

U.S. Fish and Wildlife Service

Summary of Icicle Creek Temperature Monitoring, 2005-2010



Mathew Hall and Barb Kelly-Ringel

U.S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
Leavenworth, WA 98826

On the cover: Icicle Creek upstream of the Leavenworth National Fish Hatchery. USFWS.

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Authored by

Mathew Hall
Barb Kelly-Ringel

U.S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
7501 Icicle Road
Leavenworth, WA 98826

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SUMMARY OF ICICLE TEMPERATURE MONITORING, 2005-2010

Mathew Hall and Barb Kelly-Ringel

*U.S. Fish and Wildlife Service
Mid-Columbia River Fishery Resource Office
7501 Icicle Rd.
Leavenworth WA 98826*

Abstract- Icicle Creek temperature monitoring began in 2005. ONSET Hobo Water Temp Pro V2 temperature loggers are deployed to 14 Icicle Creek sites upstream, adjacent to, and downstream of the Leavenworth National Fish Hatchery (LNFH), and in 2 tributary streams. Deployment dates were variable, however emphasis has been put on deployment during the summer months. Water temperatures were recorded at least hourly. The expected downstream warming occurs, with a mean high 7-day average daily maximum (7DADmax) of 16.7°C (range 15.6-17.8°C) at the headwaters, and 19.1°C (range 18.1-20.7°C) at the mouth. Two exceptions occur within the operational influence of the LNFH: 1) At the Snow Creek confluence, summer supplementation of water from Snow Lake cools Icicle Creeks mean high 7DADmax by 0.7°C (range 0.3-1.0°C). 2) At the LNFH spillway pool, returned river water is mixed with well water, creating an off-channel pool with a high 7DADmax that is, on average, 2.4°C (range 2.0-3.2°C) cooler than immediately upstream.

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Introduction

This report summarizes water temperature data collected by the Mid-Columbia Fisheries Resource Office in Icicle Creek and tributaries upstream, adjacent to, and downstream of the Leavenworth National Fish Hatchery (LNFH). Monitoring began in July of 2005, and will continue into the future.

Study Area

The Icicle Creek watershed drains 55,426 hectares of forested uplands on the eastern flank of the Cascade Mountain range in North Central Washington State. It is 50.8 km long from its headwaters at Lake Josephine (elevation 1423m) to its confluence with the Wenatchee River (elevation 340m) (WRWSC 1998). The upper drainage (approximately upstream of rkm 6.0) is characterized by high basin relief, glaciated cirques, and steep headwalls, with batholithic geology that has little water storage capacity. The lower drainage (approximately downstream of rkm 6.0) forms a low sloping basin filled with sand-and-gravel based glacial deposits. Approximately 87% of the watershed is publically owned and maintained by the U.S. Forest Service, with 74% of the watershed residing within the Alpine Lakes Wilderness (USFS 1994).

The Icicle Creek watershed receives 305 cm of precipitation at its highest elevations, and 50.8 cm in its lowest basin. There are 14 glaciers and 102 lakes in the watershed that store most of the available precipitation, with glacial melt estimated to generate 21% of Icicle Creek flow during the summer months (Mullen et al. 1992). Stream discharge has been recorded by the U.S. Geological Survey (Gage Station 12458000 at rkm 9.4¹) from 1936 to 1971 and from 1993 to the present. The average discharge for the period of record is 614 cfs. The minimum and maximum discharges are 44 cfs (November 30, 1936) and 19,800 cfs (November 29, 1995), respectively (USGS 2009).

Icicle Creek has two major water diversions, supplying four user groups, which affect in-stream flow and water temperature (Figure 1). Both diversions occur near the confluence of Snow Creek. At rkm 9.3, just upstream of the Snow Creek confluence, the Icicle Peshastin Irrigation District (IPID) withdraws from 60 to 103 cfs of water from April to September, and the City of Leavenworth withdraws about 2 cfs year around (Montgomery Water Group, Inc. 2004). At rkm 7.2, the Cascades Orchard Irrigation Company (COIC) withdraws 7 cfs from May through September, and the Leavenworth National Fish Hatchery (LNFH) uses 20 to 40 cfs year around. The total amount of water diverted from Icicle Creek during the summer months of June, July, and August, is about 140 cfs, while in the winter months it is about 42 cfs. (Montgomery Water Group, Inc. 2004).

Snow Creek is a major tributary of Icicle Creek, joining at rkm 9.2. Snow Creek drains a series of high mountain lakes, Upper Snow Lake being the largest by volume at approximately 12,450 acre-ft at full capacity (Anchor QEA 2010). In 1939, the U.S. Bureau of Reclamation installed a valve in the bottom of Upper Snow Lake, allowing the outfall of water into Snow Creek, and ultimately into Icicle Creek, to be

¹ All river kilometers (rkm) are approximate.

controlled. The LNFH has rights to 16,000 acre-ft of water per year from Upper Snow Lake. In a typical year, the valve is opened on July 26 (average 2006-2010) (Table 1), delivering up to 60 cfs. of water to Snow Creek, and is closed in October. During some low flow periods, supplemented Snow Creek water represents the majority of in-stream flow in Icicle Creek after the IPID diversion.

Table 1. Snow Lake valve openings, adjustments, and closures, and discharge into Snow Creek during those periods, 2006-2010.

Year	Date	Action	Discharge ¹
2006	26-Jul	Valve Opened	18 cfs
	16-Aug	Adjustment	Increased to 56 cfs
	5-Oct	Valve Closed	
2007	23-Jul	Valve Opened	53 cfs
	3-Oct	Valve Closed	
2008	29-Jul	Valve Opened	25 cfs
	12-Aug	Adjustment	Increased to 60 cfs
	3-Oct	Valve Closed	
2009	23-Jul	Valve Opened	14 cfs
	27-Jul	Adjustment	Increased to 32 cfs
	10-Aug	Adjustment	Increased to 52 cfs
	10-Sep	Adjustment	Increased to 60 cfs
	6-Oct	Valve Closed	
2010 ²	2-Aug	Valve Opened	32 cfs
	13-Aug	Adjustment	Increased to 53 cfs
	27-Aug	Adjustment	Increased to 60 cfs
	4-Oct	Valve closed	

¹ Discharge is a function of both valve opening and head pressure (level of the lake). If the valve is left in the same position, discharge will decrease as head pressure decreases. From Fred Wurster memos (2009) and Al Jensen, LNFH, pers. comm.

² Estimated based on valve opening.

The LNFH occupies land adjacent to Icicle Creek from approx. rkm 6.1 to rkm 4.1. At rkm 6.1, the Icicle Creek watershed transitions from a steep canyon to a broad valley. Channel classification transitions from B1 upstream of the LNFH Structure 2 to C4 downstream to the mouth (Rosgen 1996).

The LNFH intake is located in Icicle Creek at the shared COIC/LNFH diversion at rkm 7.2, and water is transported to the hatchery via underground piping. The LNFH also uses up to 14.4 cfs of well water to supplement its river supply, and to cool its incubation and rearing water in the summer and warm it in the winter (USFWS 2006a).

The LNFH returns water to Icicle Creek in two locations: the adult ladder outfall at rkm 4.3, which drains the adult and juvenile rearing ponds, and the pollution abatement pond at rkm 4.2, which is used to collect and settle effluent from pond cleaning before returning the water to Icicle Creek. The adult ladder outfall represents >95% of the water returned to Icicle Creek from the LNFH. Water release from the pollution abatement pond consists of a “leakage” rate of approx. 1 cfs, and a pulse of close to 5cfs for a few hours per day during routine juvenile pond cleaning (Steve Croci, LNFH, pers. comm.).

Downstream of the LNFH, Icicle Creek meanders for 4.0 rkm through a broad valley of mixed residential and agricultural properties before emptying into the Wenatchee River.

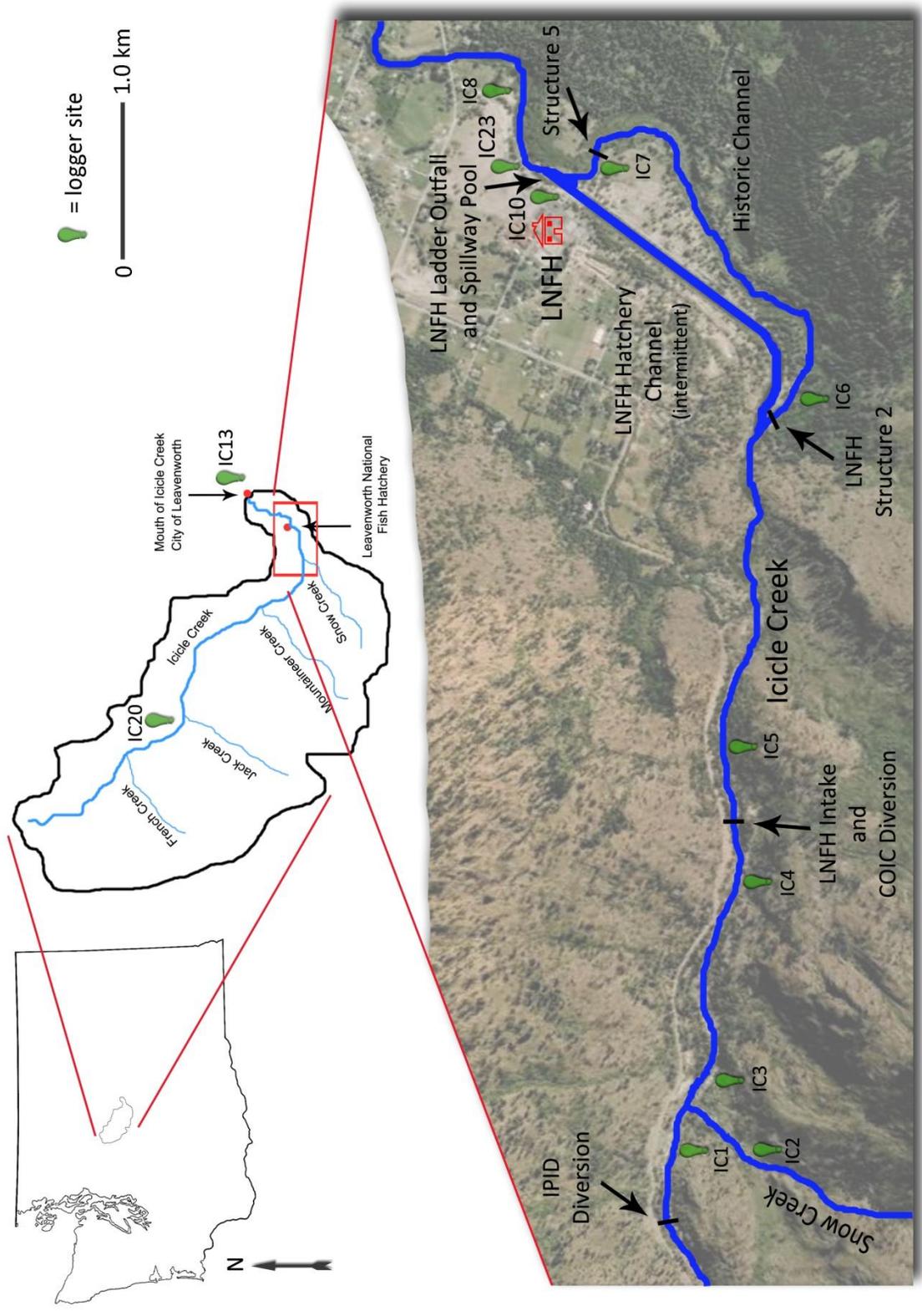


Figure 1. Map of Icicle Creek drainage with selected temperature monitoring sites and structures.

Methods

In July of 2005, ONSET Hobo Water Temp Pro V2 temperature loggers were deployed to 9 sites in Icicle Creek. The monitoring sites were selected to represent baseline conditions and as a means to assess the effects of water diversions and hatchery operations (Table 2). In 2005 and 2006 some of the loggers were removed in the late fall, and re-deployed the following spring. In 2007, the deployment was expanded to 16 sites, 2 of the original sites were dropped. All loggers recorded the temperature at least hourly when deployed. The loggers were tested for accuracy prior to deployment, and those which met ONSET's reported accuracy of ± 0.2 °C were used. Each logger was placed in a metal tube and chained or cabled to the site. The data was downloaded via the Hobo Waterproof shuttle 2-4 times per year. Air temperature was recorded at the Mid-Columbia Fisheries Resource Office (rkm 5.0).

During this monitoring effort, various deployment issues were encountered that affected the quality of the resulting data. A few of the loggers shifted location with periods of increased flow, were vandalized, failed to record, or were subject to unexpectedly low water. The Hobo Shuttles that were used were recalled and fixed by ONSET for data recording and time delay problems. With the amount of data that was collected, in the types of environments encountered, logistical difficulties can be expected. These difficulties contributed to a relatively small number of gaps in the summertime data set.

The raw data was imported into the HOBOWare Pro V2x software to calculate daily minimums, maximums, and means. A 7-Day Average Daily Maximum (7DADmax) was calculated for each site and day using the running average of the previous 7 days. Distances between loggers were measured on USGS maps using Maptech, and elevation was estimated using Google Earth.

Results

All of the raw data collected from this project is available upon request. Daily minimums, maximums, and means for selected sites in 2009 are given in Appendix A, as that year has the most complete data set. Results in this report focus on summer highs, as these are of the most interest to the water users and regulatory agencies. The summer season includes the period of Snow Creek supplementation (beginning July 25, on average), and the results presented here reflect this effect, unless otherwise noted. This is also the most complete portion of the dataset.

Air Temperature

Mean summer and high 7DADmax air temperature for the years 2005-2010 are given in Figure 2. Note that there is no data for mean summer temperature for 2005. The warmest year was 2009, with a mean summer air temperature of 22.7°C, and a high 7DADmax of 41.1°C. The coolest year was 2007, with a mean summer air temperature of 20.5°C, and a high 7DADmax of 33.7°C.

7DADmax

The 7DADmax and high daily maximum for each site by year are shown in Appendix A. The warmest mean high 7DADmax overall was 20.4°C (range 19.4-22.1°C), occurring at IC14 in the Wenatchee River.

The warmest mean high 7DADmax within Icicle Creek was 19.4°C (range 18.9-19.8°), occurring at IC8, downstream of the LNFH. The warmest mean high 7DADmax upstream of LNFH influence was 18.5°C (range 17.4-19.8°C) occurring at IC1, upstream of Snow Creek.

The summer season coolest mean high 7DADmax of 15.8°C (range 14.7-17.3°C) occurred at IC21, in Jack Creek, a headwater tributary of Icicle Creek. Within the LNFH operational influence, the summer season coolest mean high 7DADmax of 16.9°C (range 16.2-18.3°C) occurred at IC10, in the LNFH spillway pool. The mean date for the high 7DADmax from 2005 to 2010 for all monitored sites occurred on August 4.

Snow Lake Supplementation

In Snow Creek (IC2), the mean high 7DADmax for the years sampled was 17.3°C (range 15.9-18.5°C). The mean date for the 7DADmax occurred on July 22, before the average start data of Snow Lake supplementation. After supplementation, the IC2 sites' 7DADmax decreases for the remainder of the year.

Spillway Pool and Ladder Outfall

The IC10 and IC11 sites represent different locations within the LNFH spillway pool. IC11 is directly under the LNFH Ladder Drain, while IC10 is on the opposite side of the pool. The 7DADmax at these two sites are nearly identical, with the average difference in the 7DADmax of 0.1°C, less than the stated accuracy of the loggers.

The spillway pool and ladder outfall 7DADmax was 2.4°C (range 2.0-3.2°C) cooler than the nearby, upstream IC7 site (below Structure 5) for the years 2007-2010.

Other Cooling

In 2009, a 0.5°C decrease in the high 7DADmax occurred from IC4 (LNFH Intake) downstream to IC6 (LNFH Headgate). This is the only year monitored that this occurs. In 2007, a 0.6°C decrease in the high 7DADmax occurred from IC8 (downstream of LNFH) downstream to IC13 (Icicle Mouth). This is the only year monitored that this occurs.

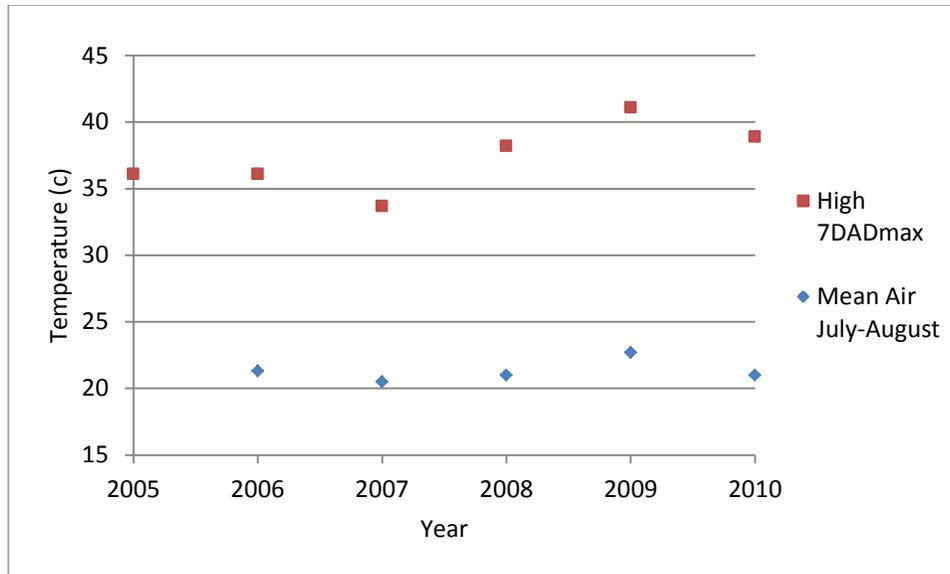


Figure 2. Mean summer and High 7DADmax air temperature for years 2005-2010

Discussion

A longitudinal temperature profile for Icicle Creek within the operational influence of the LNFH, using the high 7DADmax for 2007 and 2009, is displayed in Figure 2. These years were selected because they represent the warmest (2009) and the coolest (2007) years of the study thus far and for the completeness of the data set. This profile demonstrates the condition of Icicle Creek during the warmest period of the years monitored. Note that IC10 is located in the off-channel LNFH spillway pool.

Snow Lake Supplementation

The Snow Lake supplementation cools Icicle Creek's high 7DADmax by an average of 0.7°C (range 0.3°C to 1.0°C) at IC3, immediately downstream of the Snow Creek confluence. Cooling occurs at all years monitored. At IC1, in Snow Creek, the high 7DADmax occurred an average of 14 days earlier than in Icicle Creek (July 22 vs. Aug. 4). This is attributable to the opening of the Snow Lake supplementation valve on a mean date of July 25.

Spillway Pool and Ladder Outfall

At the LNFH, the returned river water is mixed with well water, which is between 7°C and 9°C, depending on which well is used. The mixing results in a summer cooling of the spillway pool (IC10) of 2.4°C (range 2.0-3.2°C) when compared with the nearby, upstream IC7 (below Structure 5) for the years 2007-2010. During the winter, the well water warms the discharged mix by up to 2.9°C when compared with IC7. This summer cooling (and winter warming) can be directly attributed to the operational influence of the LNFH. During periods of low flow, the spillway pool is distinctly separated from the thalweg of Icicle Creek, and the water mixes slowly. During high flow events, the thalweg of Icicle Creek overcomes its bank- full channel and readily mixes with the spillway pool.

Abatement Pond

The LNFH abatement pond contributes about 1cfs of water returned to Icicle Creek by the LNFH during most of the year. For up to a few hours each day, cleaning activities increase this contribution to no more than 5cfs (Steve Croci, LNFH pers. com.). Site IC23 is located at the outfall of the abatement pond, and the mean high 7DADmax was 19.8°C (range 18.0°C to 22.0°C). The Abatement Pond return water is likely warmer than Icicle Creek due to solar heating over its large surface area, however its flow contribution is small.

Future Monitoring

Beginning in 2011, year around monitoring will be emphasized, and extra time will be taken to improve data quantity. Additional loggers will be placed upstream of the IPID diversion, and inside the LNFH intake structure.

A queryable database will be constructed and made available online, with updates as the loggers are downloaded. A yearly summary, updating what is presented here, will be produced.

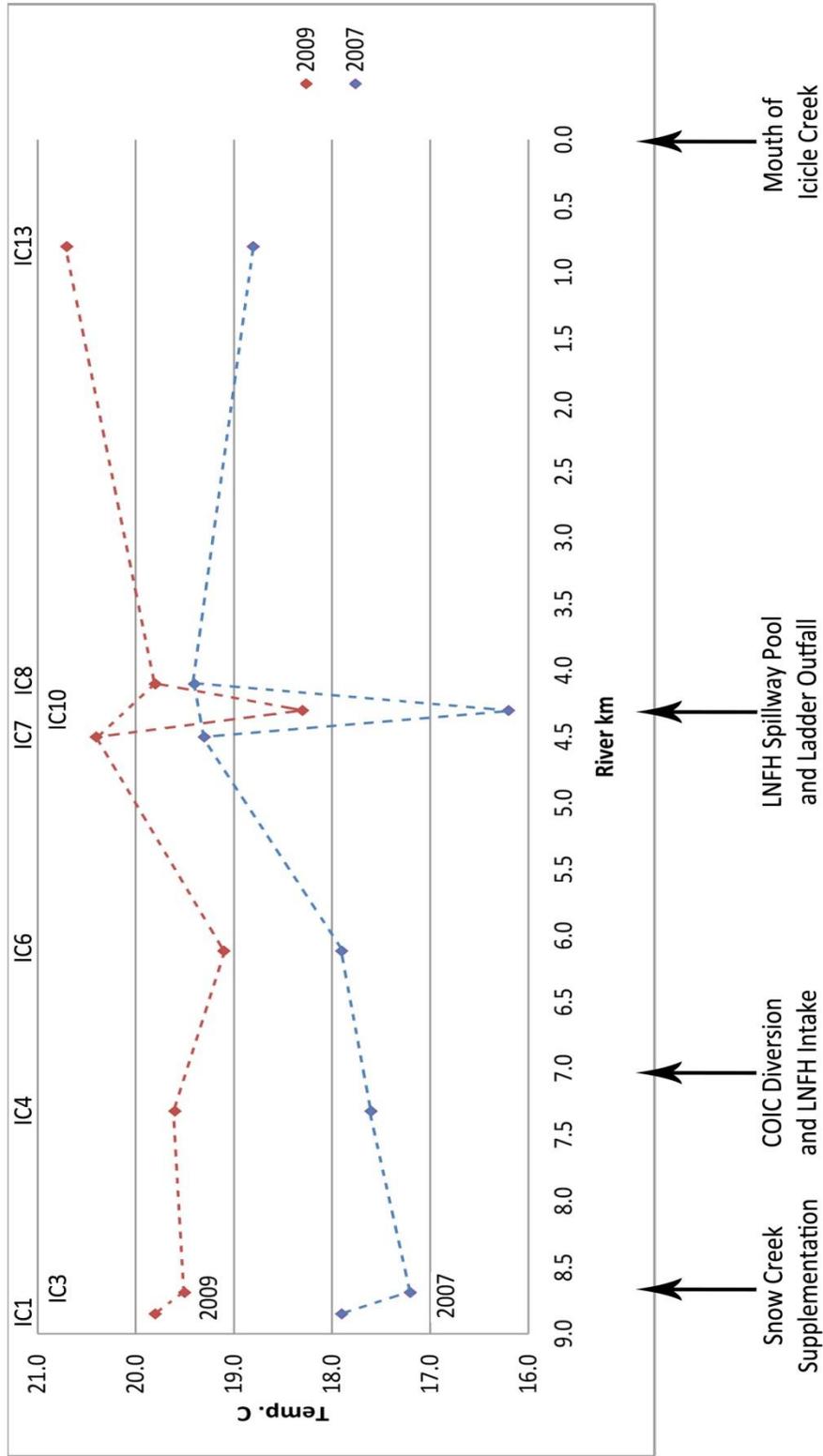


Figure 3. Longitudinal temperature profile for a portion of Icicle Creek using high 7DADmax for years 2007 (coolest year) and 2009 (warmest year).

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Appendix A: Site Descriptions, High 7DADmax, High Max, and Dates.

Site ID	Description ¹	River km	Elevation (m)	Years	High 7DADmax (C)	7DADmax-week ending	High max (C)	High max date ²
IC14	in Wenatchee River	n/a	335	2007	19.8	2-Sep	21.0	30-Aug
				2008	no data	no data	no data	no data
				2009	22.1	3-Aug	22.7	1-Aug
				2010	19.4	19-Aug	20.4	18-Aug
IC13	Icicle Mouth	0.8	334	2007	18.8	29-Jul	19.4	26-Jul
				2008	18.7	19-Aug	19.4	16-Aug
				2009	20.7	3-Aug	21.3	1-Aug
				2010	18.1	18-Aug	18.7	17-Aug
IC23	Abatement Pond outfall	4.2	339	2007	18.0	15-Jul	19.0	4-Aug
				2008	19.4	19-Aug	20.5	19-Aug
				2009	22.0	2-Aug	23.0	29-Jul
				2010	no data	no data	no data	no data
IC8	d/s of LNFH	4.1	339	2005	19.6	31-Jul	20.0	28-Jul
				2006	18.9	27-Jul	19.8	23-Jul
				2007	19.4	26-Jul	18.5	26-Jul
				2008	no data	no data	no data	no data
				2009	19.8	3-Aug	20.3	28-Jul
				2010	no data	no data	no data	no data
IC11	LNFH at Ladder outfall	4.3	340	2007	16.3	29-Jul	16.8	26-Jul
				2008	16.3	19-Aug	17.0	16-Aug
				2009	18.2	2-Aug	18.7	28-Jul
				2010	no data	no data	no data	no data
IC10	LNFH Spillway pool	4.3	340	2005	16.9	11-Aug	17.7	31-Jul
				2006	no data	no data	no data	no data
				2007	16.2	30-Jul	16.8	26-Jul
				2008	16.2	19-Aug	16.8	16-Aug
				2009	18.3	2-Aug	18.7	28-Jul
2010	no data	no data	no data	no data				
IC7	d/s of Structure 5	4.5	340	2005	no data	no data	no data	no data
				2006	19.4	28-Jul	20.2	23-Jul
				2007	19.3	29-Jul	20.2	28-Jul
				2008	18.2	19-Aug	19.2	16-Aug
				2009	20.4	3-Aug	20.9	1-Aug
				2010	no data	no data	no data	no data

¹ d/s – downstream, u/s – upstream

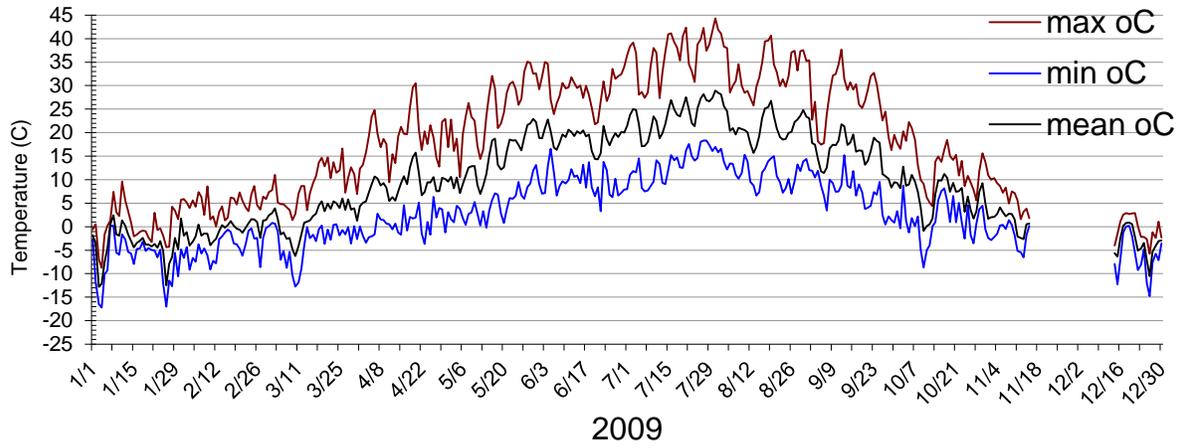
² Date of first occurrence

IC6	u/s of LNFH Headgate	6.1	350	2005	20.3	21-Aug	21.0	16-Aug
				2006	19.2	28-Jul	20.2	23-Jul
				2007	17.9	30-Jul	18.8	26-Jul
				2008	17.6	18-Aug	18.6	16-Aug
				2009	19.1	2-Aug	19.6	28-Jul
				2010	17.3	18-Aug	17.7	17-Aug
IC5	d/s of LNFH Intake	7.1	356	2005	18.8	31-Jul	19.4	28-Jul
				2006	18.8	27-Jul	19.8	23-Jul
IC4	u/s of LNFH Intake	7.3	365	2005	18.3	29-Jul	19.2	28-Jul
				2006	18.8	28-Jul	19.8	23-Jul
				2007	17.6	29-Jul	18.3	26-Jul
				2008	16.9	18-Aug	17.8	16-Aug
				2009	19.6	2-Aug	20.1	28-Jul
				2010	no data	no data	no data	no data
IC3	d/s of Snow Creek	8.7	392	2005	18.1	31-Jul	18.6	29-Jul
				2006	no data	no data	no data	no data
				2007	17.2	30-Jul	18.2	26-Jul
				2008	no data	no data	no data	no data
				2009	19.5	2-Aug	20.0	28-Jul
				2010	16.4	18-Aug	16.8	17-Aug
IC2	in Snow Creek	n/a	398	2005	16.6	23-Jul	17.4	18-Jul
				2006	17.5	14-Jul	19.0	14-Jul
				2007	18.5	16-Jul	19.7	13-Jul
				2008	15.9	26-Jul	16.7	9-Jul
				2009	18.0	28-Jul	18.7	27-Jul
				2010	17.4	30-Jul	18.3	28-Jul
IC1	u/s of Snow Creek	8.8	410	2005	18.9	31-Jul	19.5	6-Aug
				2006	18.6	27-Jul	19.5	23-Jul
				2007	17.9	29-Jul	18.7	2-Aug
				2008	18.3	19-Aug	19.3	16-Aug
				2009	19.8	2-Aug	20.2	28-Jul
				2010	17.4	18-Aug	18.0	17-Aug
IC22	d/s of Jack Creek	26.1	830	2007	no data	no data	no data	no data
				2008	no data	no data	no data	no data
				2009	17.6	3-Aug	18.0	1-Aug
				2010	no data	no data	no data	no data
IC21	in Jack Creek	n/a	833	2007	no data	no data	no data	no data
				2008	15.4	19-Aug	16.2	16-Aug
				2009	17.3	2-Aug	17.9	1-Aug
				2010	14.7	18-Aug	15.2	17-Aug
IC20	u/s of Jack Creek	30.1	836	2007	no data	no data	no data	no data
				2008	15.6	19-Aug	16.5	16-Aug

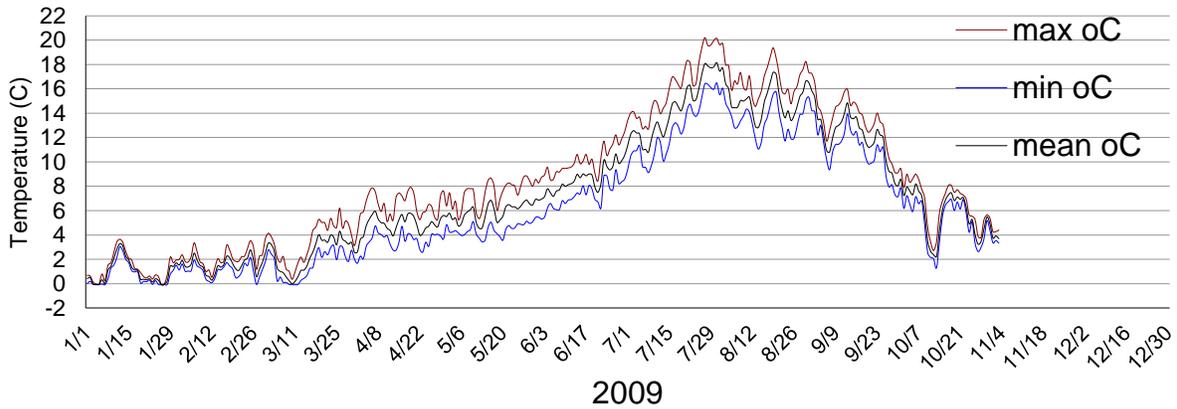
2009	17.8	2-Aug	18.3	1-Aug
2010	no data	no data	no data	no data

Appendix B: Selected Daily Means, Minimum, and Maximums for 2009

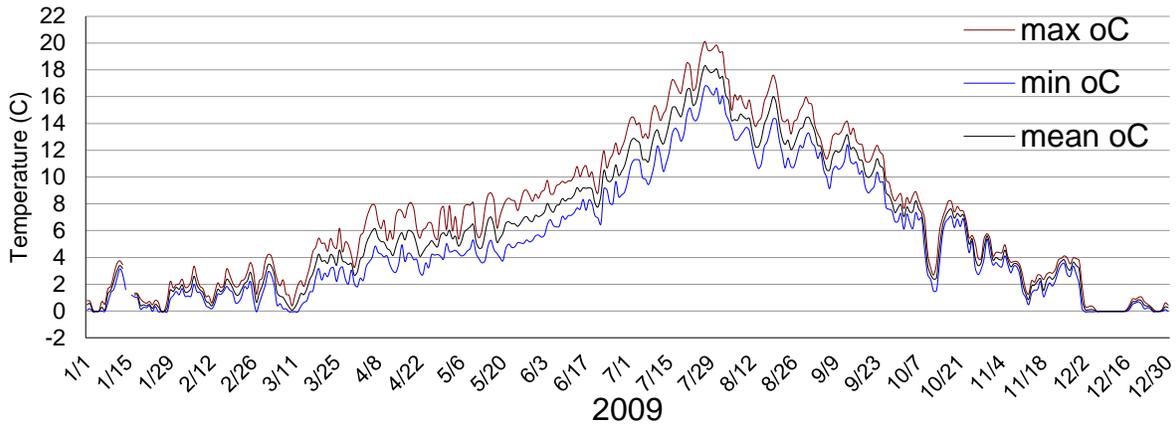
Air - rkm 5.0 - Mid-Columbia FRO



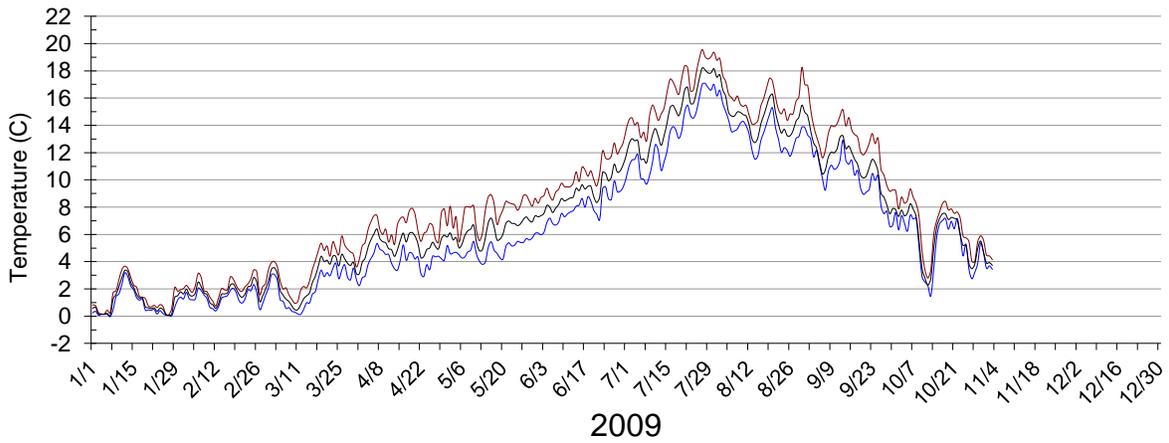
IC1 - rkm 8.8 - above Snow Creek



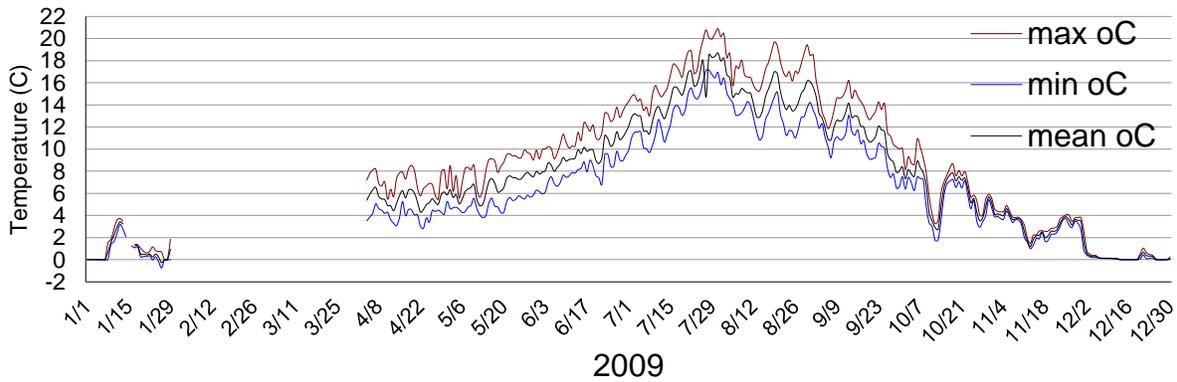
IC4 - rkm 7.3 - above LNFH Intake



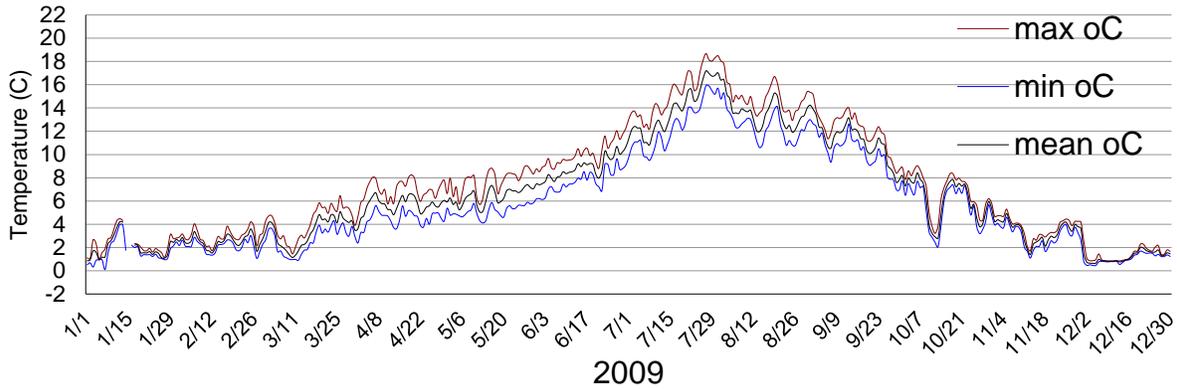
IC6 - rkm 6.1- above LNFH Headgate



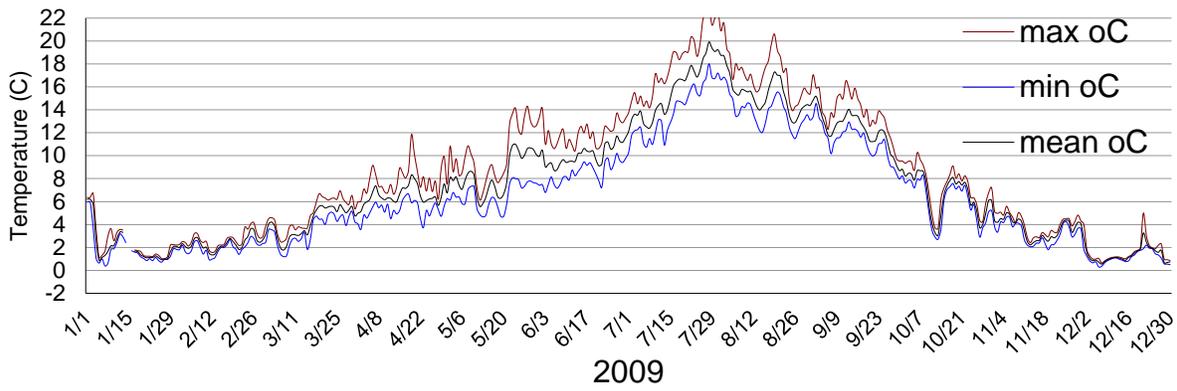
IC7 - rkm 4.5 - below Structure 5



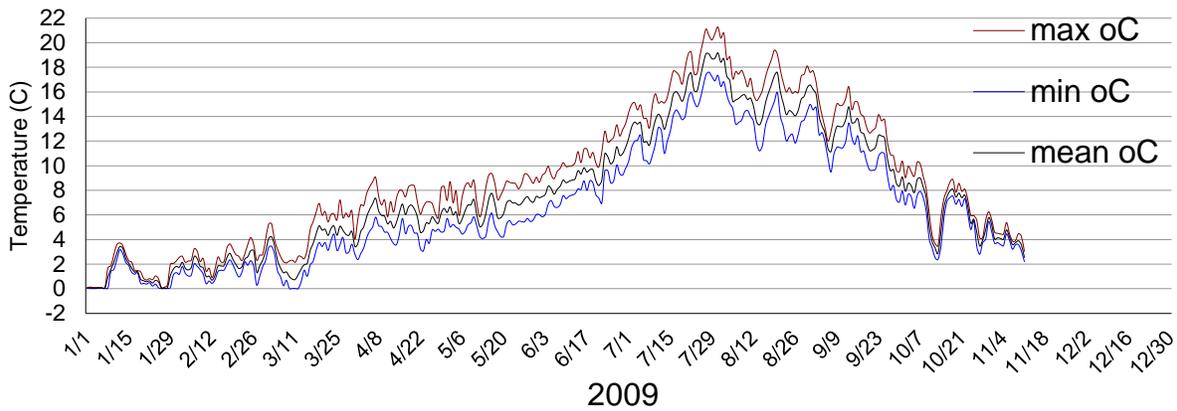
IC11 - rkm 4.3 - LNFH Ladder Outfall



IC23 - rkm 4.2 - Abatement Pond Outfall



IC13 - rkm 0.8 - Icicle Mouth



**U. S. Fish and Wildlife Service
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Leavenworth, WA**



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