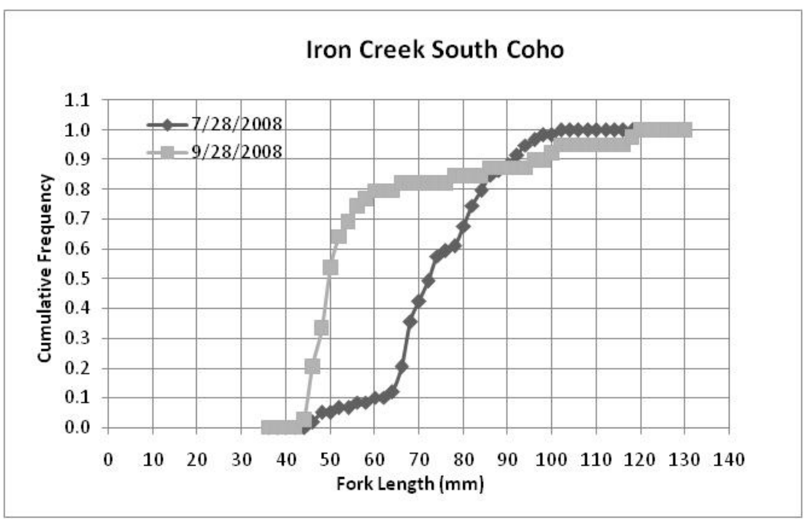

Wiggle Creek Coho
5/23/2008
7/25/2008
10/9/2008
Cumulative Percent
Length (mm)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140


Nancy Creek Coho
10/8/2008
Cumulative Frequency
Fork Length (mm)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140


Queer Creek Coho
5/20/2008
7/22/2008
10/2/2008
Cumulative Frequency
Fork Length (mm)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140


Swiftwater Creek Coho
8/1/2008
9/25/2008
Cumulative Frequency
Fork Length (mm)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140


Colter Creek Coho
6/3/2008
8/1/2008
9/25/2008
Cumulative Frequency
Fork Length (mm)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140


Iron Creek South Coho
7/28/2008
9/28/2008
Cumulative Frequency
Fork Length (mm)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140

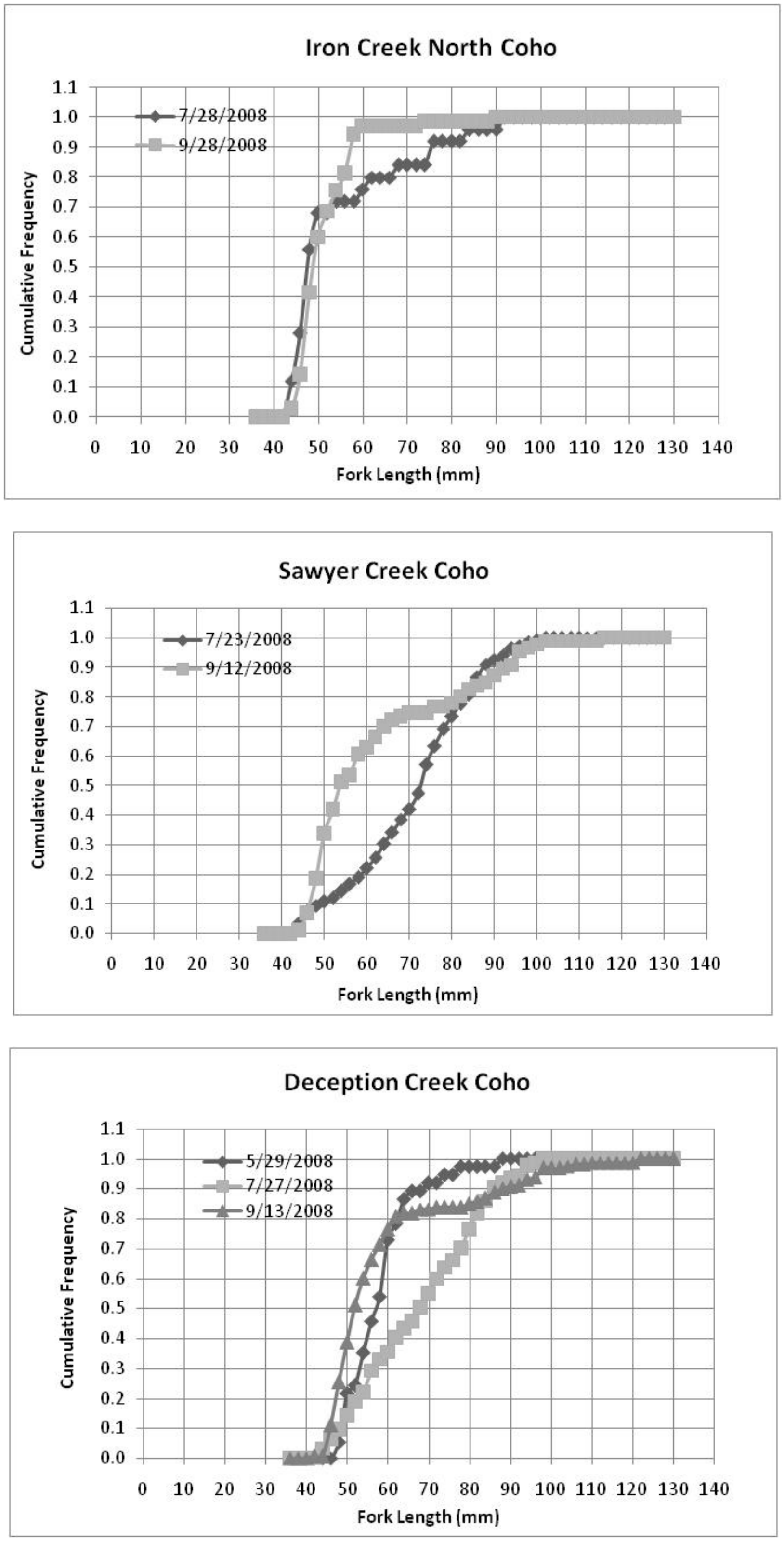


FIGURE 2. CUMULATIVE SIZE DISTRIBUTION OF JUVENILE COHO SALMON CAPTURED FOR EACH STREAM LOCATION AND SAMPLING DATE.

TABLE 3. SEASONAL CATCH RATES (AVERAGE CATCH/TRAP, N=20) OF JUVENILE SALMONIDS IN WETLAND AND UPLAND STREAMS. WETLAND STREAMS WERE DOMINATED BY COHO SALMON; WHILE COHO AND CHINOOK SALMON, DOLLY VARDEN CHAR AND RAINBOW TROUT WERE COMMON IN UPLAND STREAM CATCHES.

Wetland Streams

Coho Catch Rate /24 hrs

	Spring	Summer	Fall
Chijik Trib		23.25	15.35
Whiskers		21.95	6.05
Trapper	4.30	22.20	5.60
Wiggle	13.46	16.90	9.60
Nancy			5.45
Queer	9.08	27.10	15.20
Average	8.95	22.28	9.54

Chinook Catch Rate

	Spring	Summer	Fall
Chijik Trib		0.00	0.00
Whiskers		2.00	0.40
Trapper	0.00	0.50	0.30
Wiggle	0.00	0.00	1.67
Nancy			0.00
Queer	0.05	0.05	0.55
Average	0.02	0.51	0.49

Dolly Varden Catch Rate

	Spring	Summer	Fall
Chijik Trib		0.00	0.00
Whiskers		0.00	0.00
Trapper	0.00	0.00	0.00
Wiggle	0.00	0.00	0.00
Nancy			0.00
Queer	0.00	0.00	0.00
Average	0.00	0.00	0.00

Rainbow Trout Catch Rate

	Spring	Summer	Fall
Chijik Trib		1.00	0.05
Whiskers		0.05	0.00
Trapper	0.00	0.10	0.00
Wiggle	0.00	0.00	0.00
Nancy			0.05
Queer	0.00	0.00	0.00
Average	0.00	0.23	0.02

Total Salmonid Catch Rate

	Spring	Summer	Fall
Chijik Trib		24.25	15.40
Whiskers		24.00	6.45
Trapper	4.30	22.80	5.90
Wiggle	13.46	16.90	11.27
Nancy			5.50
Queer	9.13	27.15	15.75
Average	8.96	23.02	10.05

Upland Streams

Coho Catch Rate /24 hrs

	Spring	Summer	Fall
Swiftwater		4.50	21.90
Iron North	0.17	2.05	3.50
Iron South	0.17	2.95	1.95
Colter	3.40	1.10	3.20
Deception	3.70	6.35	8.00
Sawyer	0.60	16.30	4.30
Average	1.61	5.54	7.14

Chinook Catch Rate

	Spring	Summer	Fall
Swiftwater		2.5	5.75
Iron North	0.55	6.15	4.90
Iron South	0.08	6.30	1.70
Colter	0.00	1.40	2.55
Deception	1.50	17.05	11.25
Sawyer	0.00	8.80	8.35
Average	0.43	7.03	5.75

Dolly Varden Catch Rate

	Spring	Summer	Fall
Swiftwater		3	2.2
Iron North	0.00	0.30	0.15
Iron South	0.17	0.00	0.10
Colter	1.80	1.70	6.75
Deception	0.00	0.00	0.00
Sawyer	0.00	0.05	0.00
Average	0.39	0.84	1.53

Rainbow Trout Catch Rate

	Spring	Summer	Fall
Swiftwater		0.00	0.00
Iron North	0.45	0.80	1.20
Iron South	0.58	0.95	1.25
Colter	0.00	0.00	0.00
Deception	0.90	0.45	0.35
Sawyer	1.42	0.85	1.70
Average	0.67	0.51	0.75

Total Salmonid Catch Rate

	Spring	Summer	Fall
Swiftwater	0.00	10.00	29.85
Iron North	1.17	9.30	9.75
Iron South	1.00	10.20	5.00
Colter	5.20	4.20	12.50
Deception	6.10	23.85	19.60
Sawyer	2.02	26.00	14.35
Average	2.58	13.93	15.18

TABLE 4.BIOMASS OF SALMONID CATCHES IN WETLAND AND UPLAND STREAMS.

Wetland Streams

Coho Biomass (kg)

	Spring	Summer	Fall
Chijik Trib		1.817	1.422
Whiskers		0.817	0.308
Trapper	0.292	0.928	0.706
Wiggle	0.684	2.139	1.246
Nancy			1.100
Queer	0.544	1.470	1.393
Average	0.507	1.434	1.029

Chinook Biomass (kg)

	Spring	Summer	Fall
Chijik Trib		0.000	0.000
Whiskers		0.108	0.028
Trapper	0.000	0.016	0.018
Wiggle	0.000	0.000	0.094
Nancy			0.000
Queer	0.043	0.004	0.002
Average	0.014	0.026	0.024

Dolly Varden Biomass (kg)

	Spring	Summer	Fall
Chijik Trib		0.000	0.000
Whiskers		0.000	0.000
Trapper	0.000	0.000	0.000
Wiggle	0.000	0.000	0.000
Nancy			0.000
Queer	0.000	0.000	0.000
Average	0.000	0.000	0.000

Rainbow Trout Biomass

	Spring	Summer	Fall
Chijik Trib		0.413	0.015
Whiskers		0.006	0.000
Trapper	0.000	0.011	0.000
Wiggle	0.000	0.000	0.000
Nancy			0.007
Queer	0.000	0.000	0.000
Average	0.000	0.086	0.004

Total Salmonid Biomass

	Spring	Summer	Fall
Chijik Trib		2.230	1.437
Whiskers		0.931	0.336
Trapper	0.292	0.955	0.724
Wiggle	0.684	2.139	1.340
Nancy			1.107
Queer	0.587	1.474	1.395
Average	0.521	1.546	1.057

Upland Streams

Coho Biomass (kg)

	Spring	Summer	Fall
Swiftwater		0.154	0.540
Iron North	0.004	0.053	0.095
Iron South	0.005	0.290	0.122
Colter		0.039	0.110
Deception	0.076	0.471	0.430
Sawyer	0.011	1.453	0.275
Average	0.024	0.410	0.262

Chinook Biomass (kg)

	Spring	Summer	Fall
Swiftwater		0.111	0.367
Iron North	0.014	0.193	0.204
Iron South	0.003	0.238	0.083
Colter	0.000	0.054	0.191
Deception	0.046	0.587	0.463
Sawyer	0.000	0.404	0.449
Average	0.013	0.265	0.293

Dolly Varden Biomass (kg)

	Spring	Summer	Fall
Swiftwater		0.684	0.412
Iron North	0.000	0.090	0.056
Iron South	0.012	0.000	0.037
Colter		0.425	0.204
Deception	0.000	0.000	0.000
Sawyer	0.000	0.025	0.000
Average	0.003	0.204	0.118

Rainbow Trout Biomass

	Spring	Summer	Fall
Swiftwater		0.000	0.000
Iron North	0.031	0.115	0.116
Iron South	0.095	0.224	0.133
Colter	0.000	0.000	0.000
Deception	0.087	0.064	0.074
Sawyer	0.151	0.243	0.980
Average	0.073	0.108	0.217

Total Salmonid Biomass

	Spring	Summer	Fall
Swiftwater		0.949	1.319
Iron North	0.049	0.451	0.471
Iron South	0.115	0.752	0.375
Colter		0.518	0.505
Deception	0.209	1.122	0.967
Sawyer	0.162	2.125	1.704
Average	0.134	0.986	0.890

Discussion

Water temperatures among streams within the Susitna River Valley varied by stream type and are consistent with 2007 observations (Davis and Davis 2008). The coldest streams were those draining the Talkeetna Mountains. These streams rarely exceeded 13 or 15°C. The cold water temperatures are likely buffered by ground water input and are only moderately affected by air temperatures as indicated by the low regression slopes. The larger upland streams that have a greater exposure to solar radiation (Montana Creek, Deception Creek, Willow Creek), are warmer than the smaller upland streams which are shaded by riparian vegetation. Temperate water streams included both small and large low-sloped brown-water streams within the Susitna River drainage. Water temperatures in these streams commonly exceed 15°C. These streams are influenced to a greater degree by air temperatures, with regression slopes that range from 0.5 to 0.7. These streams are open to solar radiation, lacking the shade provided by riparian vegetation. The influence of solar radiation appears to be controlled by water volume with the larger streams tending to be cooler. The warmest streams among those measured are below large lakes. Water temperatures in these streams are greater than 15°C most of the time and commonly exceed 20°C. Regression equations indicate a strong relationship to air temperatures.

Stream water temperatures were lower in 2008 compared to 2007 (see Appendix A for 2007 temperature statistics) consistent with differences in air temperatures. August cumulative degree days ranged from 204 to 524 in 2008 down from 248 to 578 in 2007. Cumulative degree days in August were 30 to 40 degrees less in 2008 compared to 2007. The relationship between air and water temperatures (regression slopes) were consistent at most sites but decreased for small wetland streams and lake outlet streams. Differences in stream temperatures largely reflect differences in air temperatures. Air temperatures recorded by the National Weather Service at the Talkeetna Airport were warmer in 2007 compared to 2008 (Figure 3).

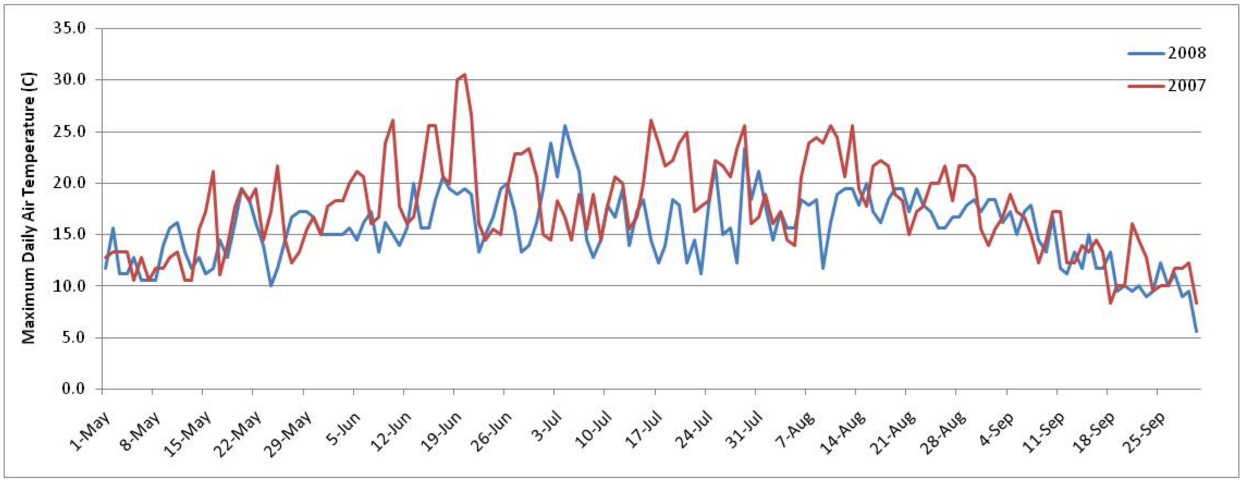


FIGURE 3. MAXIMUM DAILY TEMPERATURE AT THE TALKEETNA AIRPORT FOR 2007 AND 2008.

Juvenile coho and Chinook salmon are believed to emerge from spawning gravels in the spring. Emerging fry rear in fresh water for one or more years prior to emigration as smolt (Meehan and Bjornn 1991). Based upon this generalized life history, observations, and previous sampling, we anticipated large captures of salmon fry during the late May or early June sampling dates. However, the more intensive sampling conducted through this project revealed a large variation among streams from this generalization. In upland streams, the total catch of coho salmon less than 55 mm was greatest at 4 of the 5 sites in September. Among the wetland streams, peak number of coho salmon less than 55 mm captured occurred during July, with the exception of Whiskers Creek. Minnow trap mesh size is 0.64 mm (0.89 mm on the diagonal), which does not retain newly emerged salmon fry. Based upon minnow trap catches, the minimum length of salmon common in traps is 46 mm fork length. The predominance of fish less than 55 mm in September samples suggests either later emergence, or slower growth rates in upland, relative to wetland streams.

Coho salmon growth rates through August and September (0.26 g/g-d wetland, and 0.10 g/g-d upland) were in the lower range of previously reported values. For example, Dolloff (1987) reported growth rates ranging from 0.49 to 0.78 g/g-d among different stream types in Southeast Alaska through August and November. Growth rates as changes in fish length in this study were similar to other reported values. Juvenile salmon in Southeast Alaska increased in length at a rate of 0.10 to 0.17 mm/d compared to 0.11 to 0.12 mm/d among streams in this study. Higher growth rates have been recorded for Coastal Oregon streams, where winter growth rates ranged from 0.15 to 0.58 g/g d during winter and 0.39 to 0.84 g/g d during spring (Ebersole et al. 2006). Growth rates of 0.33 g/g d were recorded by Bennett (2006) for coho salmon overwintering in coastal streams of the Olympic Peninsula in Washington. We calculated the growth rate from the change in weight of fish representing the median length for a single cohort, rather than individual fish. This could result in lower growth rates if the number of smaller fish increased and larger fish decreased within a cohort over the sampling period. This would appear as a steeper slope in the cumulative frequency distribution, which was not apparent (see Figure 2).

Growth rates vary with temperature and food availability, which may explain the differences observed between wetland and upland streams. Average daily temperatures in August ranged from 8 to 11°C in the upland streams and from 11 to 14°C among the wetland streams. Optimal rearing temperatures for coho salmon juvenile rearing and growth are from 12 to 15°C (Richter and Kolmes 2005). Water temperatures among the upland streams were below the temperature optima which may reduce growth rates. Optimal temperatures for juvenile salmon growth are higher when fish are satiated with food (Richter and Kolmes 2005). Water temperatures during growth rate measurements in Oregon streams ranged from 17 to 22°C (Ebersole et al. 2006). Extremely high coho salmon growth rates that ranged from 1.37 to 1.43 g/g d were recorded for fish rearing in emergent floodplains of coastal Oregon at water temperatures of 16 to 19°C (Henning et al. 2006). Growth rates in all studies cited here decreased during winter months and may be associated with reduced water temperatures. However, concomitant with changes in seasonal water temperatures are changes in solar radiation and primary production.

Differences in primary production among stream types have been related to changes in fish growth rates among habitat types. Dolloff (1987) reported significantly higher coho salmon growth rates for fish in streams through meadows compared to forested streams, sloughs, and streams in cleared forests. While water temperatures were not recorded, changes in growth rates were believed to be due to differences in primary production. Dolloff cites other studies (Murphy and Hall 1981, Wilzbach et al. 1986) relating high summer coho salmon growth to increased primary production after forest harvest of the riparian area. Wetland streams appear to have high amounts of allochthonus organic matter and the limited substrates, including emergent macrophytes, are covered with periphytic algae. Determining the independent influence of temperature and food resources is needed to further understand factors influencing growth rates among stream types.

Juvenile coho salmon dominated the fish community within wetland streams. However, coho salmon catch rates and biomass of catches equaled or exceeded measures of all fish species in upland streams. Therefore, the lack of interspecific competition cannot explain growth rate differences. The reduced abundance or lack of other salmonid species within wetland streams may be due to the physical and chemical characteristics of these systems. Wetland streams were more acidic that upland streams with average pH near 6.5. The percent oxygen saturation was lower in wetland streams often down to 70%, with concentrations as low as 7.4 mg/L. Maximum temperatures in these temperate to warm-water wetland streams often exceed temperature optima and lethal limits of many salmonids. Based upon regression equations, water temperatures within the wetland streams could exceed 20°C when air temperatures are over 26°C. Optimal temperature ranges are exceeded when air temperatures are greater than 18°C. Upper incipient lethal temperatures for salmonids are around 25°C (McCullough et al. 2001) which can be exceeded in the wetland streams at air temperatures of near 30°C. However, temperature optima and lethal limits do not differ enough between the salmonid species captured in this study, with the exception of the char which could be excluded from the wetland streams based upon water temperature alone. Coho salmon juveniles may have a higher tolerance for physical and chemical conditions on the margins of optimal characteristics allowing them to use more diverse habitats.

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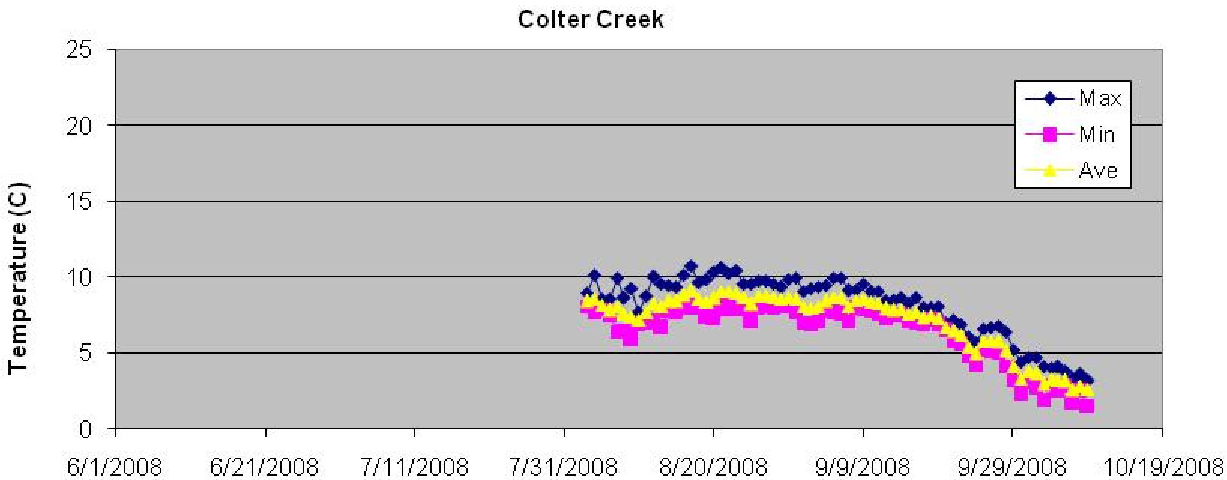
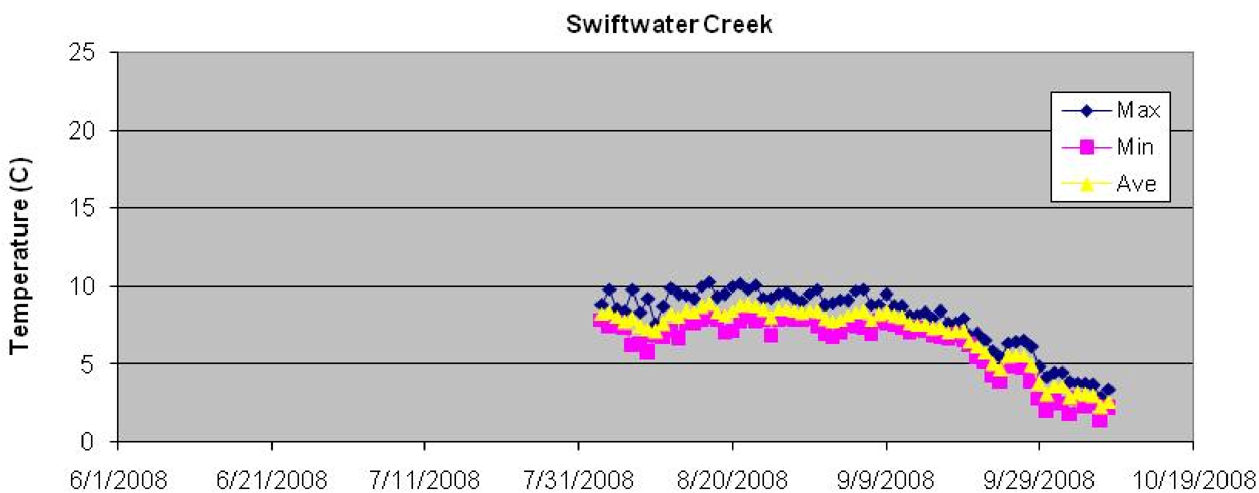
Appendix A. Stream water temperature statistics for 2007.

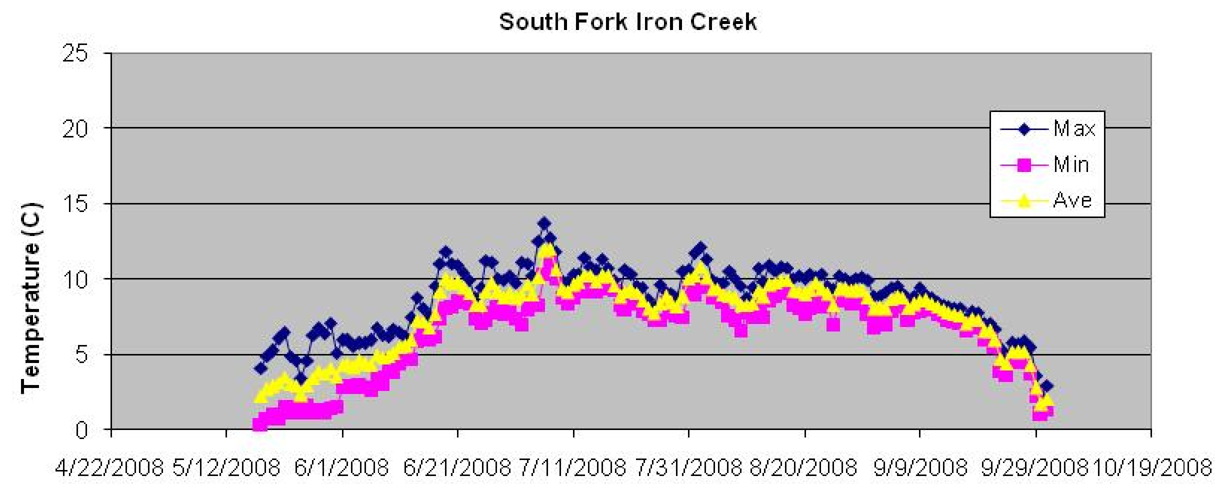
	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13°C	Percent of Total Days > 13°C	Days Max Temp >15°C	Percent of Total Days >15°C	Days Max Temp >20°C	June Cumulative Degree Days	July Cumulative Degree Days	August Cumulative Degree Days	September Cumulative Degree Days	Regression Slope	Regression r^2	Y -Intercept
Little Susitna River-Mile 12 Hatcher Pass Road	13.50	7.43	147	4	3%	0	0%	0	175	249	241	158	0.37	0.33	1.46
Iron Creek Trib North (WK2)	12.40	5.60	117	0	0%	0	0%	0	217	247	252	152	0.30	0.56	3.14
Little Susitna River at the Sushanna Bridge	13.98	6.23	120	5	4%	0	0%	0	233	291	N/A	159	0.32	0.35	3.49
Little Willow Trib South (WK3)	12.79	5.60	116	0	0%	0	0%	0	236	118*	125*	174	0.27	0.64	4.39
Little Willow Trib North (WK4)	13.56	5.89	117	2	2%	0	0%	0	244	282	290	182	0.28	0.60	4.65
Iron Creek Trib South (WK1)	15.57	5.12	117	12	10%	2	2%	0	288	324	329	192	0.37	0.62	3.98
Little Susitna River at Miller's Reach	15.35	3.87	157	13	8%	3	2%	0	292	353	342	245	0.37	0.45	4.03
Nancy Creek above Nancy Lake	15.51	4.31	69	14	20%	1	1%	0	N/A	N/A	350	247	0.50	0.77	2.53
Moose Creek at Petersville Road	19.25	4.23	69	37	54%	17	25%	0	N/A	N/A	410	261	0.63	0.73	1.84
Rabideux at South Parks Highway	19.46	4.93	69	37	54%	16	23%	0	N/A	N/A	410	268	0.62	0.75	2.1
Moose Creek at Oilwell Road	20.10	5.06	50	19	38%	8	16%	1	N/A	N/A	155*	265	0.70	0.72	0.81
Sawmill Creek at Parks Highway	19.13	4.96	69	37	54%	16	23%	0	N/A	N/A	420	278	0.59	0.75	2.87
Little Susitna River at Public Use Facility	20.31	5.35	157	87	55%	47	30%	1	380	457	416	266	0.61	0.52	2.64
Twister Creek	19.89	3.16	69	43	62%	27	39%	0	N/A	N/A	450	286	0.65	0.73	2.32
Kroto Creek at Petersville Road	22.39	6.55	52	26	50%	17	33%	5	N/A	N/A	207*	261	0.82	0.72	0.56
Meadow Creek at Beaver Lakes Road	19.41	5.24	69	42	61%	28	41%	0	N/A	N/A	441	284	0.73	0.79	1.04
Lower Trapper Creek	20.53	4.14	69	40	58%	30	43%	1	N/A	N/A	452	291	0.66	0.74	2.24
Trapper Creek above Parks Highway	19.77	4.73	69	44	64%	32	46%	0	N/A	N/A	453	296	0.67	0.76	2.44
Kroto Creek at Oilwell Road	21.70	5.47	68	40	59%	35	51%	2	N/A	N/A	451	269	0.75	0.73	0.95
Little Meadow Creek at Meadow Lakes	18.94	5.34	58	35	60%	24	41%	0	N/A	N/A	287.82*	288	0.72	0.83	1.27

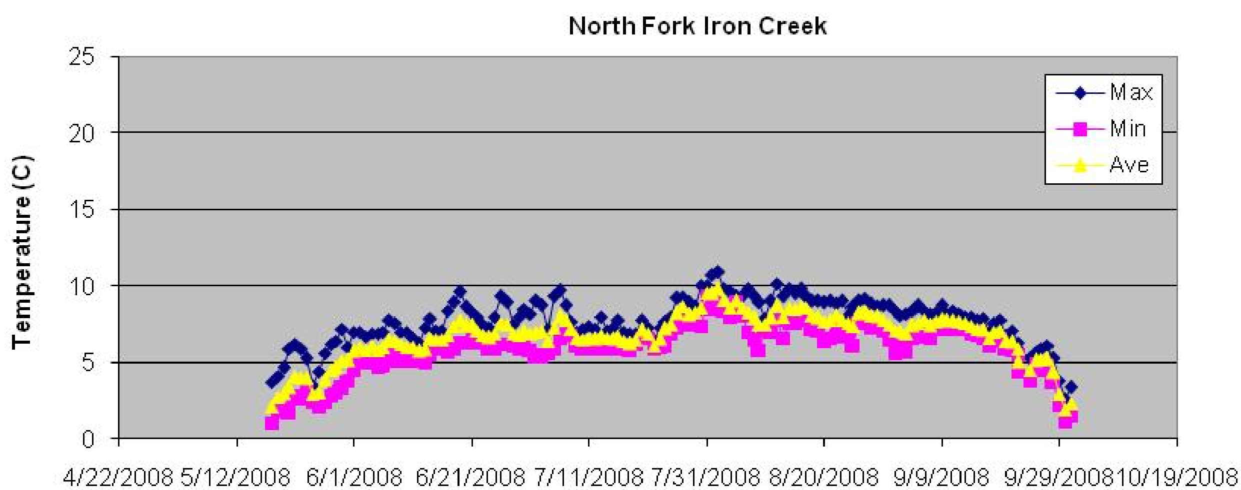
	Season Maximum	Maximum Daily Range	Total Days	Days Max Temp >13°C	Percent of Total Days > 13°C	Days Max Temp >15°C	Percent of Total Days >15°C	Days Max Temp >20°C	June Cumulative Degree Days	July Cumulative Degree Days	August Cumulative Degree Days	September Cumulative Degree Days	Regression Slope	Regression r^2	Y -Intercept
Loop															
Mile 118.2 Trail Creek	21.15	6.99	69	47	68%	36	52%	2	N/A	N/A	468	287	0.67	0.73	2.82
Wiggle Creek	21.82	4.38	69	46	67%	37	54%	4	N/A	N/A	478	289	0.75	0.73	1.42
Fish Creek below Knik-Goose Bay	20.67	4.31	69	49	71%	39	57%	1	N/A	N/A	486	326	0.72	0.77	2.51
Cottonwood Creek at Surrey Road	20.80	6.42	122	101	83%	82	67%	2	439	484	472	328	0.59	0.72	4.84
Queer Creek	21.60	5.48	69	50	72%	38	55%	4	N/A	N/A	480	320	0.68	0.75	3.18
Question Creek above Question Lake	22.30	5.31	69	49	71%	39	57%	8	N/A	N/A	498	310	0.79	0.79	1.45
Cottonwood Creek at Edlund Road	23.82	8.69	122	106	87%	98	80%	18	479	523	511	350	0.74	0.79	3.97
Cottonwood Creek at Marble Way	23.49	8.22	61	61	100%	58	95%	16	472	515	N/A	N/A	0.50	0.66	8.9
Lake Creek below Nancy Lake	23.76	4.78	69	56	81%	50	72%	18	N/A	N/A	568	392	0.82	0.82	3.42
Cottonwood Creek at Wasilla Lake Outlet	24.34	6.33	122	109	89%	99	81%	34	508	569	557	383	0.72	0.72	5.16
Cottonwood Creek at Neklason Lake Outlet	24.56	7.64	122	108	89%	98	80%	39	506	552	551	363	0.81	0.77	3.54
Question Creek below Question Lake	23.28	3.76	69	60	87%	52	75%	19	N/A	N/A	582	412	0.65	0.75	6.68
Fish Creek below Big Lake	22.66	3.65	69	61	88%	52	75%	18	N/A	N/A	578	416	0.73	0.82	5.22
Cottonwood Creek at Wasilla Lake Inlet	24.32	6.05	73	71	97%	64	88%	22	524	564	N/A	N/A	0.55	0.49	8.77

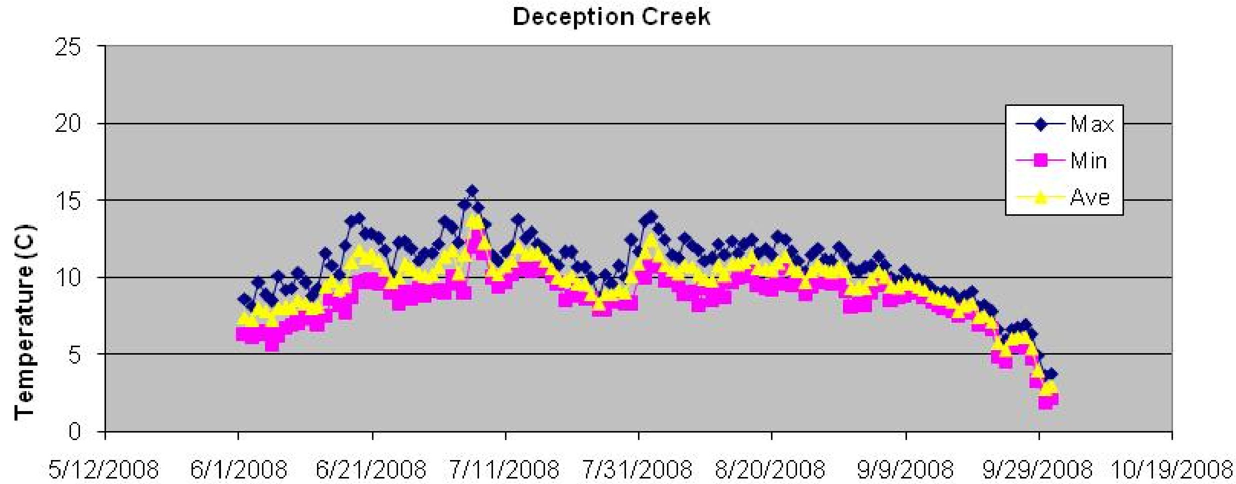
Appendix B. Stream water temperature graphs for wetland and upland streams.

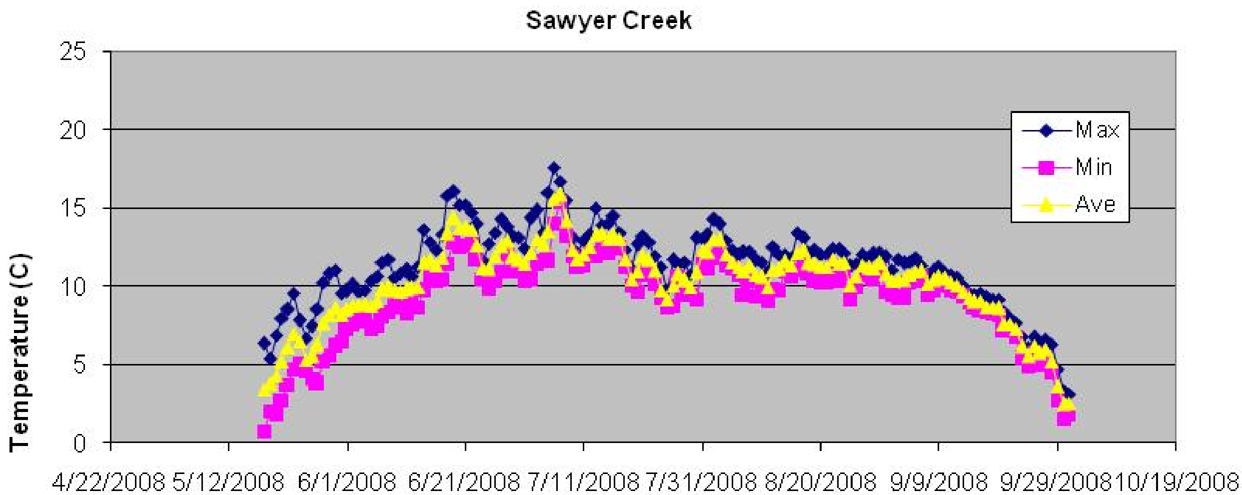

Colter Creek
Temperature (C)
25
20
15
10
5
0
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008
Max
Min
Ave

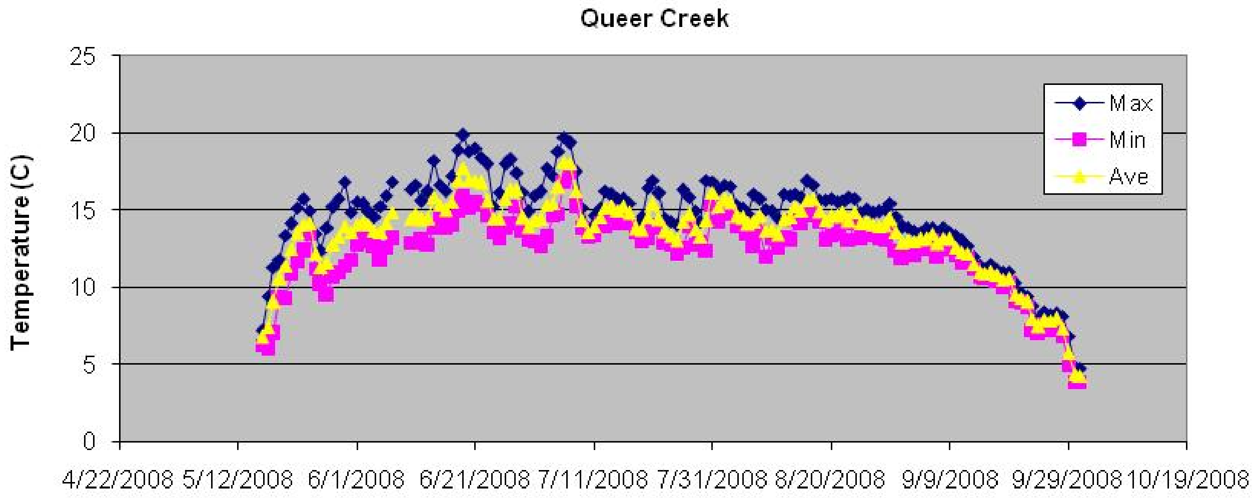

Swiftwater Creek
Temperature (C)
25
20
15
10
5
0
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008
Max
Min
Ave

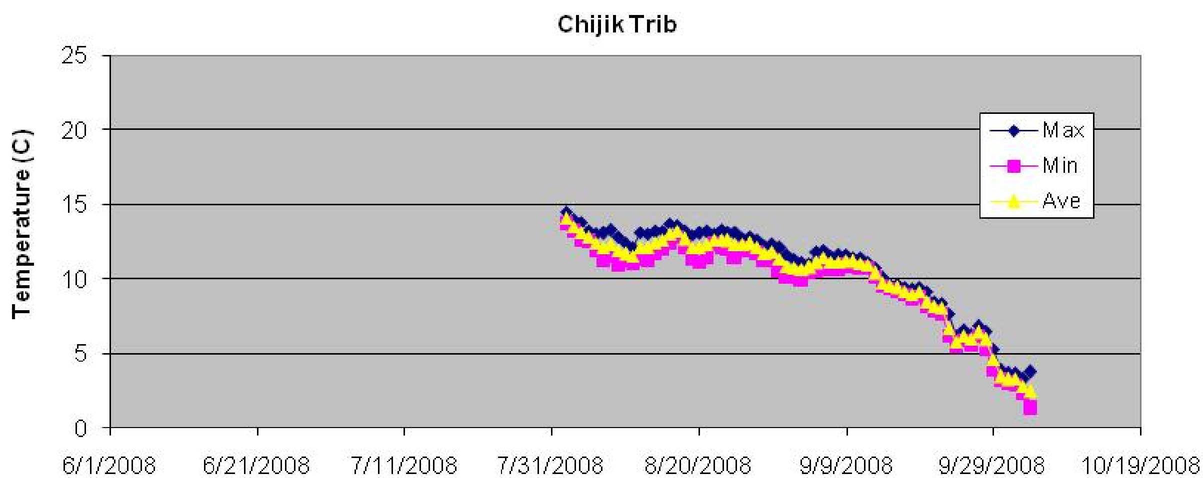

South Fork Iron Creek
Temperature (C)
25
20
15
10
5
0
4/22/2008 5/12/2008 6/1/2008 6/21/2008 7/11/2008 7/31/2008 8/20/2008 9/9/2008 9/29/2008 10/19/2008
Max
Min
Ave

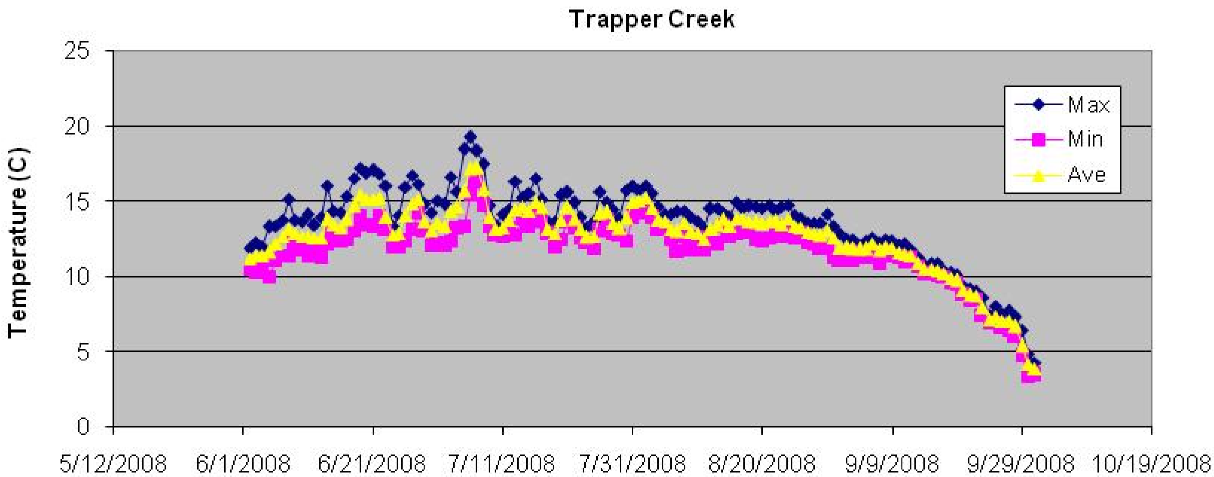

North Fork Iron Creek
Temperature (C)
25
20
15
10
5
0
4/22/2008 5/12/2008 6/1/2008 6/21/2008 7/11/2008 7/31/2008 8/20/2008 9/9/2008 9/29/2008 10/19/2008
Max
Min
Ave

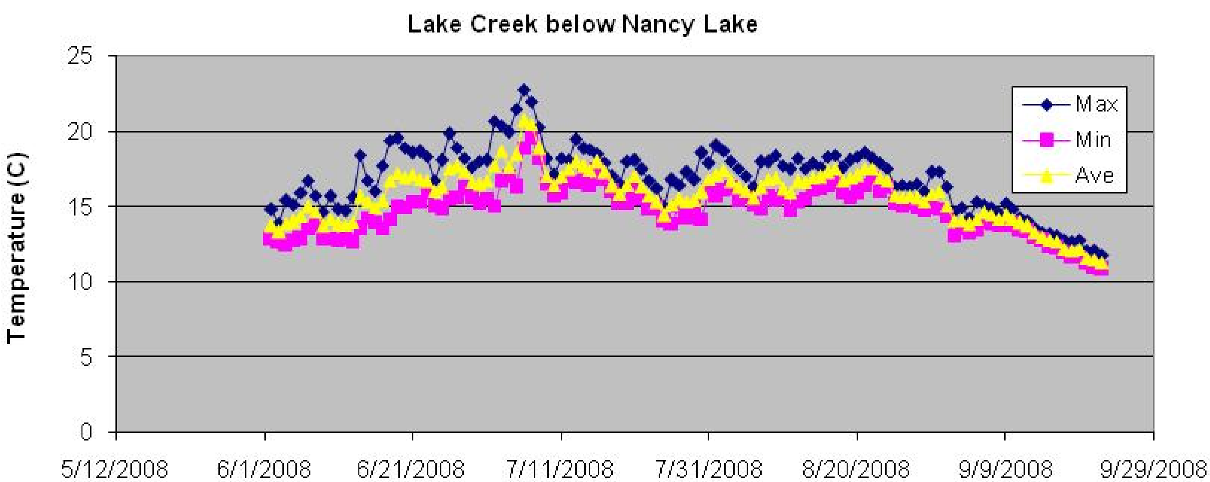

Deception Creek
Temperature (C)
25
20
15
10
5
0
5/12/2008
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008
Max
Min
Ave

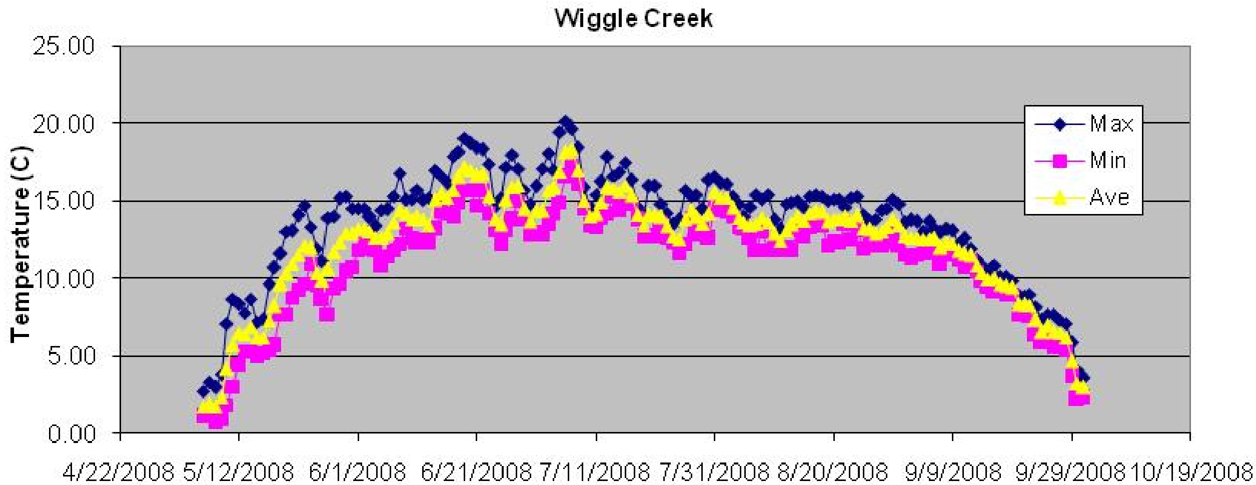

Sawyer Creek
Temperature (C)
25
20
15
10
5
0
4/22/2008
5/12/2008
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008
Max
Min
Ave

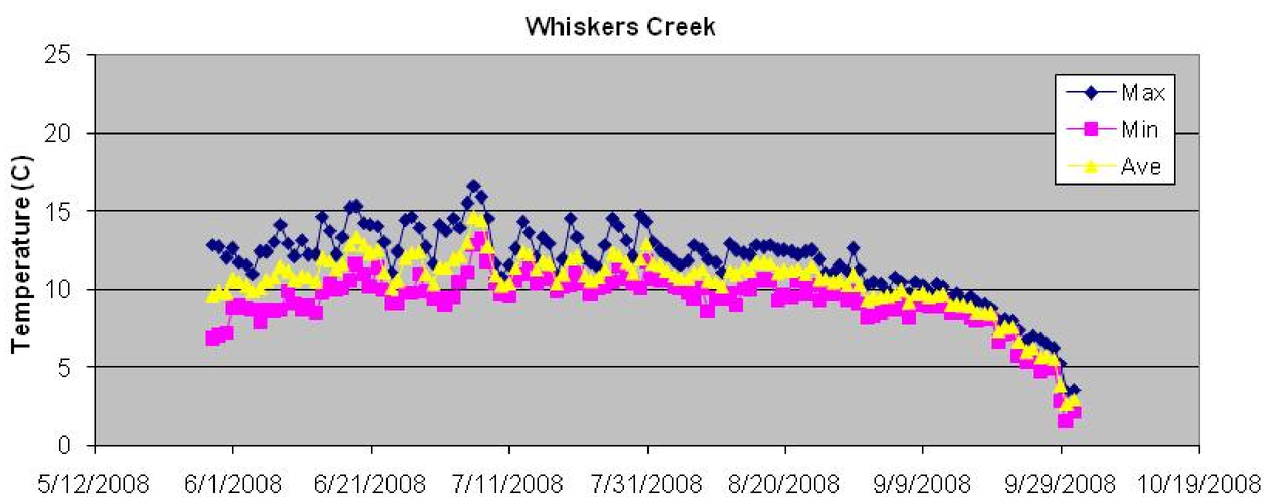

Queer Creek
Temperature (C)
25
20
15
10
5
0
4/22/2008 5/12/2008 6/1/2008 6/21/2008 7/11/2008 7/31/2008 8/20/2008 9/9/2008 9/29/2008 10/19/2008
Max
Min
Ave


Chijik Trib
Temperature (C)
25
20
15
10
5
0
6/1/2008 6/21/2008 7/11/2008 7/31/2008 8/20/2008 9/9/2008 9/29/2008 10/19/2008
Max
Min
Ave


Trapper Creek
Temperature (C)
25
20
15
10
5
0
5/12/2008
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008
Max
Min
Ave


Lake Creek below Nancy Lake
Temperature (C)
25
20
15
10
5
0
5/12/2008
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
Max
Min
Ave


Wiggle Creek
25.00
20.00
15.00
10.00
5.00
0.00
Temperature (C)
Max
Min
Ave
4/22/2008
5/12/2008
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008


Whiskers Creek
25
20
15
10
5
0
Temperature (C)
Max
Min
Ave
5/12/2008
6/1/2008
6/21/2008
7/11/2008
7/31/2008
8/20/2008
9/9/2008
9/29/2008
10/19/2008