Progress Report 2012-2013: Hangman Creek Fisheries Enhancement RM&E Summary

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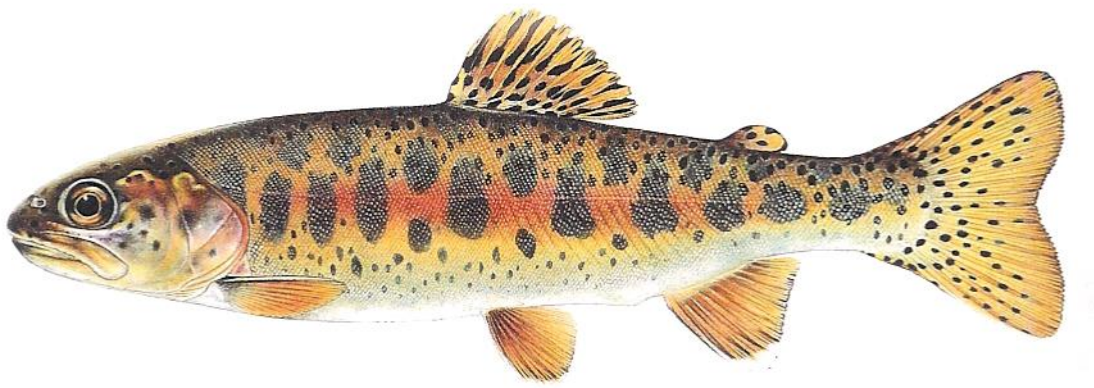

Redband trout (Oncorhynchus mykiss gairdneri)

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Abstract

The Hangman Creek Fisheries Project monitors and evaluates multiple characteristics of redband trout *Oncorhynchus mykiss gairdneri* and their associated habitats throughout the upper Hangman Creek watershed. Resident redband trout continue to persist in the restricted forested reaches near the headwaters of each subwatershed. Downstream of Indian Creek, all of the fish-bearing tributaries show discontinuous distribution due to habitat degradation stemming from agricultural practices, effectively isolating these fish within their respective tributary. Densities of these fish are influenced by localized habitat restrictions and annual variations in weather. Fluvial redband trout are plagued by degraded habitat in spawning tributaries as well as limited areas of mainstem habitat refuge for rearing, much of which is upstream of the tributaries they originate from. Habitat quality appears to be the limiting factor to redband trout survival and dispersal rates. The most limiting habitat characteristics present in the Hangman Creek watershed are low baseline flows, high summer stream temperatures, high rates of sedimentation, and a lack of complex structure; often contributed by in-stream large woody debris. The Fisheries Program will expand our restoration efforts in order to remedy a portion of these limiting factors identified in upper Indian Creek through the addition of large wood, and in the mainstem of Hangman Creek through large-scale stream and floodplain restoration. Upon initiation of these projects, monitoring of redband trout will continue to document how they react to our restoration efforts, much like what has been initiated in the 300 meter reach in Indian Creek. Directly following the rehabilitation efforts in this reach of Indian Creek, we documented a significant difference in the densities of redband trout between the treated reach and the adjacent control reaches. However, over the course of 5 years, the densities between the control and treated reaches have become more comparable and we currently do not see any measurable difference. Cumulative size distribution has changed between the treated and control reaches, where redband trout in the treated reach have trended toward larger fish that are likely utilizing the recently created large pools and forcing out the smaller fish. Monitoring activities, including action effectiveness within the Hangman watershed continue to adapt as new and more effective management and restoration actions are implemented.

1 Introduction

Fisheries assessments from 2002 - 2013 in Hangman Creek indicate distinct linkages between land management practices and the presence of salmonids. In land managed for timber production and small home sites, habitat includes medium to dense forest canopy, gravel and cobble dominated substrate, and temperatures conducive to salmonid spawning and rearing (Peters et al. 2003; Kinkead and Firehammer 2011, 2012). In valleys dominated by various agriculture practices, discharge, temperature, dissolved oxygen, excess fine sediments, and lack of canopy and instream complexity coincide with an absence of salmonids during summer rearing. These stream reaches however have been shown to have some value as migration corridors and possible fall and winter rearing. During summer rearing periods, salmonids are found in upper headwater streams where temperatures remain below 20 degrees C. Salmonids are rarely sampled in stream reaches where temperatures exceed this threshold for a significant amount of time (Kinkead and Firehammer 2011 & 2012).

The Fisheries Program's goal in the Hangman Creek watershed has been to protect and enhance the best habitat, and to improve habitat quality in other reaches to facilitate movement between disconnected rearing habitats and increase both survival and growth across all life stages and life histories for remnant populations of redband trout *Oncorhynchus mykiss gairdneri*. RM&E efforts have been designed to provide status and trend, as well as action effectiveness for restoration projects past and future.

1.1 Study Area

Hangman Creek drains 430,000 acres of northern Idaho and eastern Washington. The study area consists of the portion of the Hangman Creek watershed that lies within the Coeur d'Alene Reservation and east into the headwaters outside of the reservation. The Washington-Idaho State border, which corresponds to the border of the Coeur d'Alene Indian Reservation, marks the western boundary of the project area. The total acreage is 157,586, with 147,993 of that within the reservation. Elevations range from 754 meters in the northwest corner of the Project Area where Hangman Creek flows west into Washington to 1,505 meters at the top of Moses Mountain on the southeastern end of the Hangman/Coeur d'Alene Basin watershed divide (Figure 1). The named tributaries within the basin include Mission, Tensed, Sheep, Smith, Mineral, Nehchen, Indian, the SF Hangman and its' tributaries Conrad, Martin, and the upper part of Hangman Creek east of the Reservation along with its' named tributaries Hill and Bunnel (Figure 2). All of these tributaries were thought to be home to trout in the 1940's (Aripa 2003).

1.2 Status and Trend Monitoring

Assessment of the fisheries populations included a broad spatial sampling in order to determine distribution over the entire Hangman watershed within Idaho boundaries (Peters et al 2003), and later was prioritized in 2005 to exclude the northern part of the watershed that was almost entirely devoted to dry-land farming (Kinkead and Firehammer 2011). The spatial focus of the project was further delineated to prioritize tributaries and mainstem reaches at, or above Mission Creek where salmonid distribution is at its lowest extent (Green et al. 2008, and Herrera 2011). Previous fish assessment surveys find redband trout to be distributed throughout the upper watershed with fairly stable trends in density. The sub-watersheds located downstream of Smith Creek however have shown trout densities to be more volatile, likely due to the isolation of these streams from the more connective habitat in the upper Hangman watershed, and the dominant life history strategy of the trout which reside in each tributary (Kinkead and Biladeau 2013). These populations are likely affected by localized changes in habitat, whether they are anthropogenic or natural in origin, and/or annual variations in climate. The Fisheries Program continues to monitor the fish bearing tributaries annually for trends in fish densities in each subwatershed, specifically to determine if habitat restoration actions carried out by our program have a positive effect on the populations within each subwatershed and the upper Hangman watershed as a whole.

Many populations of redband trout throughout the Columbia River basin exhibit multiple life history strategies; such as resident, fluvial, and adfluvial forms. The retention of these life history strategies is interpreted as an evolutionary strategy that promotes adaptive flexibility in stochastic environments (McPhee et al. 2007). Fluvial forms of redband trout in the Hangman watershed are therefore important to the continued presence of trout within each subwatershed as well as the potential recolonization of subwatersheds that have been identified in their historic range. Furthermore, interbreeding between subwatersheds can decrease the likelihood of genetic isolation and the associated problems that occur with it. Previous monitoring of marked fluvial redband trout has confirmed that dispersal rates between tributaries is very low (Kinkead and Biladeau 2013). The Fisheries Program has recently upgraded our trapping and marking of fluvial redband trout to include the use of half-duplex PIT tags along with a series of passive interrogation sites to improve the monitoring of dispersal to adjacent tributaries and into rearing habits. This monitoring is used to gather baseline data on how fluvial and resident individuals influence the trout population structure throughout the Hangman watershed. This data is also used to help guide future restoration and monitoring efforts and how specific restoration actions influence dispersal, rearing habits, and survival rates of redband trout.

Habitat monitoring and assessment continues to be a large focus of the Fisheries Program in the upper Hangman Creek watershed. Throughout the first 10 years of the Hangman Fisheries project, habitat monitoring was conducted to assess the current conditions of the watershed by gathering baseline data, and to identify limiting factors for redband trout survival. Although habitat assessment continues in the Hangman watershed, most of the surveying is presently conducted for monitoring purposes. We conduct both fine and large scale monitoring, depending on the specific objective(s) associated with the site. Fine scale habitat monitoring is normally conducted to monitor for changes to a variety of physical habitat parameters within a short reach of stream. Large scale habitat monitoring is conducted to track changes in a specific habitat parameter such as temperature across multiple stream reaches. The changes over time across fine and large scale habitat monitoring sites originate from restoration efforts, private land management practices, or natural processes, although most of our current habitat monitoring is designed to track changes due to restoration actions carried out by the Coeur d'Alene Tribe Fish and Wildlife Programs.

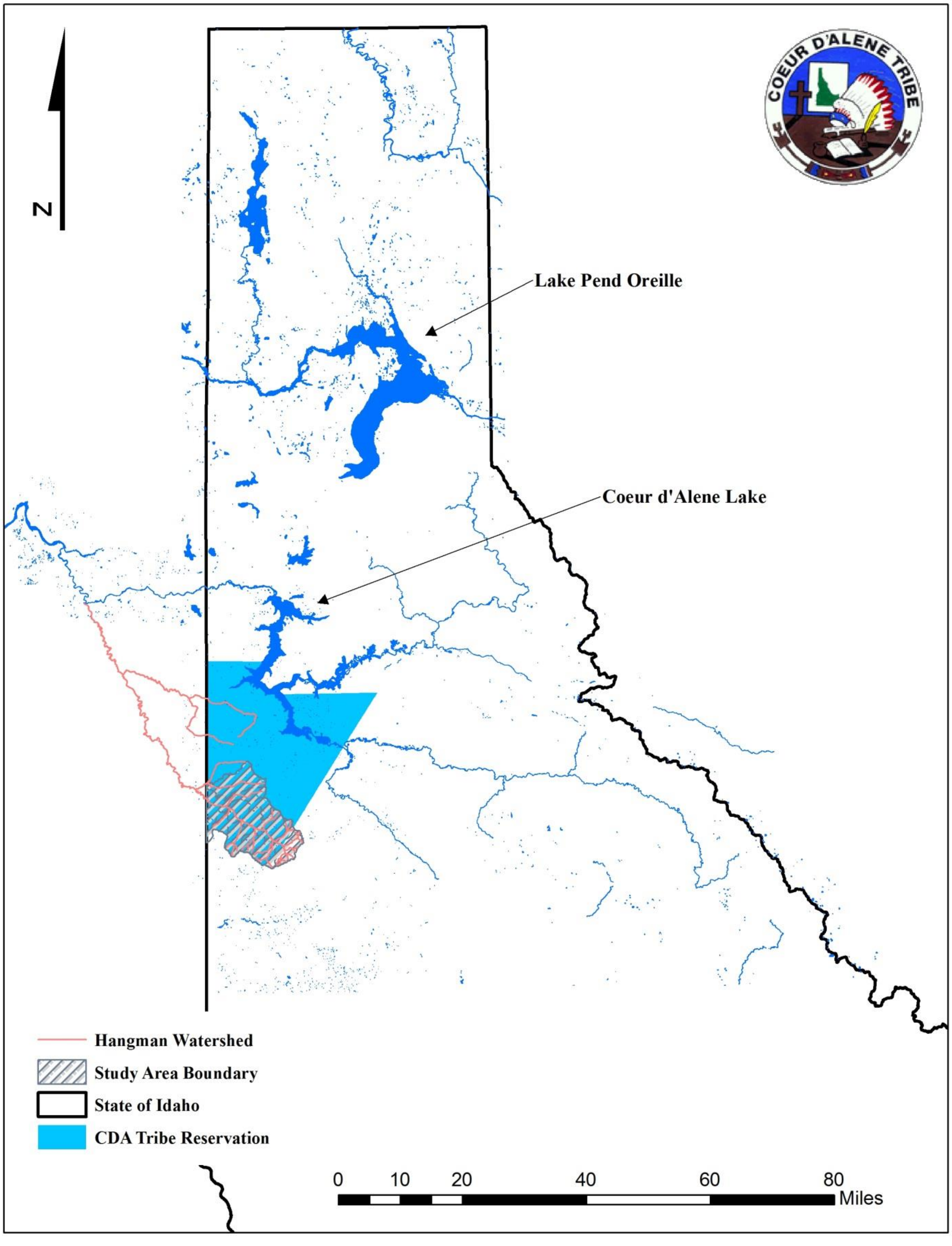


Figure 1. The Hangman Creek watershed study area, located in Idaho almost entirely within the Coeur d'Alene Reservation.

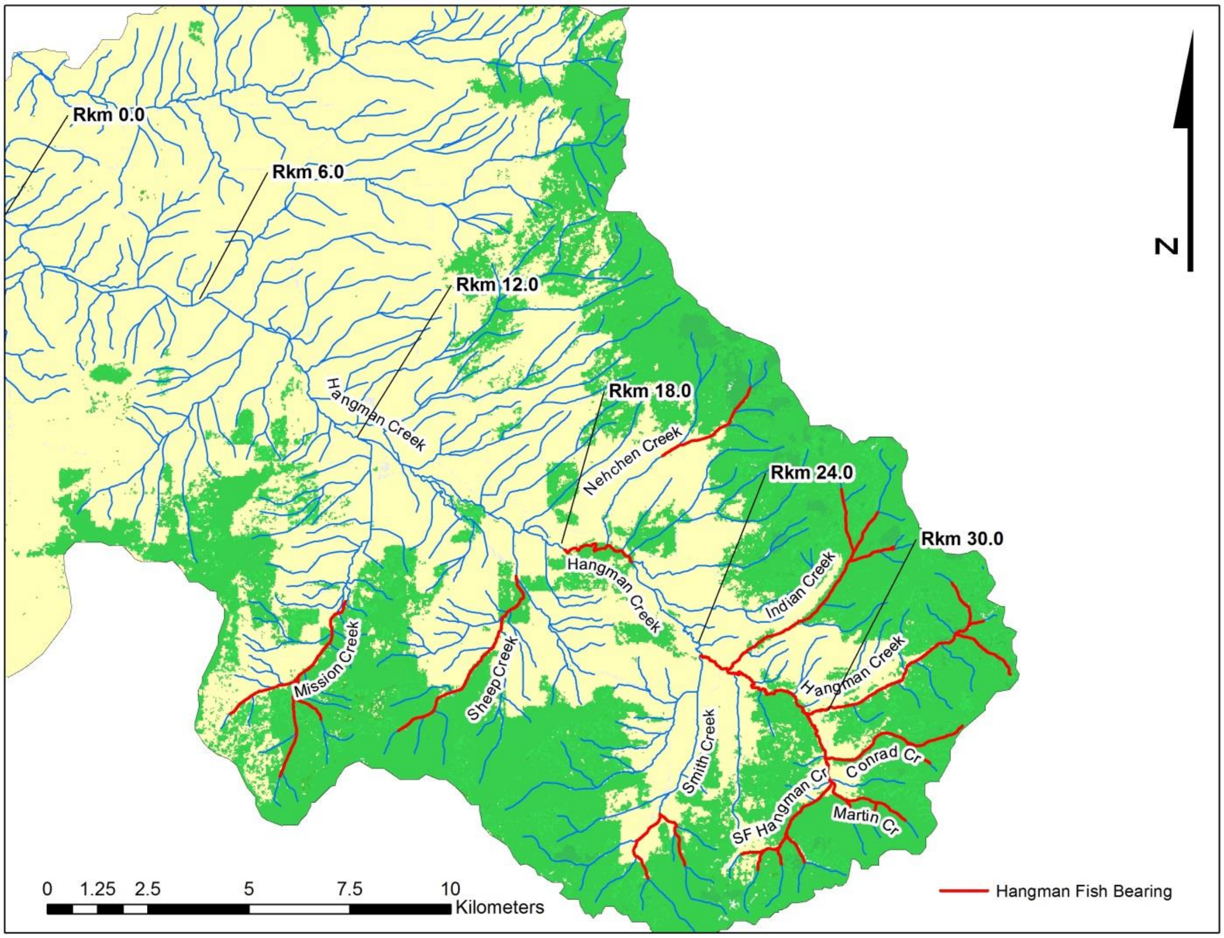


Figure 2. Hangman Creek watershed study area with stream kilometer reference points and current fish bearing stream reaches highlighted in red. Stream kilometer 0.0 is located at the Idaho-Washington state line.

1.3 Effectiveness Monitoring

As the rate and magnitude of restoration actions increase in the Hangman Creek watershed, it is important to understand not only how our efforts change the physical habitat, but what influence restoration has on the fish communities they are expected to benefit. In 2008 and 2009, large woody debris structures were installed throughout a 300 meter reach of Indian Creek located approximately 2.3 kilometers upstream of the mouth. The primary strategy for this placement was to initiate pool forming processes, as well as stabilizing banks and sorting sediment (Kinkead and Biladeau 2013). These changes in physical habitat in turn are hypothesized to influence the densities and/or the size distribution of redband trout. Upon completion of this project, fish monitoring sites were established within and adjacent to the restored reach to monitor for differences in density and size structure between the treated and control reaches, as well as to monitor for differences in density trends over time within each of the treated and control reaches.

2 Methods

2.1 Trout Status and Trend Monitoring

2.1.1 Trout Abundance and Distribution Surveys

https://www.monitoringmethods.org/Protocol/Details/616

Thirty eight sites were sampled in 2012 and in 2013 via single-pass electrofishing throughout the upper Hangman watershed to monitor annual trends in trout density (Figure 3). The length of each sample site was defined as 200 feet. All of the trout captured were counted, and measured for length to the nearest mm, and weight to the nearest 0.1 gram. Trout larger than 65mm total length captured in Indian, Sheep, and Nehchen Creek were implanted with a 12 mm half-duplex PIT tag to monitor for dispersal. Each trout implanted with a PIT tag was marked through the removal of the adipose fin. All other aquatic vertebrates captured during electrofishing surveys were counted and recorded.

In order to analyze the difference in annual trends in each subwatershed, we used a coefficient of variation. This analysis helps to compare the level of variability in trout densities over time and between subwatersheds. The coefficient of variation was calculated using the following formula:

$$CV = \frac{Standard\ Dev.of\ annual\ mean\ density}{mean\ density\ over\ all\ years\ sampled}$$

Six roving electrofishing surveys were completed in the upper Hangman watershed to determine the presence and relative abundance of redband trout in streams reaches not previously sampled, or in areas that have not been sampled for over ten years (Figure 3). These sites ranged in length from 240 – 1200 meters and were located in the upper SF Hangman subwatershed and in upper Smith Creek. All trout captured during roving surveys were counted and measured for length and weight.

2.1.2 Trout Trapping

https://www.monitoringmethods.org/Protocol/Details/609

Fixed weir migration traps were installed near the mouth of Nehchen (Rkm 0.4) and Indian Creek (Rkm 2.4) to capture upstream migrating pre-spawn adults as well as emigrating post-spawn adults and juveniles (Figure 3). Traps were fished from early March through early June. Each trout captured in the trap was counted, measured, and implanted with a 12 mm half-duplex PIT tag. Each trout was also marked with an adipose clip and a temporary hole punch in the operculum for identification upon recapture in the same trapping season. This additional mark was also used to determine if a post spawn adult had shed its tag while spawning.

2.1.3 Trout Dispersal, Migration, and Rearing Habits

Passive interrogation sites were installed in the upper Hangman Creek watershed to monitor movement of PIT tagged individuals (Figure 3). These interrogation sites were installed near the mouths of Sheep (Rkm 1.3 & 1.8), Nehchen (Rkm 0.1), and Indian Creek (Rkm 0.8), and in the mainstem of Hangman Creek at two locations (Rkm 19.8 and 24.6). These sites were installed strategically to monitor rearing habits of fluvial redband trout in the mainstem of Hangman Creek, and to monitor dispersal of all tagged redband trout into adjacent tributaries. Each site, with the exception of the two in lower Sheep Creek, used multiple antennas in order to acquire direction of movement.

2.2 Habitat Monitoring

2.2.1 Water Quality

https://www.monitoringmethods.org/Protocol/Details/565
https://www.monitoringmethods.org/Protocol/Details/593
Water quality sampling was conducted at 24 stations distributed across the upper Hangman watershed to monitor for dissolved oxygen, pH, and conductivity. Discharge and turbidity measurements were also taken at a subset of these stations. Sampling was conducted during June and August to correspond with critical egg incubation and base-flow rearing periods.

2.2.2 Continuous Temperature Monitoring

https://www.monitoringmethods.org/Protocol/Details/611
HOBO temperature loggers (onset Computer Corp.) were installed at 34 locations in 2012-13, and distributed across upper the Hangman Creek watershed to develop a stream temperature profile.

2.2.3 Longitudinal Temperature Profile Monitoring

https://www.monitoringmethods.org/Protocol/Details/595
A thermistor survey was conducted on the mainstem of Hangman Creek between stream kilometer 19.8 and 27.3. This survey was completed to monitor the difference in water temperature between the tailout and the maximum depth of each pool encountered in order to assess cold water refuge for trout during summer rearing. To qualify as a pool, the maximum depth had to be at least one foot greater than the tailout depth.

2.2.4 Physical Habitat Assessment/Monitoring

https://www.monitoringmethods.org/Protocol/Details/619
Fourteen sites throughout the upper Hangman watershed were surveyed for physical habitat attributes such as canopy cover, substrate composition, large woody debris volume, and pool habitat (Figure 3). Four of these sites were surveyed to monitor for trends or changes in physical habitat parameters over a range of 5 – 9 years.

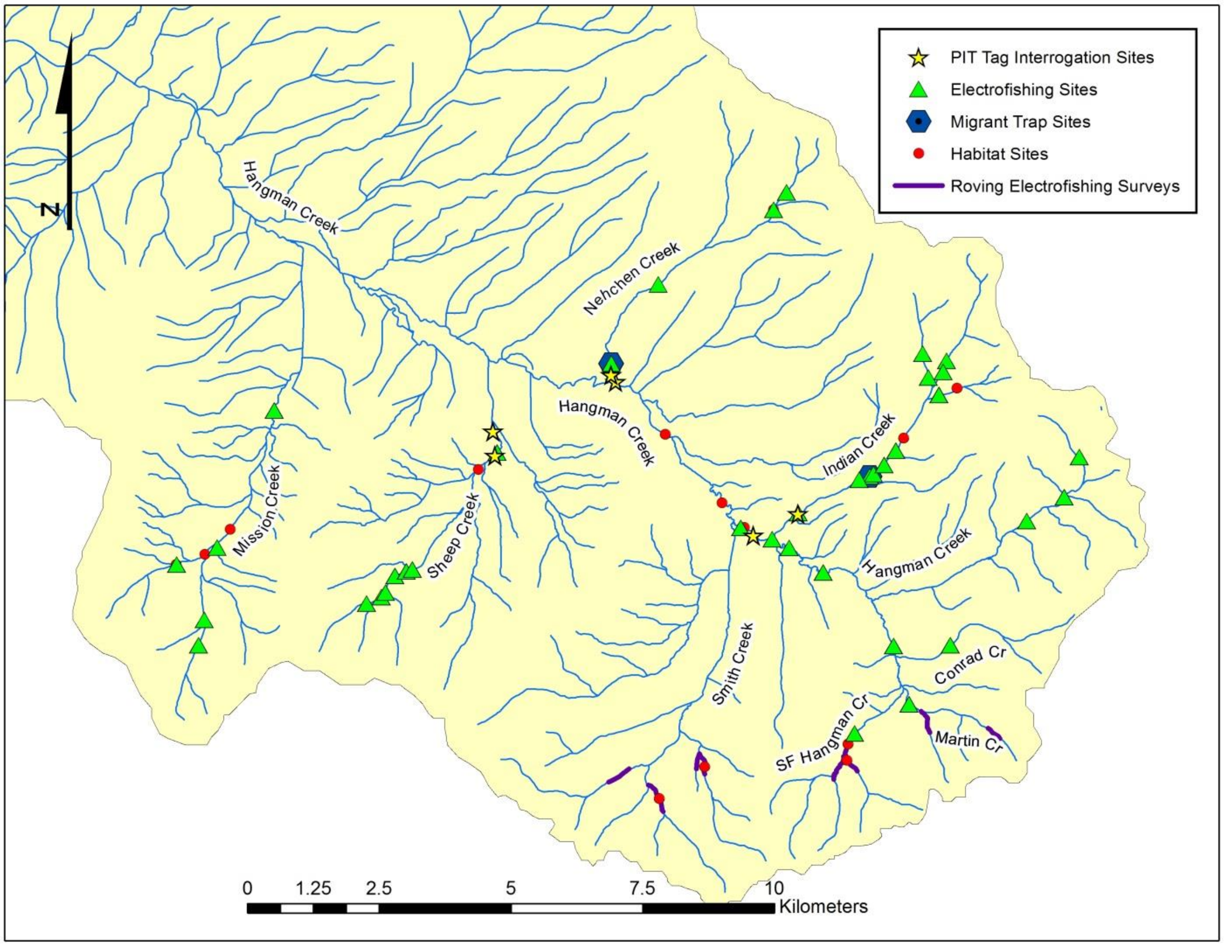


Figure 3. Location map of monitoring sites within the upper Hangman Creek watershed study area.

2.2.5 Upper Indian Creek Spawning Habitat Assessment

During late July when stream water levels were low, the upper reaches of Indian Creek were surveyed for available spawning habitat using a transect approach (Figure 4). The Middle Fork, East Fork and North Fork tributaries were divided into 100 meter long transects starting at the mouth of each tributary and ending at distinct natural fish barriers. Each transect was measured using a hip-chain and flagged and marked with a GPS waypoint. Five random stream widths were measured along each transect. Stream gradient was taken for the Middle and North Forks, and a portion of the East Fork. Survey teams walked the streams taking note of spawning gravels, the length and width of each gravel patch, and the method of creation: large woody debris (LWD) or “other”.

Gravels were considered suitable for fish spawning based on observation of substrate size, water depth, and permeability of the gravel. Spawning gravels for small bodied salmonids should be 8-64 mm with a minimum area of 1 square meter and the stream should be flowing with a depth of at least 10 cm (Schuett-Hames & Pleus 1996). Since the water level was at summer base flow, the minimum depth was expanded to include all wetted area. Gravels were considered not permeable if too much silt or sand was observed. Gravel patches as small as 1 square foot were included in this survey upon determination via field observations of resident redband trout spawning in gravel patches of this size in an adjacent tributary.

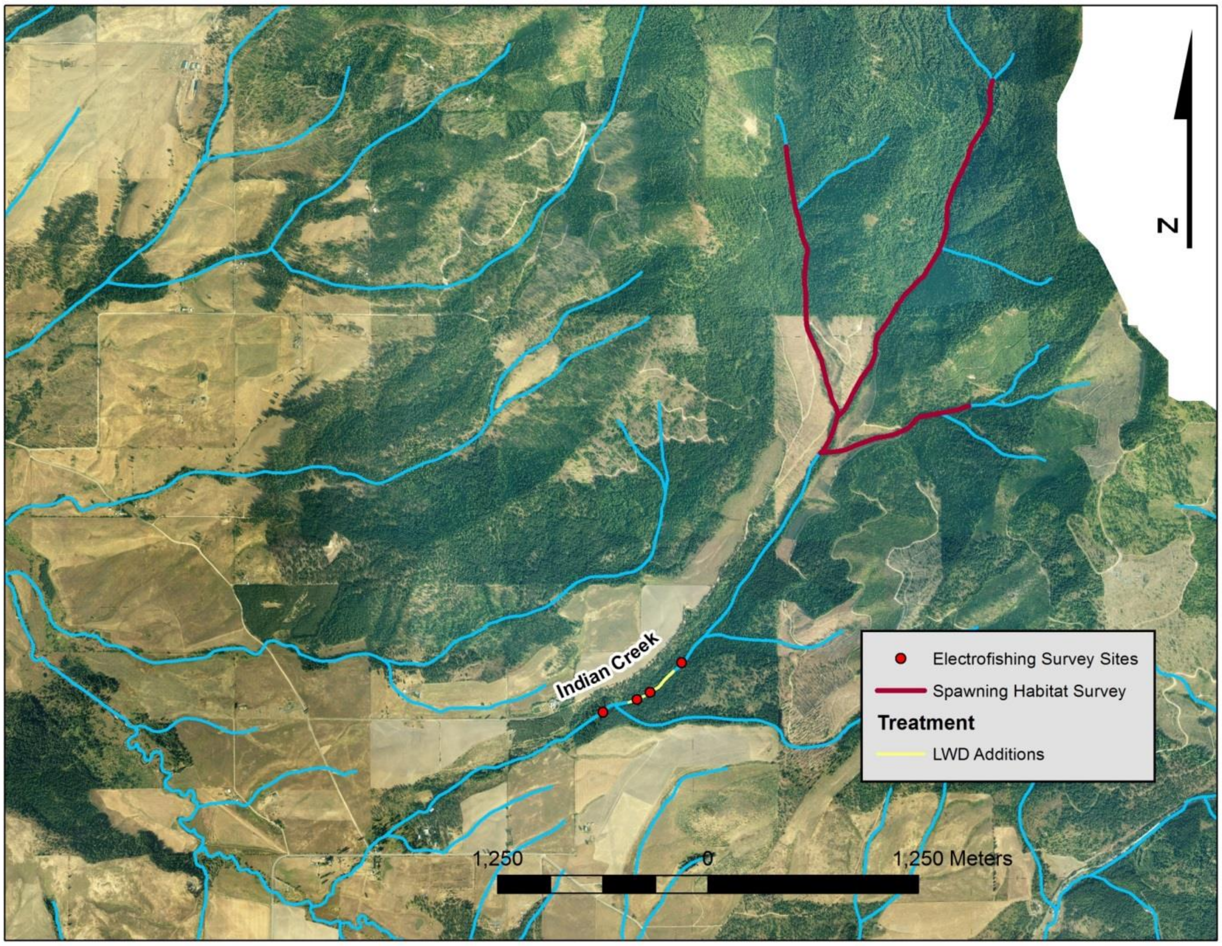


Figure 4. Location of spawning ground survey and LWD additions, along with fish sampling surveys within and adjacent to the treated stream reach in Indian Creek.

2.3 Action Effectiveness

Redband trout parameters in a LWD treated reach of Indian Creek

In 2009, annual fish sampling using electroshocking methods was set up with control/treatment pairs in order to evaluate the effectiveness of large woody debris additions on redband trout densities within reach 2 of Indian Creek. Two sites were established within the treated reach in conjunction with 2 sites on either end of the treated reach (Figure 4). A repeated measures analysis was used to compare densities of trout between the treated and control sites and to look for differences over time in trout densities. We also analyzed the cumulative distribution of total length (mm) annually in the control and treatment sites. Data from 2012 was not included in the cumulative length distribution analysis due to low sample sizes in both the control and treatment sites.

3 Results

3.1 Trout Status and Trend Monitoring

3.1.1 Trout Abundance Trends and Distribution Surveys

Trout densities continue to be the highest in the forested reaches of the upper Hangman watershed during summer sampling. Densities ranged from 0 – 67.2 fish/100 meters (Table 1). Electrofishing surveys in the tributaries of Hangman Creek (excluding the 3 mainstem sites yielded redband trout with a size range of 50 – 229mm in total length, with a mean length of 109mm. Conversely, in the 3 mainstem sites, trout ranged from 105 – 212mm with a mean length of 138mm.

A coefficient of variation has been calculated for each subwatershed sampled since 2009 (Table 2). The highest level of annual variability occurs in Nehchen Creek, however it should be noted that density estimates in this tributary are very low, which has a large influence on this calculation. Mission Creek also exhibited a relatively high level of annual variability when compared to the other sampled tributaries.

A measurable difference in trout densities is shown across the entire watershed between 2012 and 2013. The total 2012 mean density (10.3 fish/100m) is 42% lower than the mean density in 2013 (17.8 fish/100m). The same trend is seen within each subwatershed, where 2012 mean estimates range from 27% - 57% lower than 2013 mean density estimates.

Roving surveys completed during 2013 have identified the presence of redband trout in the headwaters of the SF Hangman Creek and Smith Creek sub-watersheds (Table 3).

Table 1. Trout densities sampled across the upper Hangman Creek watershed, 2012 and 2013.

Index Site	Stream km	2012 RBT Captured	2012 RBT density (fish/100 m)	2013 RBT Captured	2013 RBT density (fish/100 m)
			Hangman mainstem		
Hangman 1	24.5	0	0	5	8.2
Hangman 2	26.2	1	1.6	3	4.9
Hangman 3	27.3	1	1.6	1	1.6
			Indian Creek		
Indian 1	0.1	2	3.3	2	3.3
Indian 2	0.8	3	4.9	9	14.8
Indian 3	2.3	8	13.1	17	27.9
Indian 4	2.5	2	3.3	12	19.7
Indian 5	2.6	9	14.8	18	29.5
Indian 6	2.9	5	8.2	14	23
Indian 7	3.2	9	14.8	5	8.2
Indian 8	4.9	7	11.5	3	4.9
Indian 9	5.1	15	24.6	19	31.1
N.F. Indian 1	0.2	10	16.4	7	11.5
N.F. Indian 2	0.7	3	4.9	8	13.1
E.F. Indian 1	0.2	3	4.9	6	9.8
			Mission Creek		
Mission 1	3.6	0	0	0	0
Mission 2	6.8	6	9.8	14	23
Mission 3	8.3	1	1.6	2	3.3
Mission 4	9.1	1	1.6	9	14.8
W.F. Mission 1	0.6	16	26.2	30	49.2
			Nehchen Creek		
Nehchen 1	0.1	2	3.3	0	0
Nehchen 2	2.2	0	0	0	0
Nehchen 3	5.0	0	0	0	0
Nehchen 4	5.3	0	0	0	0
			Sheep Creek		
Sheep 1	1.9	1	1.6	2	3.3
Sheep 2	4.8	11	18	26	42.6
Sheep 3	4.9	19	31.1	29	47.5
Sheep 4	5.2	17	27.9	10	16.4
Sheep 5	5.5	17	27.9	19	31.1
Sheep 6	5.6	9	14.8	21	34.4
Sheep 7	5.9	6	9.8	2	3.3
			Upper Hangman Creek		
Hangman 4	32.3	17	27.9	37	60.7
Hangman 5	33.3	21	34.4	41	67.2
Bunnel 1	1.0	0	0	0	0
Conrad 1	0.9	0	0	1	1.6
Martin 1	0.4	10	16.4	31	50.8
S.F. Hangman 1	1.1	5	8.2	9	14.8
S.F. Hangman 2	3.3	4	6.6	1	1.6

Table 2. Coefficient of variation calculations for each subwatershed sampled from 2009 - 2013.

Stream	Mean Density 2009	2010	2011	2012	2013	SD	Mean	CV
Mission	6.56	2.87	6.56	7.87	18.03	5.71	8.38	**0.68**
Sheep	10.93	20.22	14.75	18.73	25.53	5.54	18.03	**0.31**
Nehchen	0	1.09	2.05	0.82	0	0.86	0.79	**1.08**
Indian	17.43	20.42	18.48	9.25	16.39	4.26	16.39	**0.26**
Upper Hangman	15.85	34.43	25.68	21.31	43.17	10.83	28.09	**0.39**
SF Hangman	15.16	13.11	9.02	7.79	17.21	4.00	12.46	**0.32**

Table 3. Roving electrofishing survey results in the Upper Hangman Creek watershed, 2013.

Stream	Stream km (starting location)	Survey Length (m)	RBT Captured	RBT density (fish/100 m)
	SF Hangman Creek			
S.F. Hangman	3.5	1200	2	0.2
Papoose	0	1050	1	0.1
Martin	2.1	240	7	2.9
Tenas (Tributary of Martin)	0	420	17	4
	Smith Creek			
M.F. Smith	0.4	900	16	1.8
E.F. Smith	0.4	260	2	0.8

3.1.2 Trout Trapping

A total of 490 trout were trapped between 2012 and 2013 in Nehchen and Indian Creeks, of which 133 were recaptured fish (previously marked) and 191 were implanted with HDX PIT tags (all in 2013). In Indian Creek, fish captured in the upriver trap ranged from 105 – 334mm in total length, with a mean length of 187mm. Fish captured in the downriver trap ranged from 86 – 328mm, with a mean total length of 168mm. In Nehchen Creek, captured fish in the upriver trap ranged from 106 – 262mm in total length, with a mean length of 195mm. Fish captured in the downriver trap ranged from 97 – 171mm, with a mean length of 172mm (Table 4).

Table 4. Migrant trapping results from Nehchen and Indian Creek, 2012 and 2013.

Stream	Trap Type	2012 Total Fish	2012 150mm+ (% Total)	2012 200mm+ (% Total)	2013 Total Fish	2013 150mm+ (% Total)	2013 200mm+ (% Total)
Nehchen	Up	5	5 (100)	2 (40)	4	2 (50)	0
	Down	79	43 (54)	17 (21)	67	47 (70)	19 (28)
Indian	Up	77	51 (66)	22 (28)	95	87 (91)	37 (39)
	Down	71	37 (52)	16 (22)	92	48 (52)	18 (19)

3.1.3 Trout Migration, Dispersal and Rearing Habits

A total of 508 individual redband trout were implanted with HDX PIT tags during summer electrofishing surveys in 2012 and 2013, and during spring trapping in 2013. Prior to March 1, 2014, 110 individual fish (22%) were detected by the passive interrogation sites. Of these fish, 86 (78%) were determined to be actively emigrating from the stream in which they were tagged and into the mainstem of Hangman Creek. Sixty-seven (78%) of these fish were tagged at the migrant traps in Nehchen and Indian Creek. Prior to March 1, 2014, very few of the emigrant trout (1.1%) were identified as dispersing into an adjacent tributary (Table 5).

Table 5. Summary of individual fish implanted with PIT tags in the upper Hangman Creek watershed, 2012 and 2013.

	# Tagged Fish			
Sub-watershed	**Electrofishing**	**Migrant Trapping**	**# Emigrant Fish**	**# Dispersing Fish**
Sheep Creek	153	0	1	0
Nehchen Creek	7	61	57	0
Indian Creek	170	117	28	1

The 85 emigrant redband trout originating from Nehchen and Indian Creeks were tracked throughout the summer of 2013 to determine preferred areas for rearing in the mainstem of Hangman Creek. Of these 85 fish, 52 (61%) reared in areas upstream of the creek they originated from, most of which was occurring upstream of the PIT tag interrogation site at stream kilometer 24.6 (Table 6).

Table 6. Summary of rearing habits of PIT tagged fluvial fish originating from Nehchen and Indian Creek, 2013.

	2013 Summer Rearing Locations		
Stream of Origin (Rkm at mouth)	# Downstream of Rkm 19.8 (%)	# Between Rkm 19.8 - 24.6 (%)	# Upstream of Rkm 24.6 (%)
Nehchen Creek (19.8)	23 (40%)	20 (36%)	14 (24%)
Indian Creek (25.6)	3 (10%)	7 (20%)	18 (70%)

3.2 Habitat Monitoring

3.2.1 Water Quality

Measured levels of discharge and dissolved oxygen in the Hangman watershed during baseline flow periods are consistently low in the majority of sampled locations, with the exception of Indian Creek and the upper most reach of Hangman Creek. Aside from these two areas, discharge levels range from 0.0 (or dry) to less than .05cfs. Within Indian Creek, the NF of Indian consistently provides the highest levels of baseline flow. All forested locations with a baseline flow greater than 0.01 cfs during 2012 and 2013 had dissolved oxygen concentrations above 7 mg/L (Table 7). Detailed water quality data for each survey location are exhibited in appendix A.

Table 7. Water quality metrics sampled during baseline flows in the upper Hangman Creek watershed, 2012 and 2013.

	2012		2013	
Site (rkm)	DS (cfs)	D.O. (mg/L)	DS (cfs)	D.O. (mg/L)
		Hangman		
Hangman-Stateline (0.0)	1.80	2.38	0.30	3.44
Hangman-Buckless (19.4)			0.12	4.33
Hangman-SF Road (28.9)			0.24	6.13
Hangman-Forest (32.4)	0.136	9.01	0.43	7.93
		Mission		
Mission-Desmet (12.1 + 0.1)	0.002	1.14	0.00	DRY
Mission-KVR (12.1 + 3.5)	0.018	2.24	0.01	3.61
MF Mission (12.1 + 7.6)	0.060	7.37	0.03	7.23
EF Mission (12.1 + 7.7)	0.004	6.38	0.00	DRY
WF Mission (12.1 + 6.1)	0.006	4.16	0.00	3.71
		Sheep		
Sheep-HWY 95 (17.1 + 1.2)	0.044	4.69	0.01	3.48
Upper Sheep (17.1 + 5.0)	0.03	7.25	0.03	7.25
		Nehchen		
Lower Nehchen (19.8 + 0.6)	0.00	DRY	0.0	DRY
Upper Nehchen (19.8 + 5.0)			0.04	6.77
		Smith		
Smith (24.7 + 1.8)	0.00	DRY	0.00	DRY
		Indian		
Indian-Sanders (25.6 + 0.9)	0.383	7.73	0.46	7.16
Indian-Pow Wow (25.6 + 2.3)	0.612	8.59	0.60	8.14
MF Indian (25.6 + 5.0)	0.096	8.04	0.12	7.30
NF Indian (25.6 + 4.6)	0.197	8.69	0.32	9.14
EF Indian (25.6 + 5.0)	0.066	7.09	0.06	7.31
		SF Hangman		
Upper SF Hangman (28.8 + 3.5)	0.00	DRY	0.00	DRY
Martin (28.8 + 2.1)	0.00	DRY	0.00	DRY
		Upper Hangman Tributaries		
Bunnel (33.3 + 1.0)	0.024	8.28	0.03	7.43
Parrot (33.4 + 1.0)	0.010	7.53	0.01	6.41

3.2.2 Continuous Temperature Monitoring

Temperature profiles in the mainstem of Hangman Creek exhibit profound differences as you move downstream from the headwaters (stream km 34.3) through stream kilometer 21.5. This is especially prevalent during the hottest portion of the summer, where maximum daily stream temperatures increased by over 10.5 degrees Celsius on July 15, 2012, and over 14 degrees Celsius on June 30, 2013 through this 13 kilometer reach (Figure 5). For all locations in the upper Hangman watershed, a measurable difference was observed in the % mean time that temperatures exceeded thresholds between 2012 (11.45%) and 2013 (22.25%) (Table 8). Detailed temperature profiles at each survey site are exhibited in appendix B.

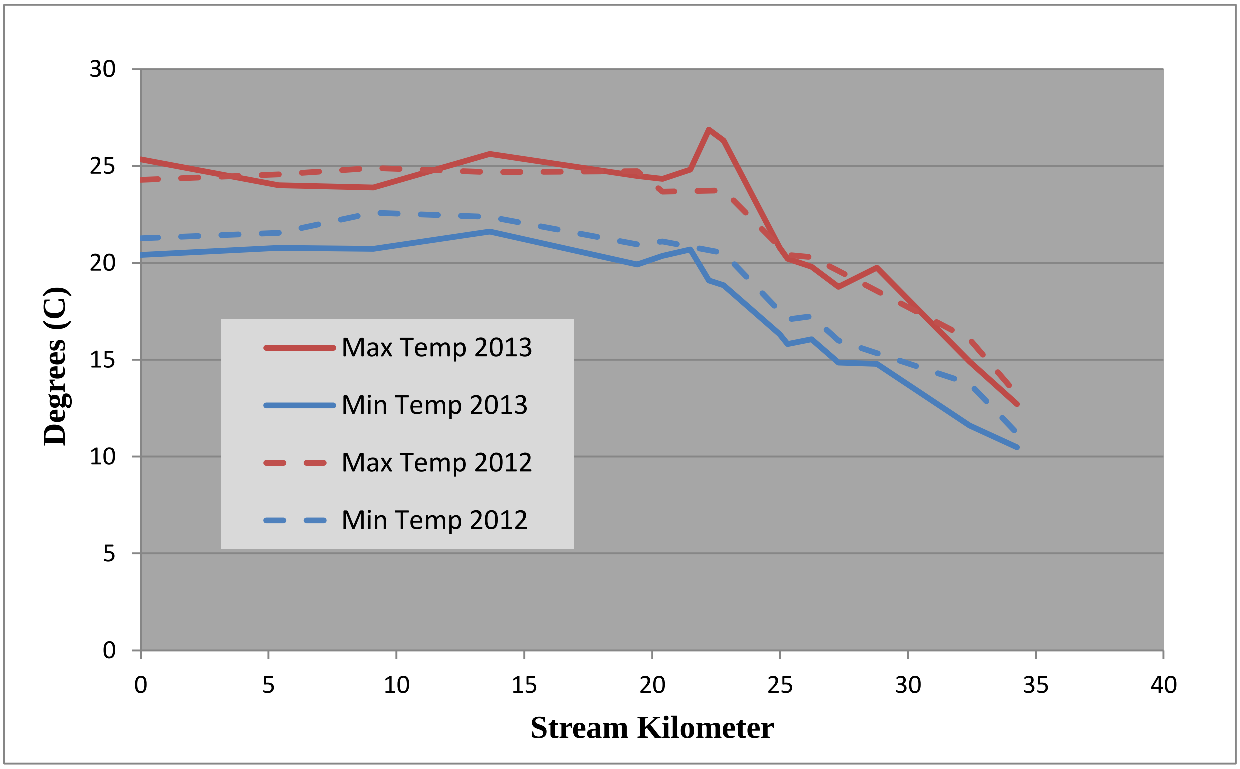


Figure 5. Seven-day moving average temperature profile through the mainstem of Hangman Creek on the hottest recorded day in 2012 and 2013.

Table 8. Stream temperature summary of threshold exceedance for all locations in the upper Hangman watershed, 2012 and 2013.

Location (River Km)	**Spawning Limit** % hrs Exceeds 14 Deg C May 1 - June 30		**Rearing Limit** % hrs Exceeds 20 Deg C July 1 - August 31		**Overall** May 1 - August 31	
	2012	*2013*	*2012*	*2013*	*2012*	*2013*
Hangman-Stateline (0.0)	40.70	69.45	44.61	43.47	42.45	63.72
Hangman-Liberty (5.4)	39.62	69.95	40.73	52.20	39.90	66.73
Hangman-Farm (9.1)	41.04	70.48	47.82	54.87	44.25	69.62
Hangman-HWY 95 (13.7)	32.17	66.03	57.46	61.94	44.61	63.45
Hangman-Buckless (19.4)	21.29	54.98	40.59	35.65	30.64	44.73
Hangman-Nehchen Bluff (20.4)	22.85	55.86	37.08	39.31	29.63	46.99
Hangman Morefield (21.5)	.	56.57	.	50.18	.	52.79
Hangman Relief Channel (22.2)	.	55.53	.	60.75	.	57.36
Hangman-Beasley (22.8)	21.61	51.10	40.18	60.29	30.60	55.37
Hangman Airport (24.9)	.	27.87	.	4.50	.	15.85
Hangman-V. Larson (25.3)	5.87	22.36	3.55	2.05	4.57	11.91
Hangman-Crawford (26.2)	6.91	20.23	3.89	0.00	5.23	10.09
Hangman-Cordell (27.3)	2.22	10.50	0.76	0.00	1.43	5.22
Hangman-Bennett (28.8)	.	20.03	.	0.21	.	10.09
Hangman-Forest (32.4)	1.44	0.00	0.00	0.69	0.73	0.34
Bunnel (33.3 + 1.0)	0.00	0.00	0.00	0.00	0.00	0.00
Mission-DeSmet (12.1 + 0.1)	35.09	56.02	15.89	39.80	25.21	47.63
Mission-KVR (12.1 + 3.5)	10.59	29.01	1.36	2.60	5.80	15.43
Mission-Allotment632 (12.1 + 6.1)	0.00	1.28	0.00	0.00	0.00	0.63
Mission-M.F. (12.1 + 7.6)	0.00	0.00	0.00	0.00	0.00	0.00
Mission-W.F. (12.1 + 6.1)	6.75	6.98	0.00	.	3.37	.
Sheep-HWY 95 (17.1 + 1.2)	21.20	38.09	12.63	2.53	16.51	19.87
Sheep BD4 (17.1 + 1.7)	.	37.36	.	3.89	.	20.12
Sheep-Upper (17.1 + 5.0)	0.00	0.03	0.07	0.00	0.03	0.02
Nehchen Lower (19.8 + 0.6)	4.84	.	1.67	.	3.27	.
Nehchen Upper (19.8 + 5.0)	0.00	.	0.00	.	0.00	.
Indian Sanders (25.6 + 0.8)	.	10.07	0.00	0.76	0.00	5.28
Indian-Pow-wow (25.6 + 2.3)	0.00	2.40	0.00	0.00	0.00	1.17
Indian-Upper (25.6 + 5.0)	0.00	0.00	0.00	0.00	0.00	0.00
Indian-E.F. (25.6 + 5.0)	0.00	0.00	0.00	0.00	0.00	0.00
Indian-N.F. (25.6 + 4.6)	0.00	1.98	0.00	0.00	0.00	0.97
S.F. Hangman-Lower (28.8 + 1.3)	7.64	7.17	0.00	0.00	3.67	3.56
Martin (28.8 + 2.1)	0.00	1.88	0.00	0.00	0.00	0.91
S.F. Hangman-Upper (28.8 + 3.5)	0.00	0.00	0.00	0.00	0.00	0.00

3.2.3 Longitudinal Temperature Profile Monitoring

A total of 183 pools were encountered in the mainstem of Hangman Creek between stream kilometer 19.8 and 27.3. Temperature differences between the tailout and the maximum depth of each pool ranged from -0.2 to 8.0 degrees Celsius. All pools with a residual depth greater than 3.6 feet exhibited a measurably cooler temperature than the associated tailout (appendix C).

3.2.4 Physical Habitat Assessment/Monitoring

Habitat surveys in the mainstem, particularly in areas adjacent to agriculture, show a lack of large woody debris recruitment (under 1 m^3/100 meters) and low levels of canopy cover contributed by woody plants (under 50%). In general, habitat surveys conducted in headwater forested reaches showed higher levels of canopy cover (over 90%) and increased volumes of large woody debris. Noteworthy metrics include the lack of LWD and a correspondingly low level of pool habitat in Nehchen 5.0 and WF Mission 0.6, as well as the high levels of fine sediment in Mission 6.3 and EF Smith 1.0 (Table 9).

*Table 9. Habitat survey metrics for specific locations within the upper Hangman Creek watershed, 2012 and 2013. *Indicates sites which were sampled previously.*

		Mean percent canopy cover		**Mean percent fines**		**Large woody debris metrics**		**Pool habitat metrics**	
Stream	**Rkm**	**Total**	**% non-woody plants**	**Bankfull**	**Wetted**	**Count (#/100 m)**	**Volume (m^3/100 m)**	**Percent pool**	**Mean residual pool depth (m)**
				2012					
WF Mission	0.1	93.2	0	52.3	22.6	12.0	2.8	16.8	0.2
WF Mission	0.6	97.4	0	47.1	15.1	5.0	0.4	6.7	0.3
Mission	6.3	98.3	0	71.1	34.7	37.0	3.1	19.7	0.3
Sheep	2.4	73.4	0	26.8	14.3	16.0	8.9	12.4	0.4
Indian	3.5	99.8	0	36.6	15.8	26.0	4.3	7.9	0.4
EF Indian*	0.8	99.4	0	33.4	6.1	28.0	11.8	7.0	0.3
				2013					
Hangman*	22.0	13.1	100	28.3	6.5	0.0	0.0	4.3	0.7
Hangman	24.4	46.2	88	35.1	5.9	9.0	0.4	23.8	0.9
Hangman	25.0	37.6	57	28.6	10.4	5.0	0.2	22.2	0.5
Nehchen*	5.0	89.1	8	29.1	5.3	8.0	1.4	5.7	0.2
Papoose	0.0	91.2	17	35.1	13.8	16.0	5.3	14.2	0.2
SF Hangman*	3.0	96.9	2	26.3	9.3	23.0	6.6	28.5	0.3
Smith	5.9	96.6	1	29.4	3.6	20.0	3.6	10.7	0.2
EF Smith	1.0	99.3	0	73.7	43.1	8.0	0.5	13.8	0.4

The results shown in four previous Rosgen channel typing surveys (Kinkead and Firehammer 2011 & 2012) show similar linkage of land management to fine sediment loading and a lack of wood and pool habitat. No measurable changes in canopy cover or percent fines were observed in the 4 survey sites from their initial assessment to the repeated survey. Hangman 22.0 showed an increase in the number of pools; however mean residual pool depth decreased substantially over the 9 year period. EF Indian 0.8 showed a large decrease in the number of pools and the mean residual pool depth while large woody debris volume increased substantially. It is noteworthy that clear cuts on the EF Indian Creek outside of the riparian area have left the conifers in the riparian area exposed to edge effects. The remaining 3 surveys sites all showed a measurable decrease in the count and volume of large wood (Table 10).

Table 10. Habitat metrics at repeated survey sites over a 5 - 9 year period in the upper Hangman Creek watershed.

			Large woody debris metrics		Pool habitat metrics	
Year Surveyed	**Mean percent canopy cover by woody, non-herbaceous plants**	**Mean percent fines at bankfull width**	**Count (#/100 m)**	**Volume (m^3/100 m)**	**# Pools/ 100 m**	**Mean residual pool depth (m)**
		Hangman 22.0				
2004	6.3	39.3	1.0	0.0	2.6	2.1
2013	0	28.3	0.0	0.0	4.3	0.7
		EF Indian 0.8				
2004	87.8	33.9	27.0	3.5	13.2	0.6
2012	99.4	33.4	28.0	11.8	3.0	0.3
		Nehchen 5.0				
2004	85.3	29.4	12.0	3.0	1.1	0.4
2013	89.1	29.1	8.0	1.4	5.7	0.2
		SF Hangman 3.0				
2008	97.3	29.3	30.0	10.9	2.6	0.2
2013	96.9	26.3	23.0	6.6	9.5	0.3

3.2.5 Upper Indian Creek Spawning Habitat Assessment

Spawning habitat comprised 2.32% of the total area in the 3 headwater streams of Indian Creek. Where recorded, wood contributed to the formation of an estimated 56% of the available spawning habitat. Stream reaches with the highest amount of spawning habitat had a gradient of less than 3%. Incidentally, spawning habitat in these reaches were also the most influenced by in-stream wood (Table 11).

*Table 11. Results from spawning ground survey conducted in upper Indian Creek, 2013. *Indicates areas of recent timber harvest.*

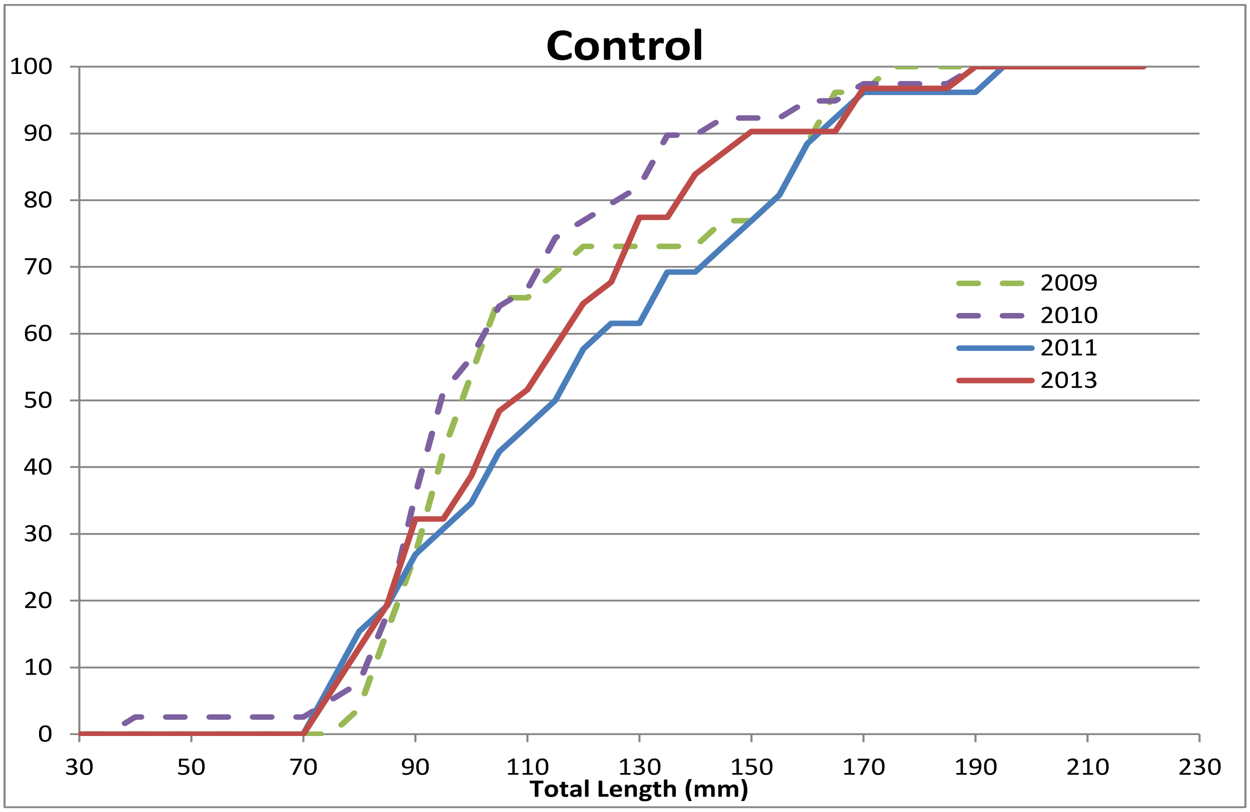
Stream Km	Mean Stream Gradient	% Spawning Habitat	% Total Spawning Habitat Formed From Wood
		Middle Fork Indian Creek	
0.0-0.7*	4.0%	1.52	.
0.7-0.9	4.6%	4.28	.
0.9-1.4	9.0%	0.69	.
1.4-1.5	6.2%	2.89	.
1.5-2.0	9.4%	0.89	.
2.0-2.4	2.0%	8.44	.
		North Fork Indian Creek	
0.0-0.1	7.0%	1.33	.
0.1-0.9*	6.0%	1.81	47
0.9-1.1	3.9%	2.49	56
1.1-1.4	12.0%	0.69	46
1.4-1.6	2.0%	4.38	80
		East Fork Indian Creek	
0.0-0.2*	2.8%	2.11	88
0.2-0.6*	4.9%	0.32	56

3.3 Action Effectiveness

Redband trout parameters in a LWD treated reach of Indian Creek

Results from the repeated measures analysis over the 5 year sampling period from 2009 – 2013 do not indicate a significant difference (p-value = 0.147) between the number of fish caught in the treated and control reaches of Indian Creek. The repeated measures analysis did report a significant difference in the number of fish caught annually across all sites, indicating annual trends in fish abundances between treatment and control sites are not affected independently from one another (p-value = 0.042). The repeated measures output is exhibited in appendix D.

Results from the cumulative size distribution analysis for redband trout in the control and treatment sites in 2009, 2010, 2011, and 2013 suggest a trend toward a smaller proportion of younger/smaller individuals in the treatment sites, while size distribution in the control sites stays relatively constant. During 2009 and 2010, directly following the additions of large wood, 50% of the individuals sampled in the treated reach were smaller than 95 and 110 mm in total length, respectively. In 2011 and 2013, individuals smaller than 95 and 110 mm in length only composed 20% of the fish sampled, respectively. Throughout all survey periods from 2009 - 2013 in the control sites, individuals smaller than 115 mm made up at least 50% of the total fish sampled. There was a slight increase in size distribution from 2009 to 2013 in the control sites, where initially 50% of the fish sampled were smaller than 95 mm in length, and this had increased to 115 mm by 2013 (Figure 6). Examples of the large woody debris structures are exhibited in appendix E.



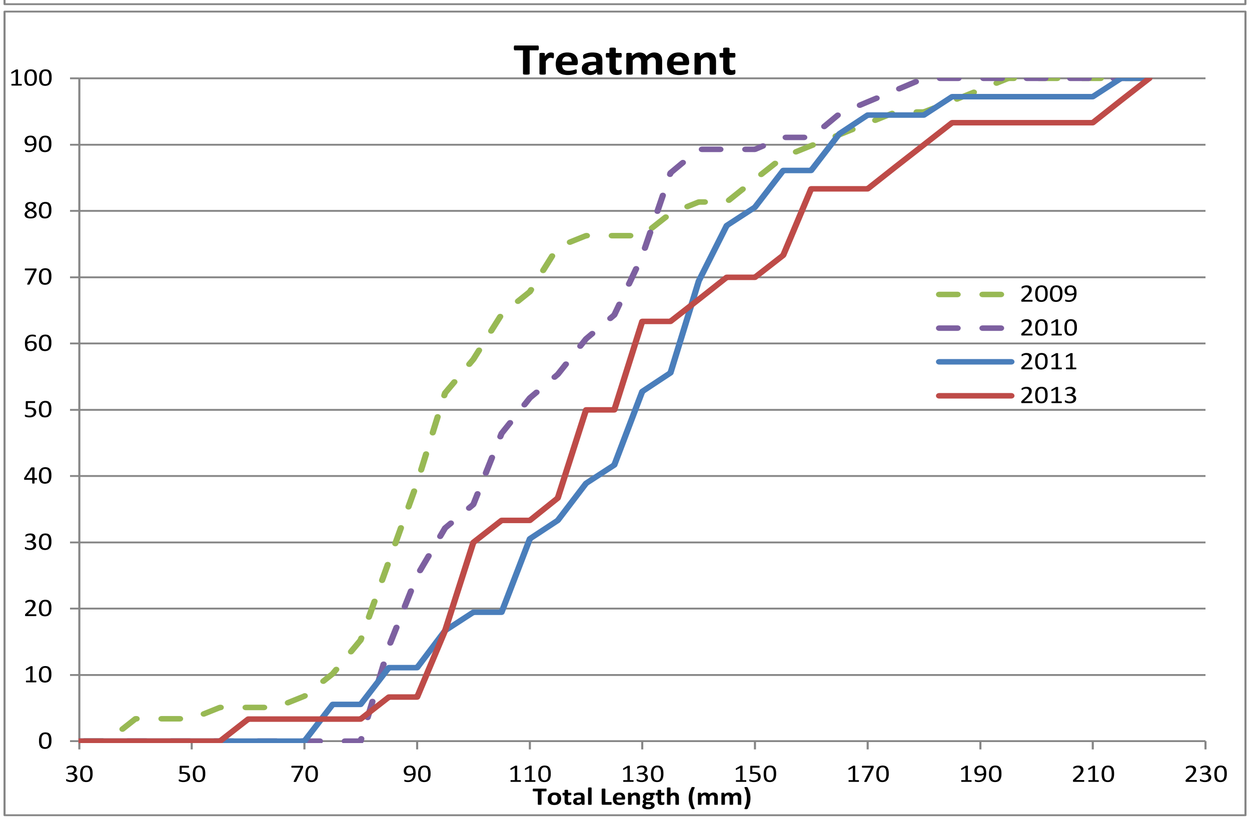


Figure 6. Cumulative size distribution of redband trout sampled in the control and treated reaches of Indian Creek, 2009-2013.

4 Discussion/Conclusion

4.1 Status and Trend Monitoring

Redband Trout Trends, Distribution, and Habits

Redband trout distributions continue to be largely limited to forested reaches of the Hangman watershed. The reaches of Hangman Creek upstream of and including Indian Creek form a continuous expanse of this type of hospitable habitat, allowing dispersal of fish among tributary habitats, which helps to explain the relatively stable densities of trout sampled annually in these tributaries. This also helps explain the summer rearing habits of the PIT tagged fluvial fish originating from Indian and Nehchen Creek, which are moving upstream into these same reaches, seeking out areas of refuge.

Fluvial life history strategies, although less common in the Hangman watershed, have the potential to have the largest impact on dispersal and recolonization into adjacent tributaries. Current habitat conditions however are not conducive to downstream dispersal. Stream conditions in the Hangman mainstem downstream of Smith Creek (stream km 24.7) are, at best, only hospitable for very short time periods. PIT tag interrogation data suggests that fluvial fish do not use the majority of the reach of Hangman Creek between Sheep Creek (stream km 17.1) and Smith Creek as rearing habitat. The majority of the tagged fluvial individuals inhabit areas upstream of this reach during summer and fall rearing periods, likely to escape elevated stream temperatures, low dissolved oxygen levels, and instream habitat lacking complex structure. Repeated habitat surveys in the mainstem confirm that these habitat conditions are not improving in this reach, and will likely continue to provide suboptimal habitat without intervention involving implementation of significant restoration actions.

The implications of this avoidance behavior by fluvial individuals can have a detrimental effect on our goal of increasing dispersal into downstream adjacent tributaries which are functionally isolated from the rest of the population. This had lead the Fish and Wildlife Programs to initiate a large scale, valley-wide restoration effort, which attempts to rehabilitate the portion of Hangman Creek and the surrounding floodplain between Nehchen and Indian Creek. This 5+ kilometer stream reach will be a major focal point of restoration in the upper Hangman Creek watershed, specifically to reconnect the stream to the adjacent valley through the reactivation of relict channels and floodplain swales. It is hoped that this will in turn lead facilitate the reestablishment of a native vegetative community and lead to increased baseline flows and cooler stream temperatures. Prior riparian enhancement efforts, such as those undertaken directly upstream of Nehchen Creek on T1031, are slow to affect positive changes in instream habitat when they are not accompanied by channel modifications that help reconnect the entrenched stream and adjacent floodplain (Kinkead and Biladeau 2013). The intensive restoration methods planned for 2014 – 2017 upstream of T1031 is designed to address a number of habitat limitations while initiating natural processes and function within a short time period.

Residency in redband trout is by far the dominant life history strategy within the upper Hangman watershed. PIT tag data from fish captured in summer electrofishing surveys estimates fluvial fish production in the sampled tributaries to be quite low. This is especially apparent in Sheep Creek where less than 1% of the tagged individuals emigrated into the mainstem of Hangman Creek. We speculate that Mission Creek has an even lower proportion of fluvial individuals, perhaps none at all. Due to the lack of a migratory component in these lower tributaries of the watershed, the entire subpopulation relies on successful reproduction from a relatively small number of mature resident individuals which can fluctuate annually depending on local habitat conditions. Therefore, these isolated streams express a higher rate of annual variability in densities, and without introgression from the rest of the population, will continue to genetically diverge and be more susceptible to extirpation. Physical habitat measurements conducted in these isolated streams further emphasizes the need for restoration efforts aimed at providing these resident fish with larger reaches of higher quality rearing habitat, stemming from increased baseline flows, cooler stream temperatures, increased habitat complexity, and a decrease in erosion and sedimentation. Through this type of rehabilitation, the mortality rates within these tributaries may be buffered from annual variation in weather patterns. The major difference in trout densities between 2012 and 2013 is an example of how weather, particularly total annual precipitation and timing, can influence survival. The year 2012 had one of the lowest mean trout densities recorded in the Hangman Creek watershed since consistent monitoring was initiated. Coincidentally, this was preceded by a very low water year in 2010. The 2013 survey, however, had some of the highest mean densities recorded, and was preceded by 2 years of consistently higher water in 2011 and 2012.

The habitat conditions which are present throughout the tributaries of Hangman Creek are restricting densities and survival of resident redband trout. Fine sediment input continues to be a problem throughout the watershed, as shown in upper Smith and Mission Creek surveys. The extensive road network to support timber harvest, much of which consists of native surface roads, is likely the main contributor of fine sediment to these subwatersheds, and throughout the headwaters of Hangman Creek. This same trend was apparent to Eaglin and Hubert (2011) who found a positive correlation between the amount of fine substrate and embeddedness to the proportion of culvert crossings and the extent of logging in the drainage. They also found that these changes to the landscape due to logging practices had a negative correlation on standing stocks of trout.

Lack of large wood recruitment and the correspondingly low levels of pool habitat, as exhibited in the upper Nehchen and Mission Creek surveys, has long been known to be a limiting factor in trout densities (Kail et al 2007, Roni and Quinn 2001, Shields et al 2001). This is especially troublesome in these two tributaries, as each of them run dry from the mouth to stream kilometer 3.7 and 6.6, respectively, during base flow periods. The redband trout are already restricted to the headwaters of these tributaries, and without higher quality rearing habitat in these areas, the carrying capacities will remain well below their potential.

It is important to continue monitoring these subpopulations while protecting their associated stream habitats in hopes of reconnecting these isolated subpopulations to the remainder of the Hangman Creek watershed. This holds true as well for all of the resident subpopulations throughout the upper Hangman Creek watershed. Indian Creek for example continues to be a stronghold for redband trout and is currently the furthest downstream tributary in a continuous reach of hospitable habitat. The habitat survey data in upper Indian Creek however has shown that even though densities of fish in these areas are relatively high, there may in fact be habitat restrictions. The elevated levels of fine sediment documented can severely restrict the amount of available spawning habitat, especially in headwater reaches where the majority of spawning is thought to occur. The assessment of spawning habitat throughout upper Indian Creek supports this claim. Although much of these reaches have a relatively high gradient (>4%) the potential for an increased amount of spawning habitat is present, especially through the addition of large wood.

The majority of the marked fish captured in Indian Creek are believed to be resident, although a significant proportion of fluvial individuals are present as well. Habitat improvements throughout this subwatershed can lead to increases in densities of fish with either life history strategy. The spawning ground survey was intended to assess the amount of spawning habitat available in the headwaters of Indian Creek, with a goal of identifying opportunities for increasing these habitats through the addition of large wood. Spawning habitat availability may be the greatest limiting factor for increasing the size of this subpopulation. An increase in the densities stemming from higher rates of spawning success may lead to density dependent influences such as changes in dispersal rates. Einum et al (2006) observed this type of behavior in wild juvenile Atlantic salmon *Salmo salar,* where individuals, especially during the parr stage, increasingly dispersed from high-density areas into lower density areas downstream. Increased spawning success may be the simplest way to initiate this type of behavior. Restoration actions that can accomplish this, in conjunction with the planned rehabilitation in the mainstem of Hangman Creek may be the most effective way to establish a continuous expanse of hospitable salmonid habitat while initiating an increase in dispersal and recolonization into adjacent tributaries.

4.2 Action Effectiveness

Redband trout parameters in a LWD treated reach of Indian Creek

Through 5 years of sampling, there is no detectable difference in trout densities within and adjacent to the treated reach in Indian Creek. This suggests the additional pool habitat in the treated reaches, which was created through the addition of large wood, does not provide a measurable benefit to this subpopulation of redband trout at the scale of treatment (<1 km), or at minimum, did not invoke any type of localized response. Previous reporting however did indicate a significant difference in trout densities directly following treatment and for the next two years (Kinkead and Biladeau 2013). Studies by Roni and Quinn (2001) show a measurable increase in the densities of juvenile salmonids in LWD treated reaches where pool habitat was increased. However, resident trout in this same study only showed measurable increases in density during winter rearing periods when aggressive behavior is much less common. Muhlfeld and Bennet (2001) found this same type of seasonal behavior in redband trout through radio telemetry studies in Montana, where redband actively seek out larger complex pool habitat, especially during winter. Although we have not made direct observations of behavior during winter, we can speculate that this may be occurring in Indian Creek, especially in light of the shift in cumulative length frequency distributions that has developed between the treated and control sites. It is likely the newly created pool habitat is preferable within this reach of stream and attracted trout within and adjacent to the areas where LWD was added, resulting in an immediate response in localized densities. Over time and as the newly recruited trout matured, larger and more aggressive fish claim these areas of preferred habitat, forcing smaller fish out during periods when aggressive behavior is more common. This time frame (summer) also happens to coincide with our sampling efforts.

5 Adaptive Management & Lessons Learned

5.1 Marking and Tagging

The Fisheries program has adapted our marking technique to discontinue the use of visual elastomer tags and adopt the use of half-duplex PIT tags. In doing so, we have gained new insight on the habits and life histories of redband trout in a relatively short time frame with minimal effort and expense. Passive interrogation of tagged fish through strategically placed, fixed antenna sites is a relatively low cost method to gain a lot of valuable information on fish habits over time, while minimizing deleterious effects on fish caused by multiple capture and handling events. This type of monitoring will continue to guide our restoration efforts in the upper Hangman watershed by better describing habitat constraints operating at multiple spatial scales to restrict redband trout survival and dispersal. Documenting shifts in these behaviors over time following implementation of restoration actions is consistent with the overall goal of the Hangman Fisheries Project. This type of approach may be particularly useful in effectiveness monitoring of the planned restoration efforts in upper Indian Creek and in the mainstem of Hangman Creek between stream kilometers 19.8 and 25.6.

5.2 Spawner Abundance Estimates

Current project deliverables incorporate an estimate of spawner abundances in Indian and Nehchen Creek via our trapping efforts. Due to the different life history strategies present in each of these subwatersheds, this has proven to be difficult to estimate with any certainty. It is likely resident and fluvial fish are each recruited to our migrant trap without any way of differentiating between the different life histories. Traditionally, we determined any fish under 150 mm total length was not a mature fluvial adult; however, field observations have shown a number of 130mm – 150mm sexually mature males are caught in the Indian Creek migrant traps, and following spawning periods, emigrate out of Indian Creek into the mainstem of Hangman Creek. Furthermore, we capture far more adult fish in the downriver trap in Nehchen Creek than upriver fish. These fish are currently presumed to be residing in upper Nehchen Creek in a stream reach that, until 2014, was never sampled during our summer electrofishing surveys, where they reach sexual maturity, spawn then emigrate into Hangman Creek. Due to the slow growth rates of redband trout in headwater streams, it is impossible to differentiate these fish from the emigrating juveniles originating from similar locations. Trapping efforts however have proven to be a much more productive way to focus our efforts on sampling fluvial individuals and implanting them with PIT tags than summer electrofishing surveys. Marked fish have recently given us valuable information on preferable rearing habitats. Furthermore, they will help guide future main-stem restoration projects while monitoring the effects of such projects on redband trout.

5.3 Migrant Fish Trapping Techniques

We have modified and upgraded our migrant traps over time due to the high level of effort required to install and maintain these traps during spring runoff. Furthermore, the older fixed panel weirs which were wrapped with chicken wire would occasionally result in mortality of fish that could become entrapped in the wire-mesh. Our new trap style uses a more fish-friendly aluminum grate which is not only easier to install annually, but also easier to clean and maintain throughout the year. Pictures of each trap style are exhibited in appendix F.

5.4 Effectiveness Monitoring Design and Implementation

Current results describing the effectiveness of restoration efforts in Indian Creek are based on the comparison of control and treatment sites post-treatment. This monitoring design was created and implemented after the restoration process was initiated. A stronger analysis of restoration effects on redband trout densities would have been to initiate multiple sampling events prior to restoration in both of the projected control and treatment sites, consistent with a traditional BACI design. Initial restoration designs for the two treated reaches were intended to treat the most impaired reaches in the area; the first with mean pool depths of 0.17m, and the second section with indications of active channel incision processes and increased bank erosion. The restoration design included objectives to aggrade or maintain channel elevation, decrease bank erosion, provide fish cover, as well as create pool habitat, and sort gravels for spawning, which for the most part was accomplished (Kinkead and Biladeau 2013). It is possible, however, that the most limiting factor for trout densities in Indian Creek is not the availability of pool rearing habitat. Habitat surveys throughout Indian Creek show abnormally high levels of fine sediment throughout the drainage, which may be limiting spawner success and therefore recruitment rates. Current and future restoration efforts aim to address these issues in upper Indian Creek. Furthermore, action effectiveness monitoring has and will be incorporated into the overall RM&E design, and will therefore be more effective in assessing future project affects on various aspects of redband trout population dynamics.

6 *References*

Aripa, F. 2003. Personal communication with tribal elder.

Eaglin, G. S. and W. A. Hubert. 1993. Management briefs: Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming. North American Journal of Fisheries Management. V13, I4: 844-846.

Einum, S., L. Sundt-Hansen, and K. H. Nislow. 2006. The partitioning of density-dependent dispersal, growth and survival throughout ontongeny in a highly fecund organism. Oikos. V113, I3: 489-496.

Green, G.I., B. Kinkead, and D. Callery. 2008. Prioritization Area Selection within the Hangman Watershed of the Coeur d'Alene Reservation. Coeur d'Alene Tribe.

Herrera Environmental Consultants. 2011 Recommendations for Beaver Habitat Restoration in the Upper Hangman Watershed. Technical Report prepared for the Coeur d'Alene Tribe. 128pp.

Kail, Jochem, D. Hering, S. Muhar, M Gerhard, and S. Preis. 2007. The use of large wood in stream restoration: experiences from 50 projects in Germany and Austria. Journal of Applied Ecology. 44: 1145-1155.

Kinkead, B.A., and J.A. Firehammer. 2011. Progress Report: 2004-2007 Hangman Creek Fisheries Restoration . BPA Project #2001-032-00. 263pp. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Kinkead, B.A., and J.A. Firehammer. 2012. Final Progress Report: 2008-2009 Hangman Creek Fisheries Restoration. BPA Project #2001-032-00. 113pp. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Kinkead, B.A., and T. J. Biladeau. 2013. Progress Report 2010-2011: Hangman Creek Fisheries Restoration, 5/1/2010 - 04/30/2012 Annual Report, 2001-032-00, RM&E and Restoration Summaries.

Peters R., B.A. Kinkead, and M. Stanger. 2003. Year-End Report: 2001-2002 Implement Fisheries Enhancement on the Coeur d'Alene Indian Reservation: Hangman Creek. BPA Project # 2001-032-00. 189 pp. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

McPhee MV, Utter F, Stanford JA *et al*. 2007. Population structure and partial anadromy in *Oncorhynchus mykiss* from Kamchatka: relevance for conservation strategies around the Pacific Rim. Ecology of Freshwater Fish, 16, 539-547.

Roni, P. and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Science. 58: 282-292.

Shields, F. D., N. Morin, and R. A. Kuhnle. (2001) Effect of large woody debris structures on stream hydraulics: From Proceedings of the conference on Wetland Engineering and River Restoration. Reno, Nevada, August 27-31, 2001.

Schuett-Hames, D. & Allen Plues. 1996. Literature Review and Monitoring Recommendations for Salmonid Spawning Habitat Availability. Washington State Department of Natural Resources Timber-Fish-Wildlife Research Report. TFW-AM9-96-002.

7 Appendices

7.1 Detailed data sets

7.1.1 Appendix A: Detailed Water Quality Results

Table A-1: Complete results from water quality sampling during June and August, 2012-3.

Hangman-Stateline

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 16:30		119	6.15	10.97	6.10	83.45
8/23/12 15:35		1.80	2.38	17.90	6.67	205.20
6/4/13 18:00	7.84	0.68	6.57	19.85	7.30	110.70
8/22/13 13:11	3.46	0.30	3.44	18.08	8.66	186.46

Hangman-Buckless

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 15:00		76.68	8.21	9.84	6.06	54.64
6/4/13 17:25	6.39	4.755	7.3	18.11	6.44	60.64
8/22/13 12:15	3.29	0.12	4.43	17.38	7.1	78.24

Hangman-SF Road

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 11:50		7.554	8.56	8.2	5.9	45.67
6/4/13 16:50	8.65	1.152	8.44	1328	6.05	40.39
8/22/13 11:46	4.04	0.24	6.13	14.88	7.34	60.545

Hangman-Forest

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 23:18		5.465	9.08	6.88	5.67	39.31
8/23/12 11:10		0.136	9.01	10.74	5.32	42.27
6/4/13 15:20	7.15	0.447	8.89	9.88	5.65	38.22
8/22/13 10:34	3.08	0.43	7.93	12.26	7.35	51.83

Mission-Desmet

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 10:45		4.135	7.99	11.49	6.62	87.97
8/13/12 14:35		0.002	1.14	16.77	6.01	305.7
6/3/13 10:45	11.4	0.52	7.19	18.44	5.94	94.5
8/21/13 10:35		0.00	DRY			

Table A-1 continued. Results from water quality sampling during June and August, 2012-3.

Mission-King Valley

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 10:13		2.526	9.61	7.21	5.6	58.06
8/13/12 14:05		0.018	2.24	12.91	4.9	130.9
6/3/13 14:15	22.6	0.452	7.53	11.62	5.45	61.41
8/21/13 10:32	3.24	0.01	3.61	12.72	7.08	144.58

Mission-MF

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 14:26		0.759	11.24	6.76	5.7	33.58
8/13/12 11:00		0.06	7.37	13.61	4.74	42
6/3/13 12:10	7.95	0.152	9.16	8.58	4.66	29.1
8/21/13 8:56	3.46	0.03	7.23	11.73	7.09	44.02

Mission-EF

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 14:54		0.732	10.58	7.99	5.64	40.18
8/13/12 11:30		0.004	6.38	12.79	5.12	51.65
6/3/13 11:49	12	0.075	8.69	9.35	5	32.5
8/21/13 9:27	6.49	0.00	5.09	12.36	6.66	62.607

Mission-WF

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 16:39		0.816	9.71	8.79	6.08	55.1
8/13/12 13:20		0.006	4.16	14.63	4.84	66.78
6/3/13 13:20	8.98	0.108	8.23	11.36	5.31	41.1
8/21/13 10:10	9.35	0.00	3.71	12.23	6.81	79.73

Sheep-HWY 95

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 13:35		7.766	9.86	8.13	6.13	68.25
8/13/12 16:00		0.044	4.69	18.23	6.2	70.72
6/3/13 15:00	12.7	0.456	7	14.79	5.74	51.44
8/21/13 11:41	3.12	0.01	3.48	13.31	6.64	107.72

Sheep-Upper

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 12:55		1.232	11.88	6.83	5.42	30.68
8/13/12 16:10		0.03	7.25	14.71	3.85	31.12
6/3/13 14:30	3.97	0.114	9.62	9.06	4.88	22.56
8/21/13 11:13	1.91	0.02	8.02	12.72	7.07	35.07

Table A-1 continued. Results from water quality sampling during June and August, 2012-3.

Nehchen-Lower

Date/Time	Turbidity (NTU)	DS ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 14:30		8.915	8.94	8.83	5.42	84.19
8/13/12 16:20		0	DRY			
6/3/13 17:10	7.46	0.46	8.07	11.74	5.51	37.67
8/21/13 13:28		0.000	DRY			

Nehchen-Upper

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 15:45		4.453	9.56	7.13	5.21	26.26
6/3/13 17:40	2.42	0.312	9.41	8.6	5.18	24.02
8/21/13 13:28	1.48	0.04	6.77	13.16	7.02	39.37

Indian Creek-Sanders

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 14:15	12.6	8.584	11.84	7.91	5.73	34.57
8/10/12 15:15		0.383	7.73	16.76	5.86	41.15
6/4/13 13:45	4.44	1.19	8.83	12.72	5.5	32.03
8/22/13 10:08	2.18	0.46	7.16	14.41	7.35	44.59

Indian Creek-Pow Wow

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 14:35	12.9	6.552	10.09	7.62	5.76	33.45
8/13/12 14:30		0.612	8.59	14.82	5.8	38.44
6/4/13 12:40	2.16	1.083	9.44	10.23	5.53	29.59
8/22/13 9:37	1.52	0.60	8.14	12.87	7.42	41.384

Indian Creek-Upper

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 15:20	8.29	3.096	10.44	6.67	5.75	33.96
8/10/12 13:25		0.096	8.04	12.74	5.92	57.88
6/4/13 11:30	3.00	0.364	9.66	7.94	5.62	42.33
8/22/13 8:43	0.79	0.12	7.3	11.72	7.57	67.666

Indian Creek-NF

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/6/12 15:00	7.94	1.88	10.47	7.25	5.6	26.2
8/12/12 13:55		0.197	8.69	15.44	5.3	22.61
6/4/13 12:00	2.02	0.315	10	10.03	5.06	18.67
8/22/13 9:02	2.57	0.32	9.14	13.08	7.11	24.67

Table A-1 continued. Results from water quality sampling during June and August, 2012-3.

Indian Creek-EF

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 15:45	7.63	1.404	9.72	7.23	6.03	37.33
8/10/12 12:45		0.066	7.09	12.03	5.63	43.89
6/4/13 10:50	1.79	0.093	9.11	7.98	4.72	36.53
8/22/13 8:16	1.16	0.06	7.31	11.72	7.12	49.22

Smith

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 11:05		3.89	8.48	8.02	6.11	75.67
8/23/12 9:40		DRY				
6/4/13 15:50	5.51	0.255	7.45	13.96	6.14	86.83
8/22/13 11:16		DRY				

SF Hangman-Lower

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/4/13 16:35	5.89	0.906	7.23	13.45	6.39	56.84

SF Hangman-Upper

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 12:05		1.065	9.18	6.98	5.9	52.97
8/23/12 11:15		Dry				
6/4/13 15:13	3.96	0.123	8.33	8.92	5.89	49.24
8/22/13 11:45		DRY				

Conrad

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 13:00		4.245	8.64	9.2	6.2	44.17
6/4/13 10:45	5.87	0.06	7.87	13.27	6.26	36.72

Martin

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/7/12 12:20		1.106	8.29	8.1	6.29	59.14
6/4/13 16:05	3.16	0.174	7.26	10.15	6.4	63.01
8/22/13 11:23	1.72	0.08	4.93	11.22	7.41	102.989

Bunnel

Date/Time	Turbidity (NTU)	DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 9:50		1.335	10.18	6.42	5.05	33.78
8/23/12 10:15		0.024	8.28	10.38	3.89	33.19
6/4/13 14:20	2.79	0.066	9.19	8.84	5.29	32.3
8/21/13 12:19	1.75	0.03	7.43	12.28	7.07	42.33

Table A-1 continued. Results from water quality sampling during June and August, 2012-3.

Date/Time	Turbidity (NTU)	Parrot DS Ft³/sec	D.O. mg/L	Temp (C)	pH	Cond
6/8/12 10:38		0.756	9.48	6.16	5.22	37.54
8/23/12 10:40		0.01	7.53	10.71	5.35	70.05
6/4/13 15:00	18	0.037	8.37	8.11	5.73	42.96
8/21/13 12:29	2.72	0.01	6.41	12.04	7.47	75.98

7.1.2 Appendix B: Detailed Continuous Temperature Monitoring Results

Each figure represents the average weekly maximum/minimum (red/blue) temperature profiles. Green lines represent an estimated threshold temperature for spawning (14° C). Purple lines represent an estimated threshold temperature for rearing (20° C).

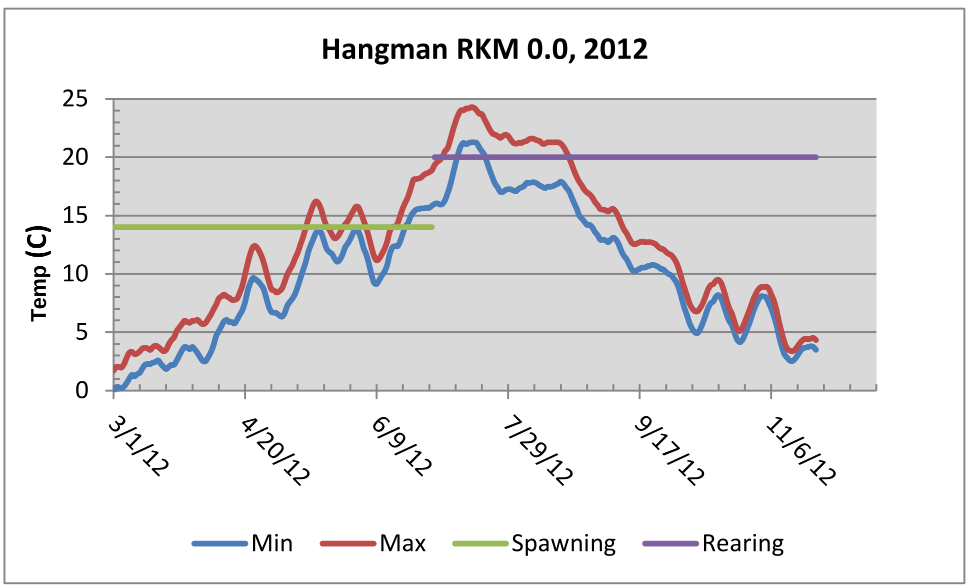


Figure B-1: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2010 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

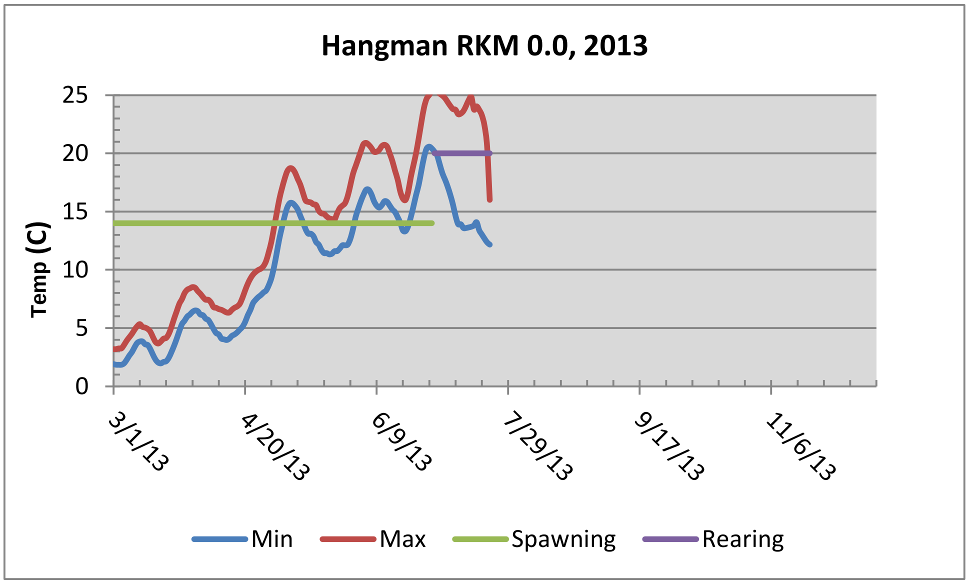


Figure B-2: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Stateline in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

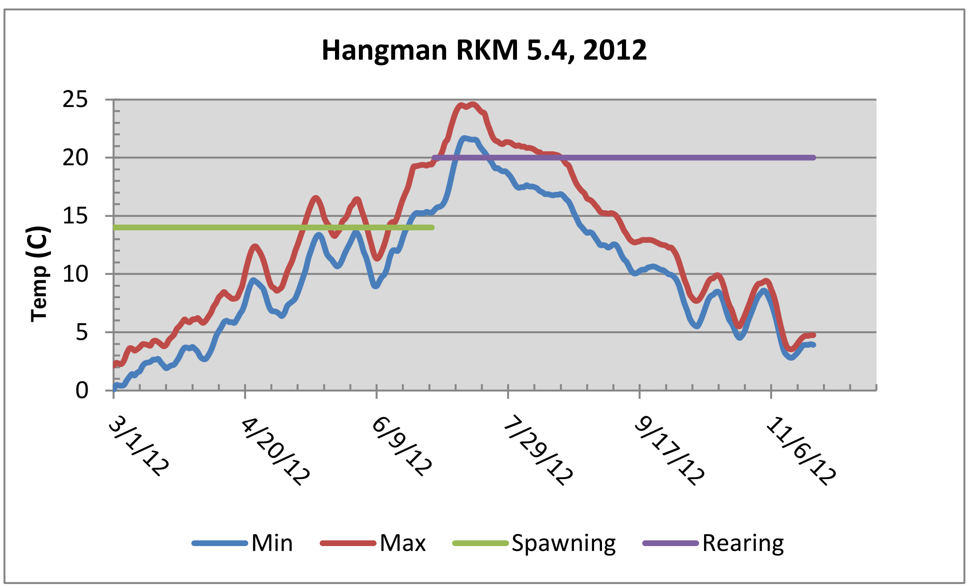


Figure B-3: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

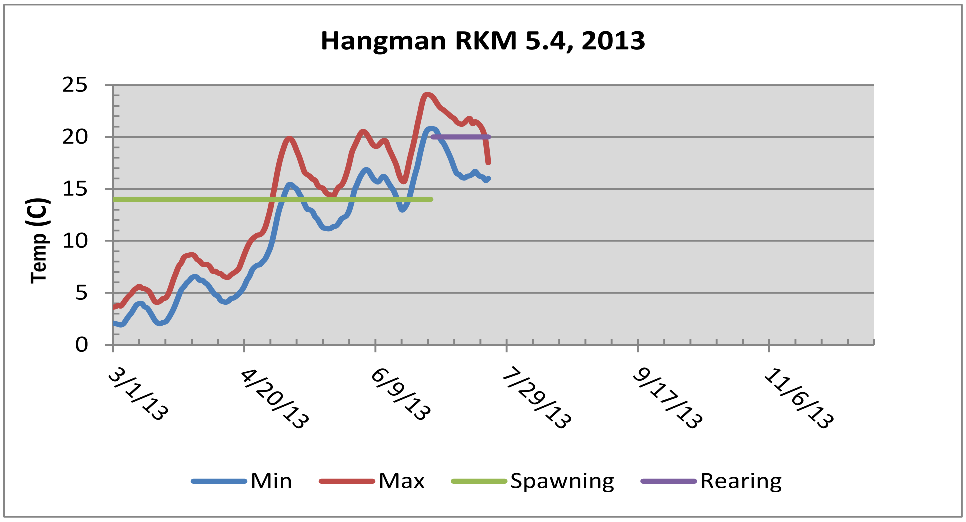


Figure B-4: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Liberty Butte in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

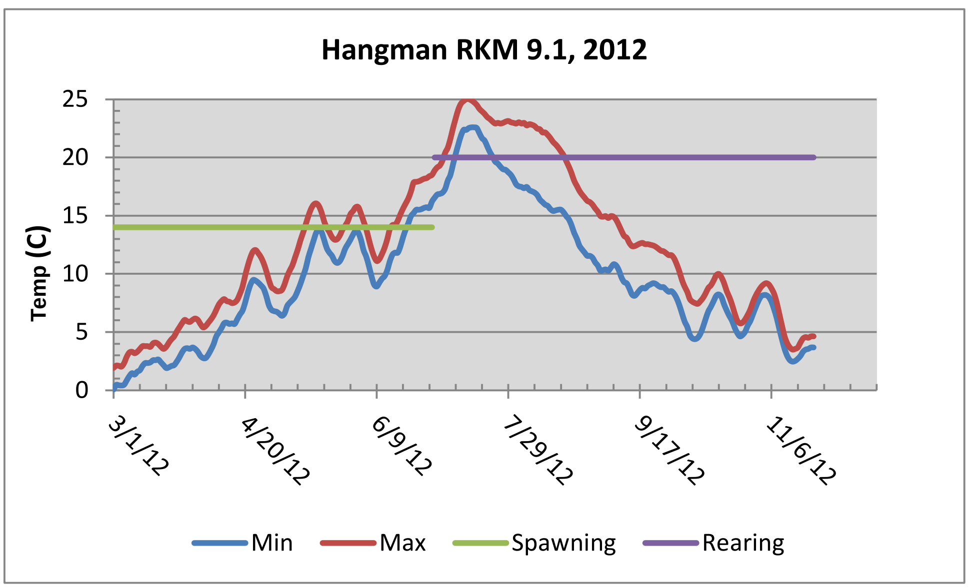


Figure B-5: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

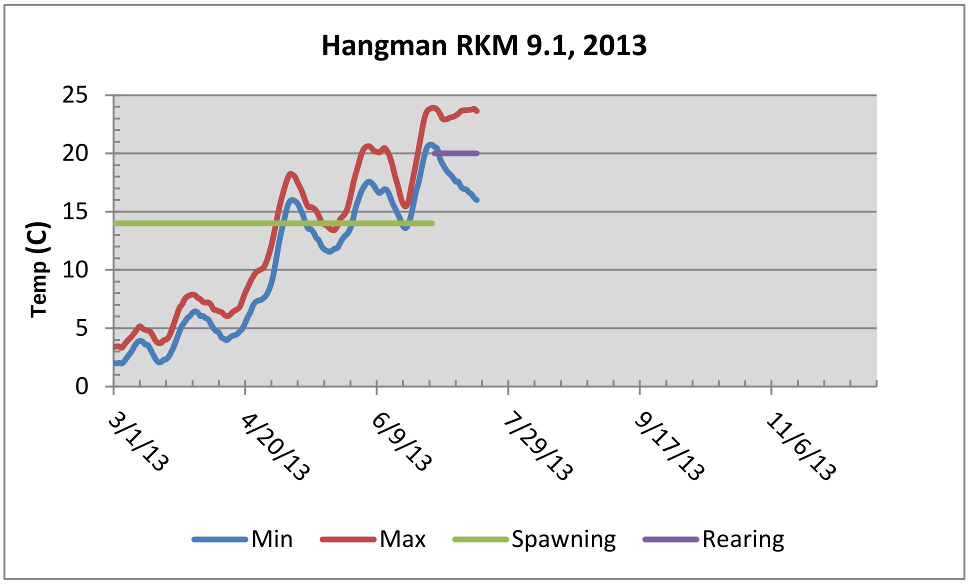


Figure B-6: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Tribal Farm in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

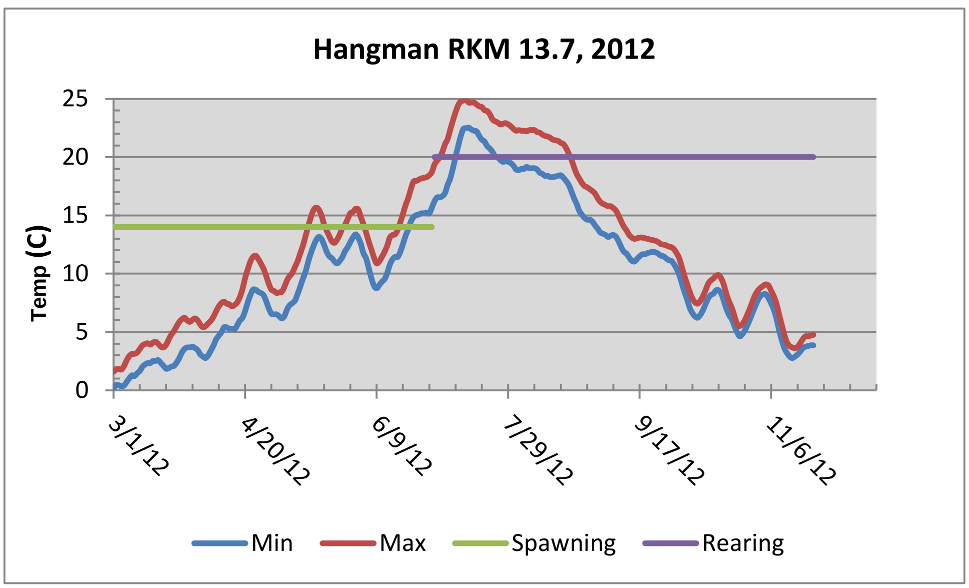


Figure B-7: Average weekly maximum/minimum temperature profiles of Hangman Cr. at HWY 95 in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

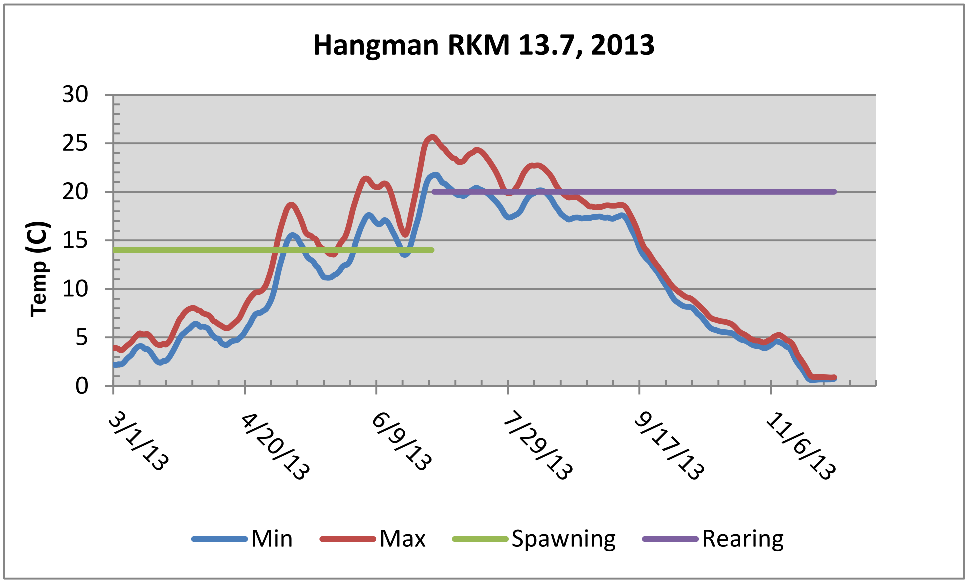


Figure B-8: Average weekly maximum/minimum temperature profiles of Hangman Cr. at HWY 95 in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

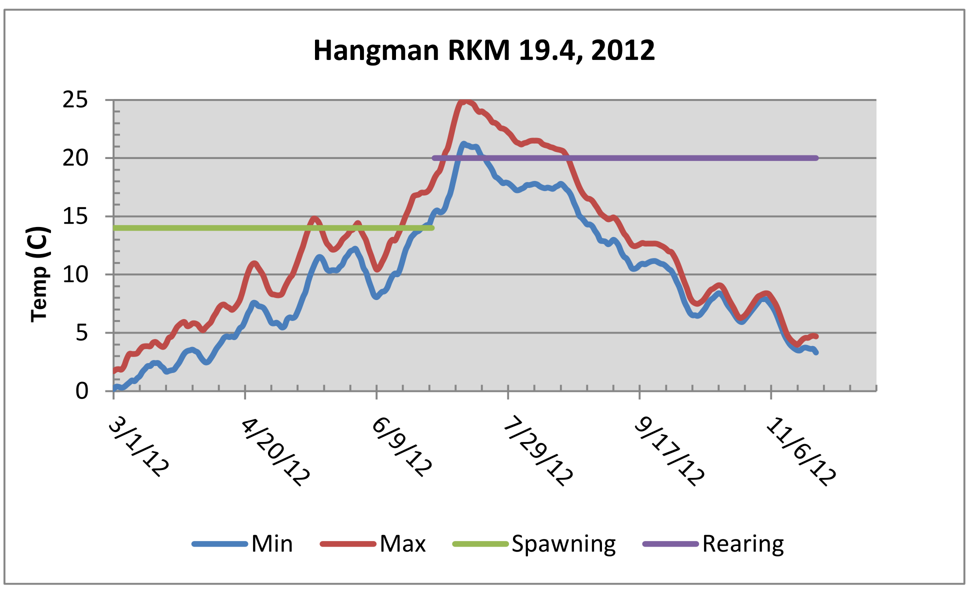


Figure B-9: Average weekly maximum/minimum temperature profiles of Hangman Cr. at RKm 19.4 in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

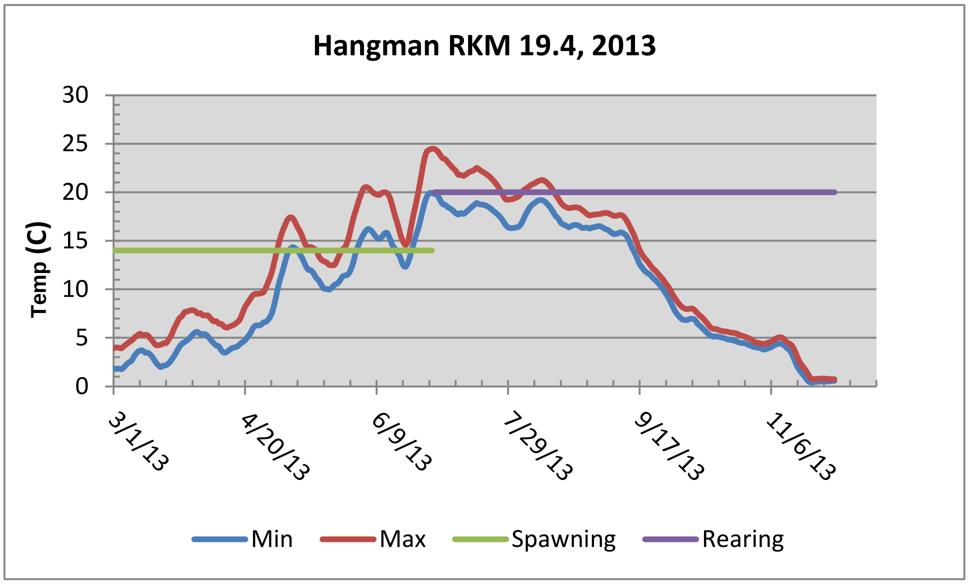


Figure B-10: Average weekly maximum/minimum temperature profiles of Hangman Cr. at RKm 19.4 in 2013marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

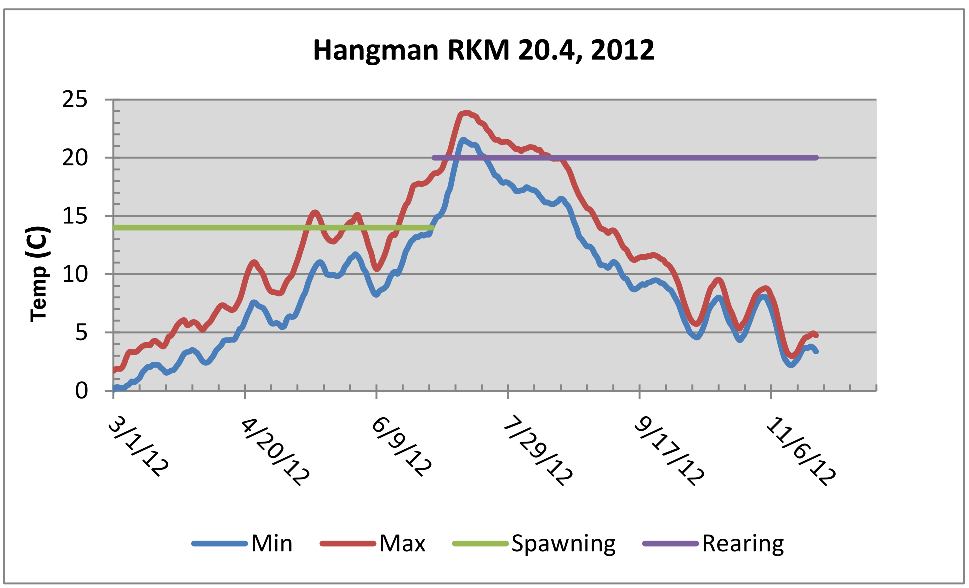


Figure B-11: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

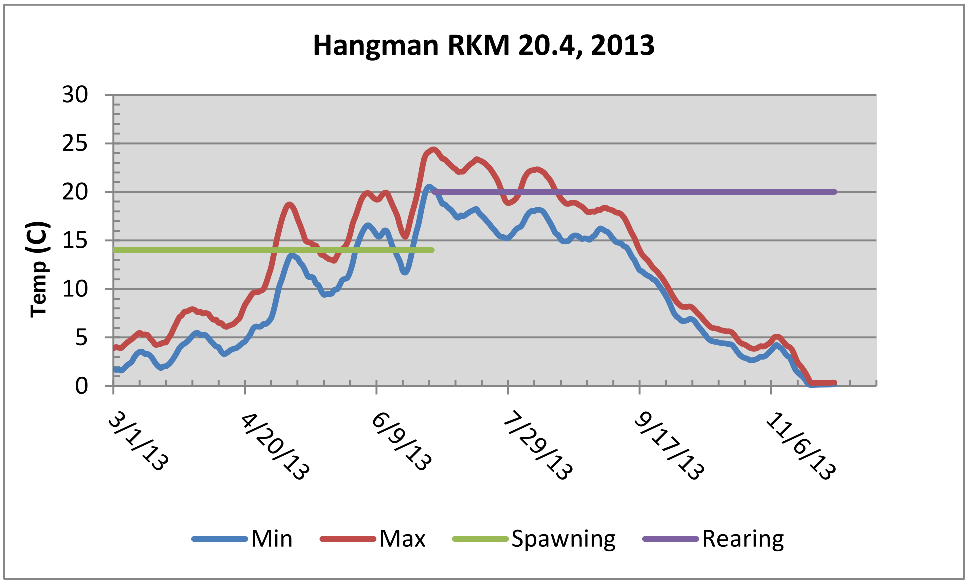


Figure B-12: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Nehchen Hump in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

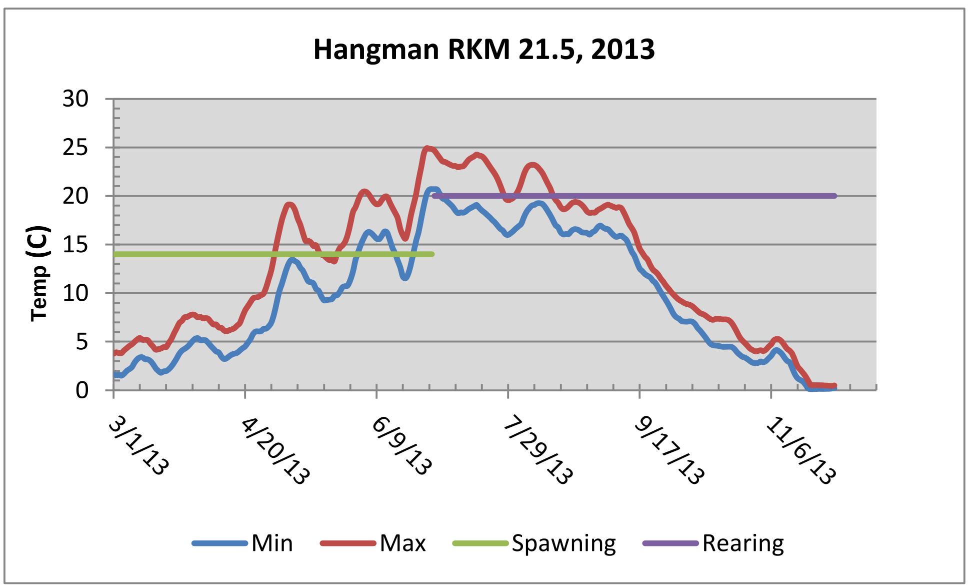


Figure B-13: Average weekly maximum/minimum temperature profiles of Hangman Cr. at RKm 21.5 in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

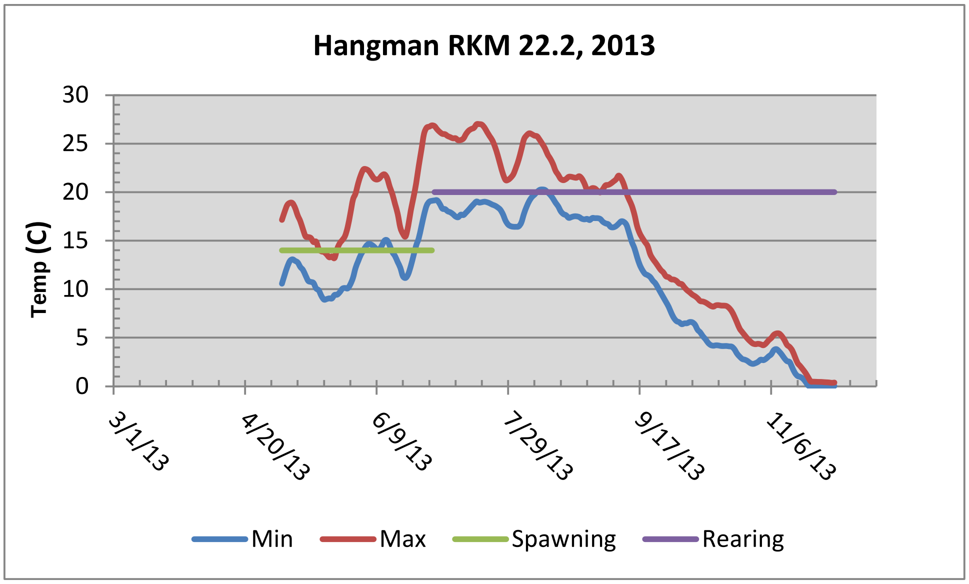


Figure B-14: Average weekly maximum/minimum temperature profiles of Hangman Cr. at RKm22.2 in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

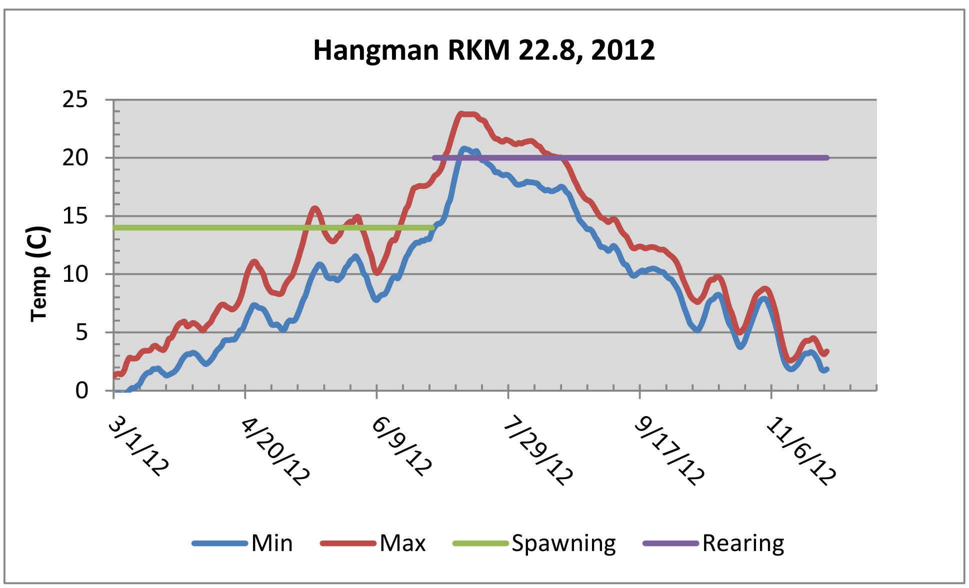


Figure B-15: Average weekly maximum/minimum temperature profiles of Hangman Cr. at RKm22.8 in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

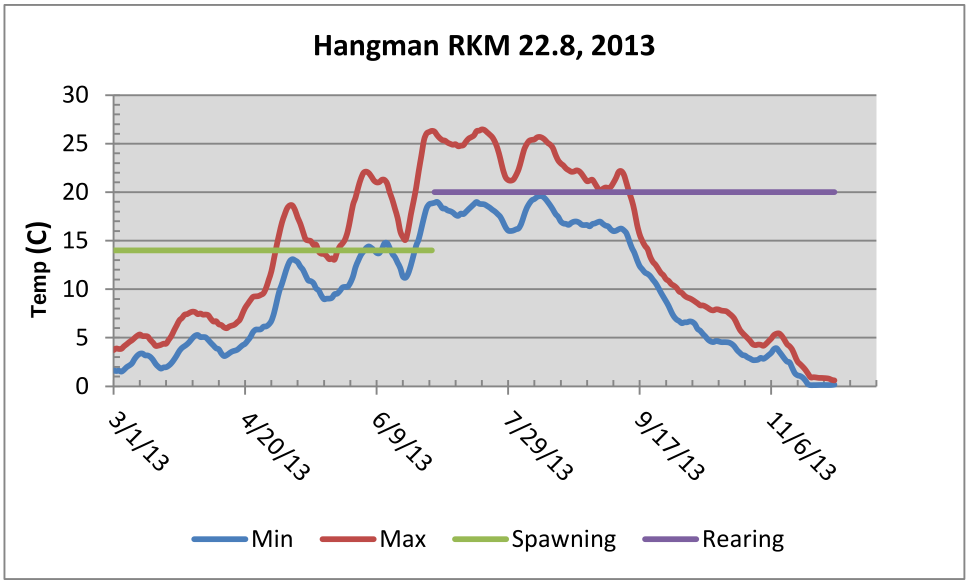


Figure B-16: Average weekly maximum/minimum temperature profiles of Hangman Cr. at RKm22.8 in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

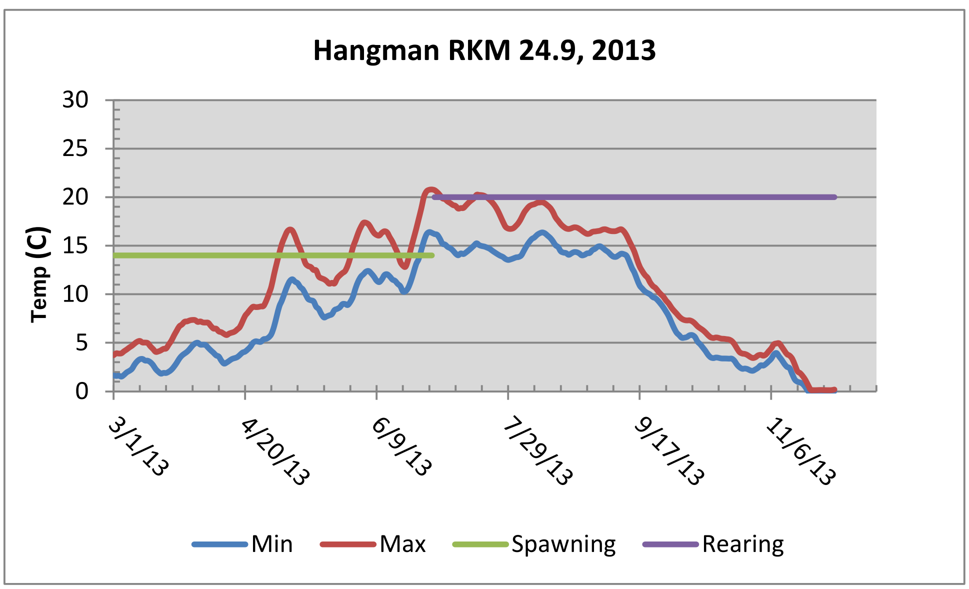


Figure B-17: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Sanders in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

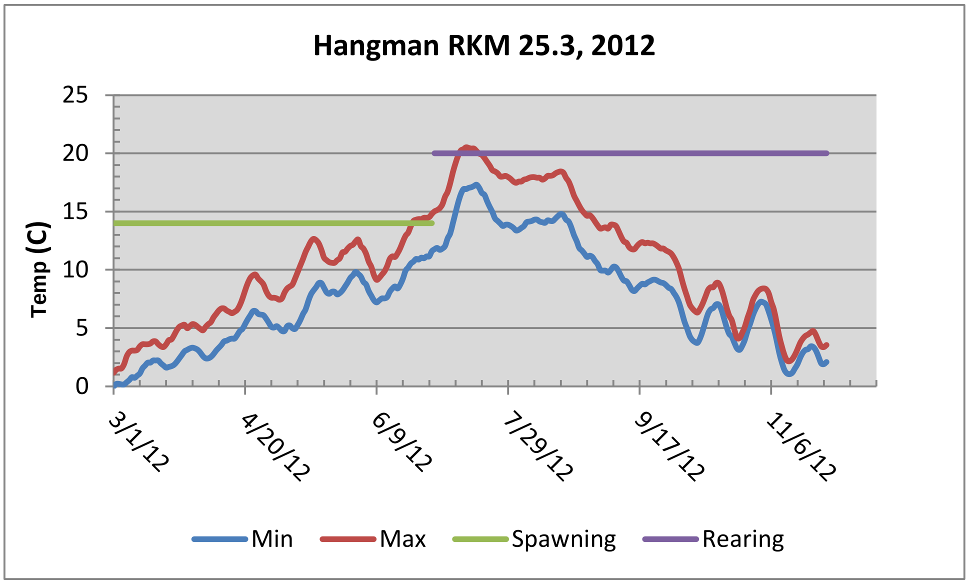


Figure B-18: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford property in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

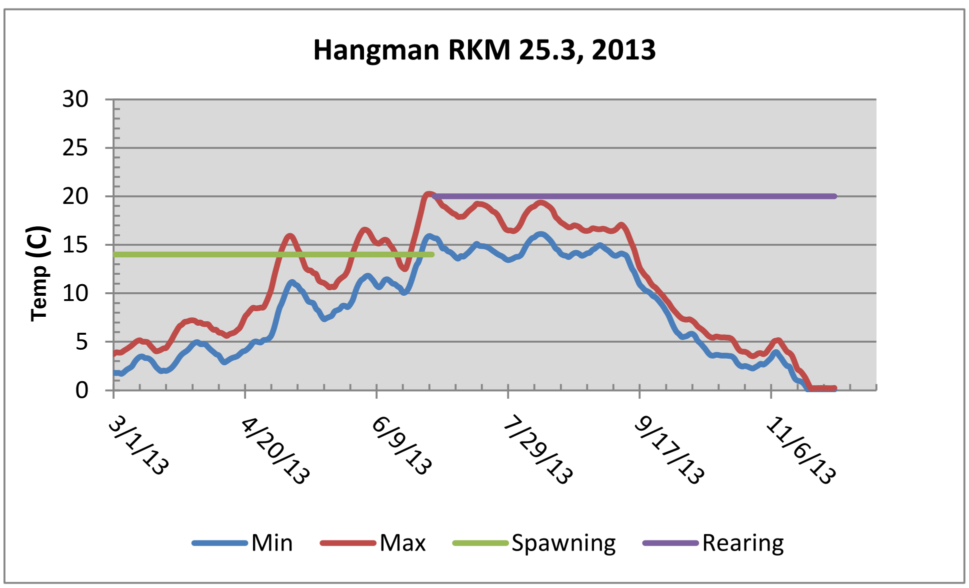


Figure B-19: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Crawford property in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

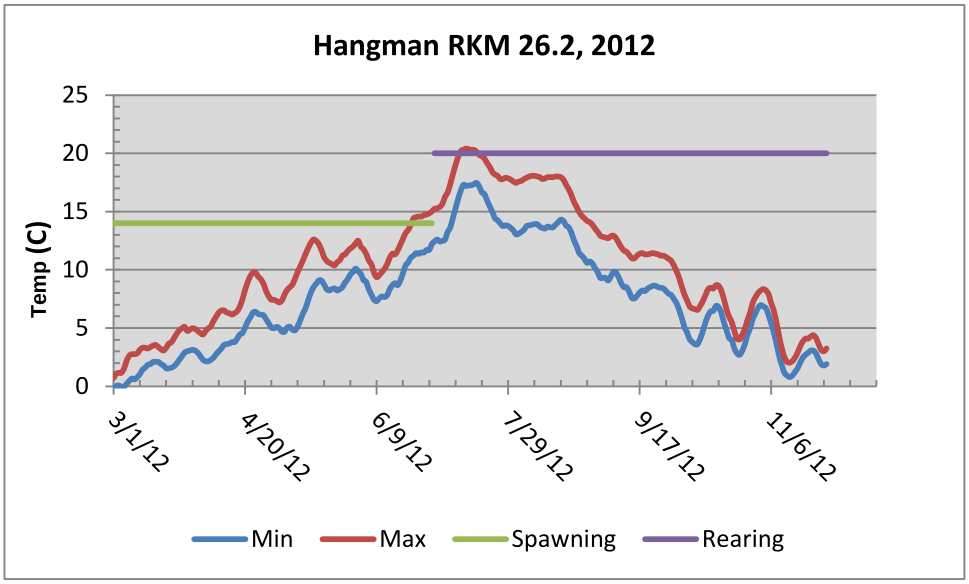


Figure B-20: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Cordell property in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

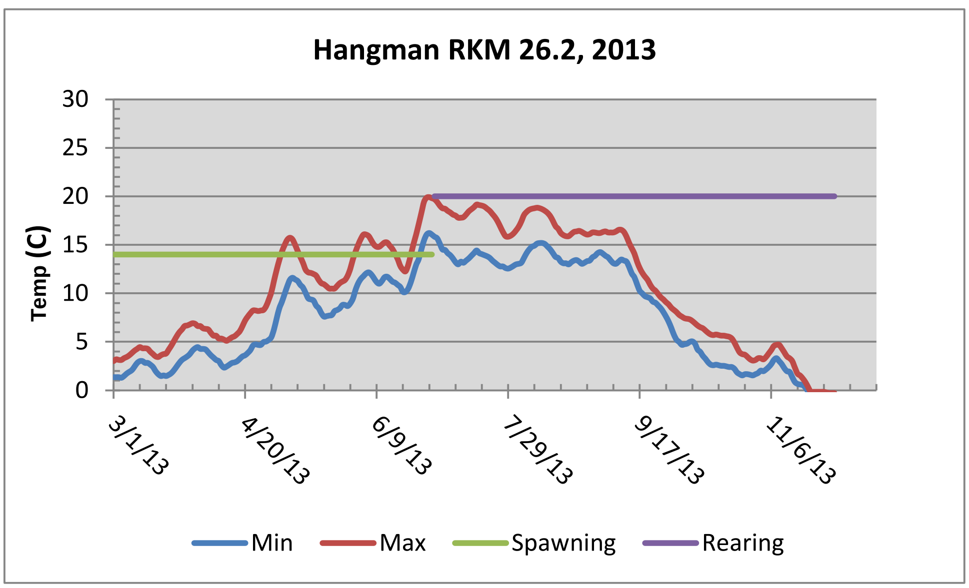


Figure B-21: Average weekly maximum/minimum temperature profiles of Hangman Cr. - Cordell property in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

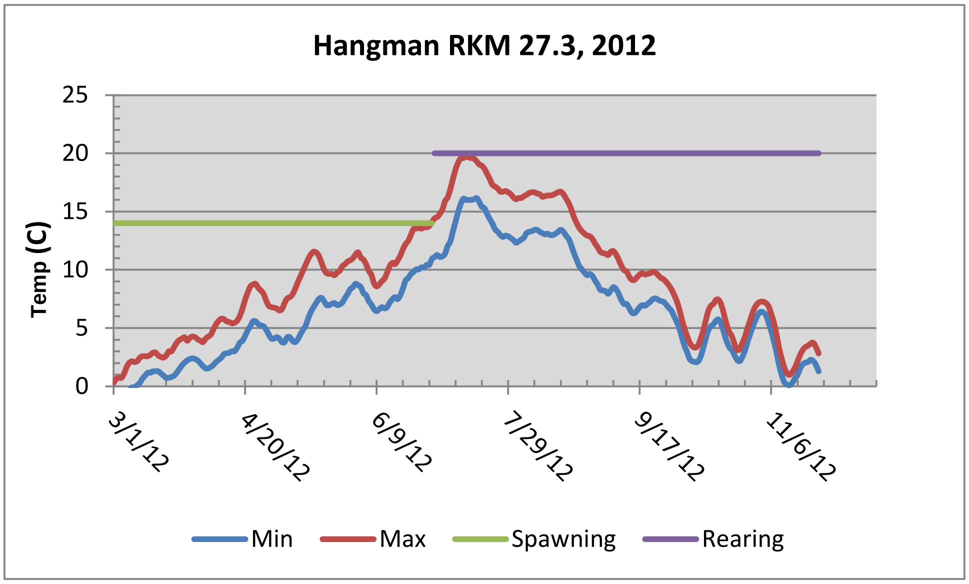


Figure B-22: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

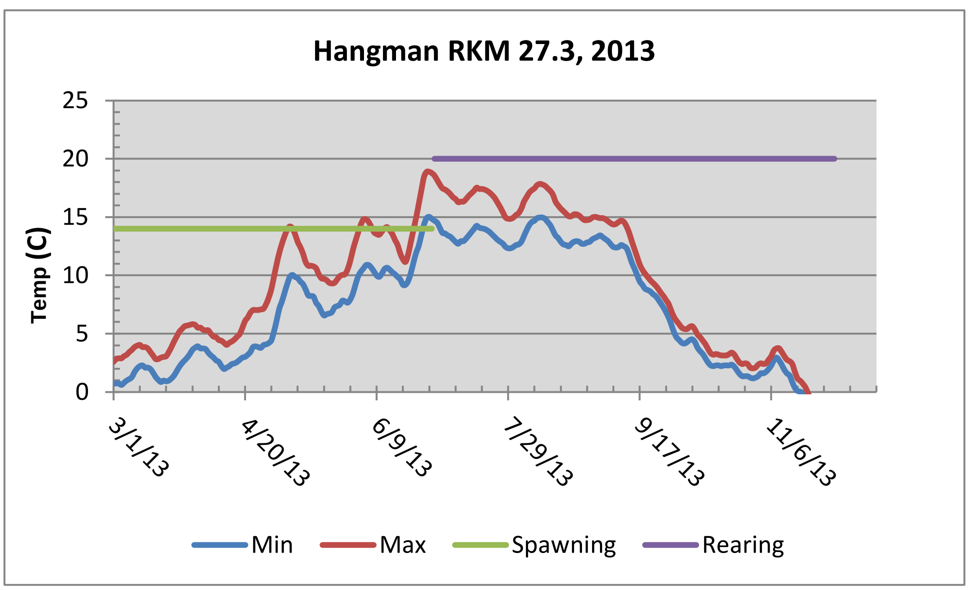


Figure B-23: Average weekly maximum/minimum temperature profiles of Hangman Cr. at Bennett in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

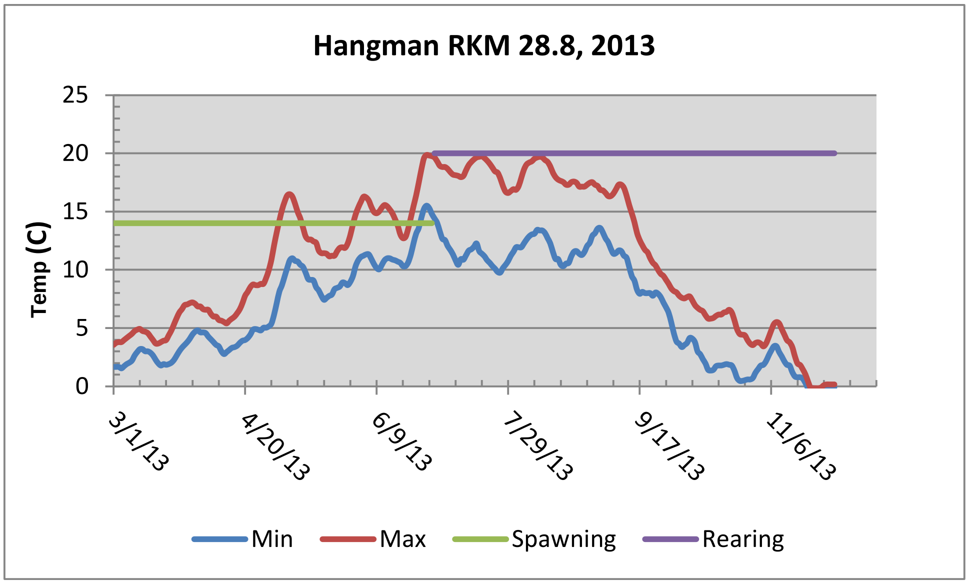


Figure B-24: Average weekly maximum/minimum temperature profiles of Hangman Cr. at SF Rd. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

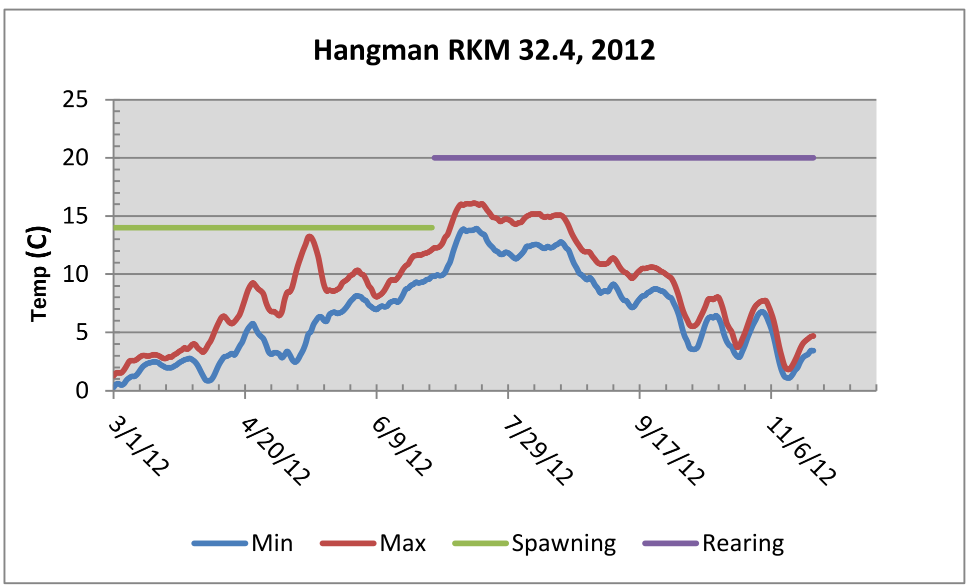


Figure B-25: Average weekly maximum/minimum temperature profiles of Hangman Cr. Forest in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

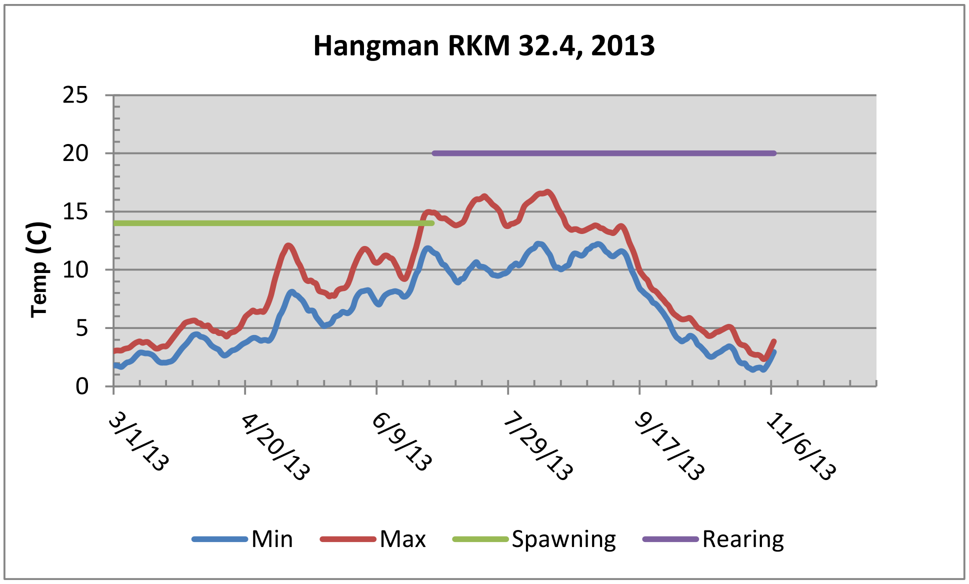


Figure B-26: Average weekly maximum/minimum temperature profiles of Hangman Cr. Forest in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

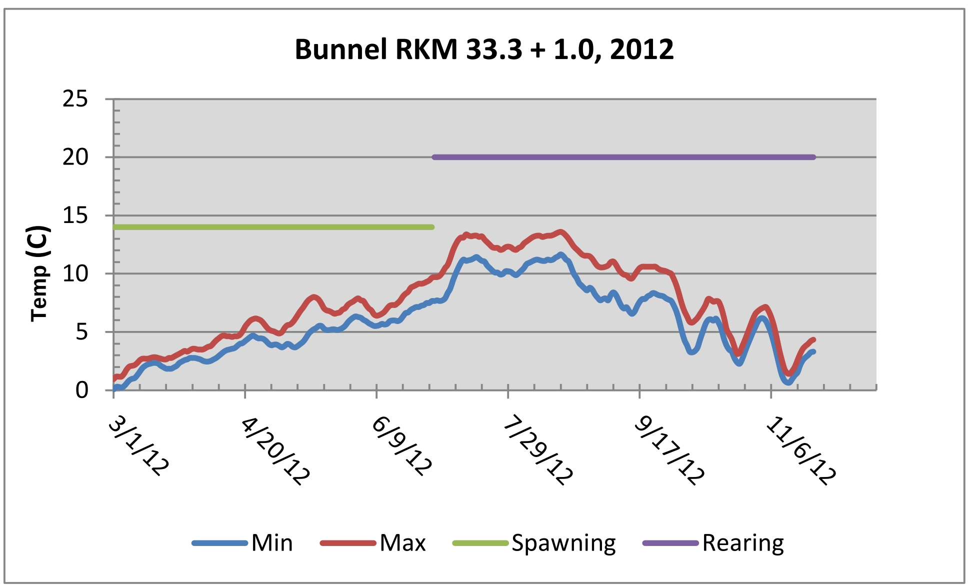


Figure B-27: Average weekly maximum/minimum temperature profiles of Bunnel Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

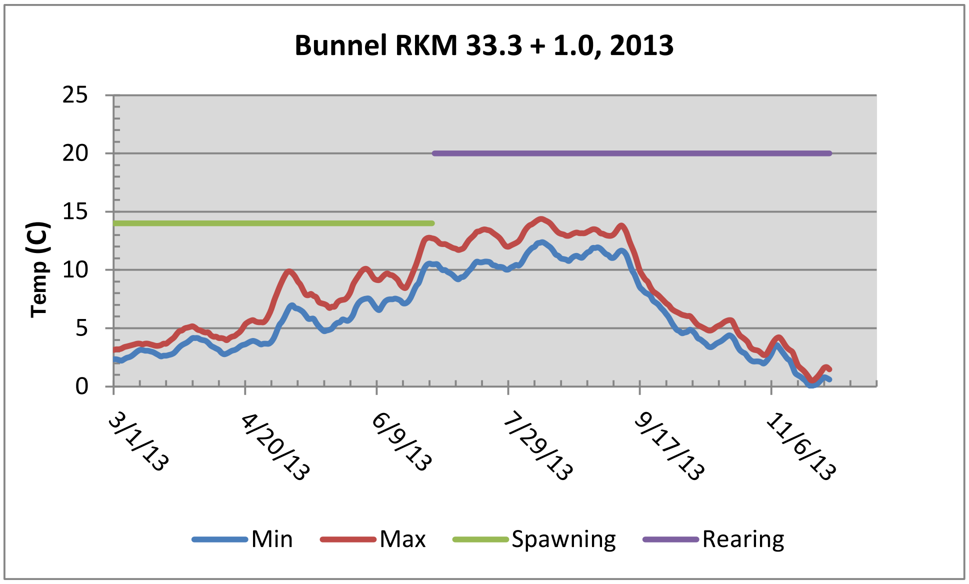


Figure B-28: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

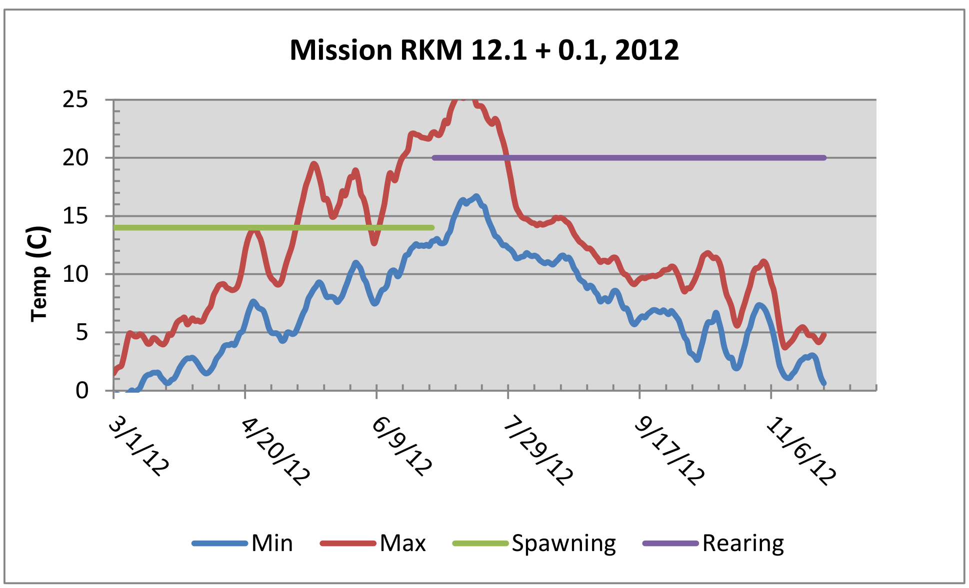


Figure B-29: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

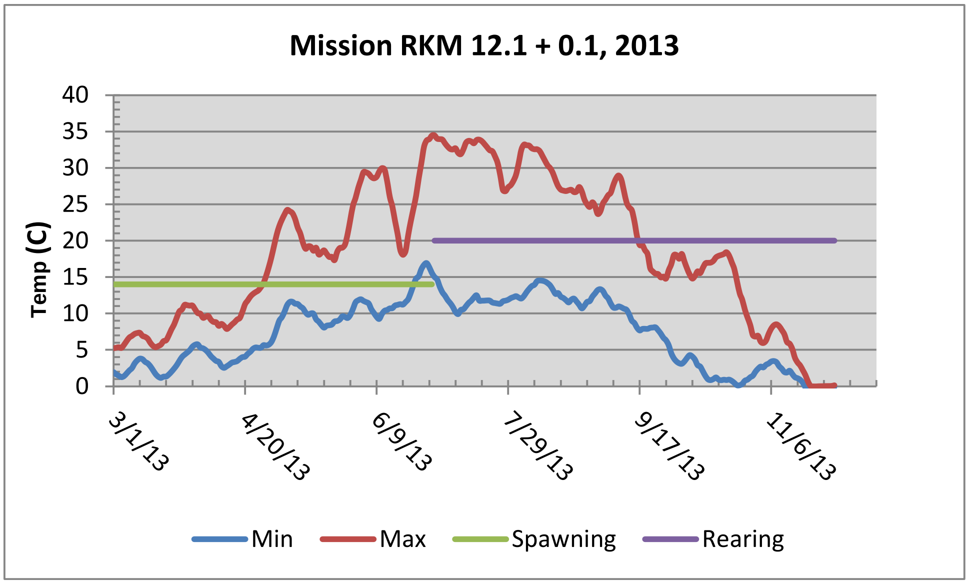


Figure B-30: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

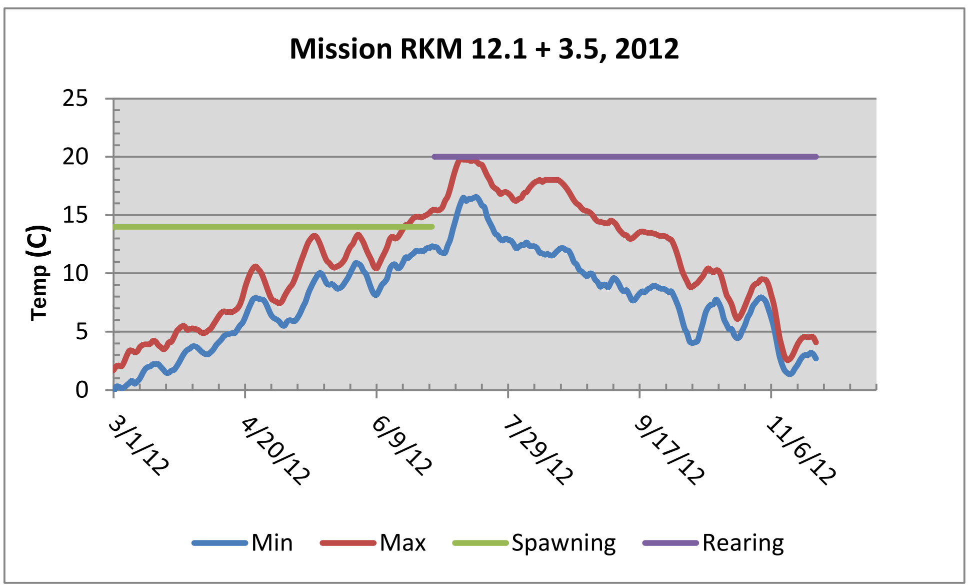


Figure B-31: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

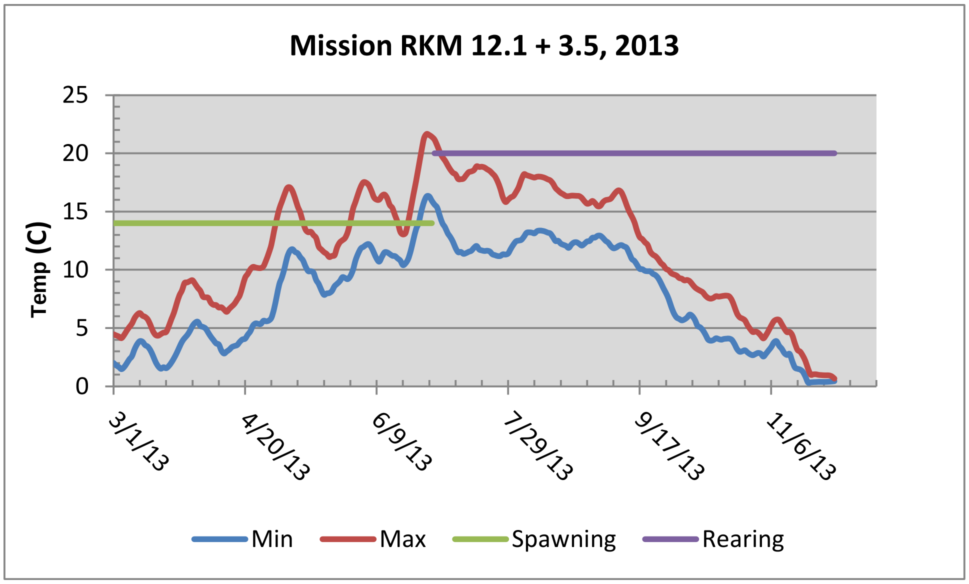


Figure B-32: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

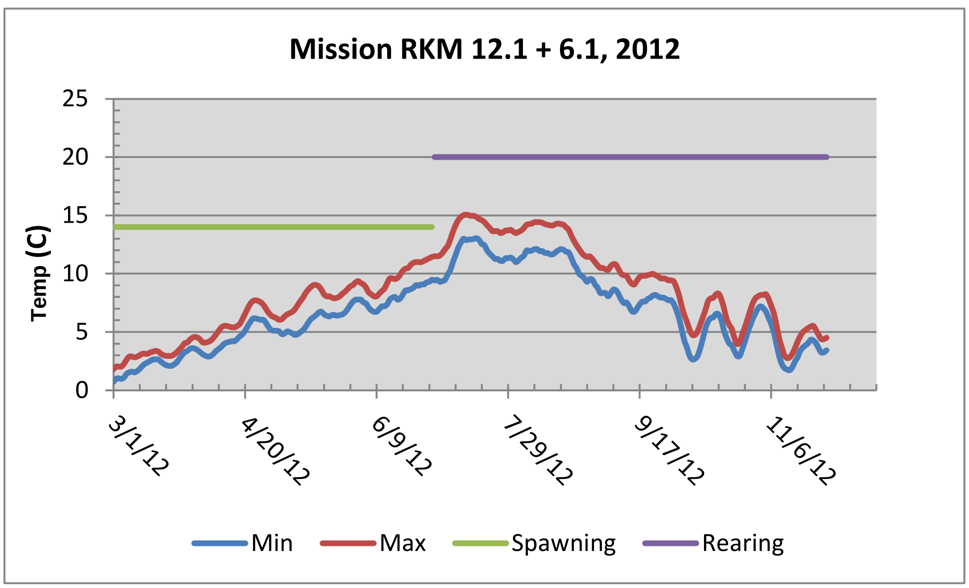


Figure B-33: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

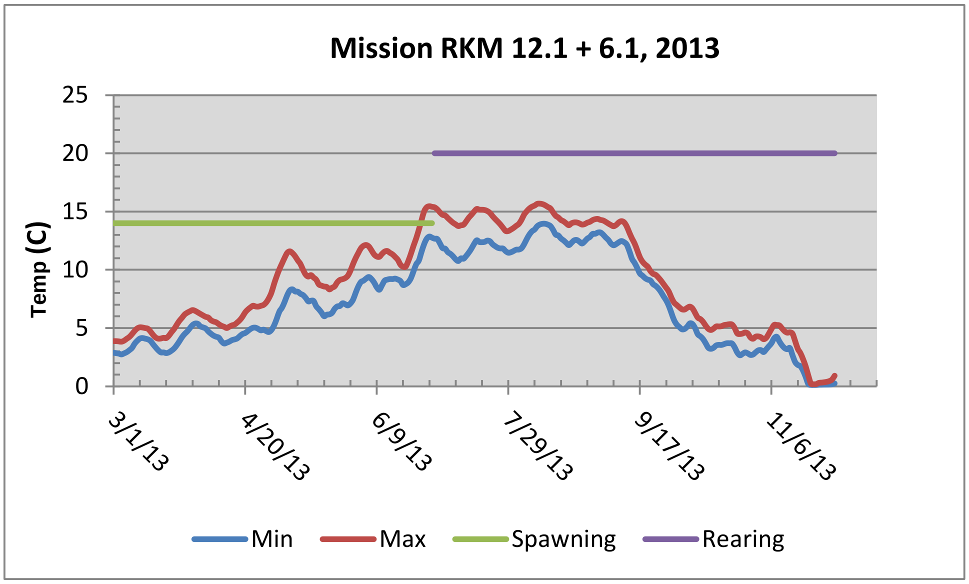


Figure B-34: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

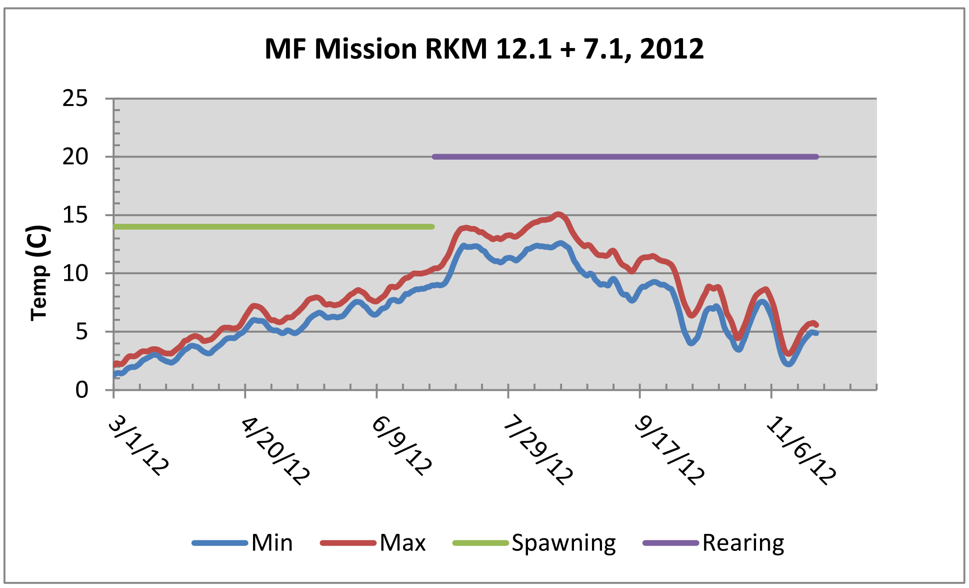


Figure B-35: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

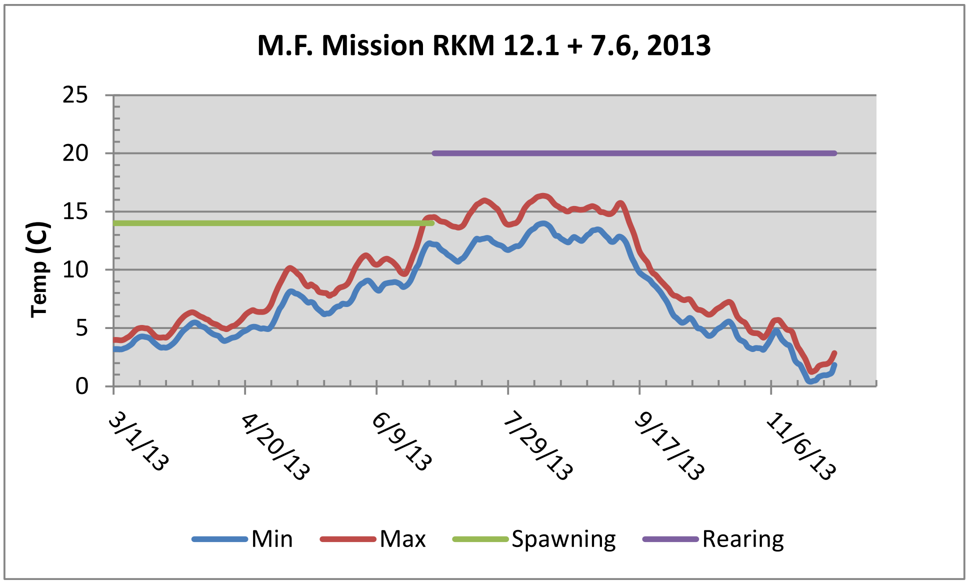


Figure B-36: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

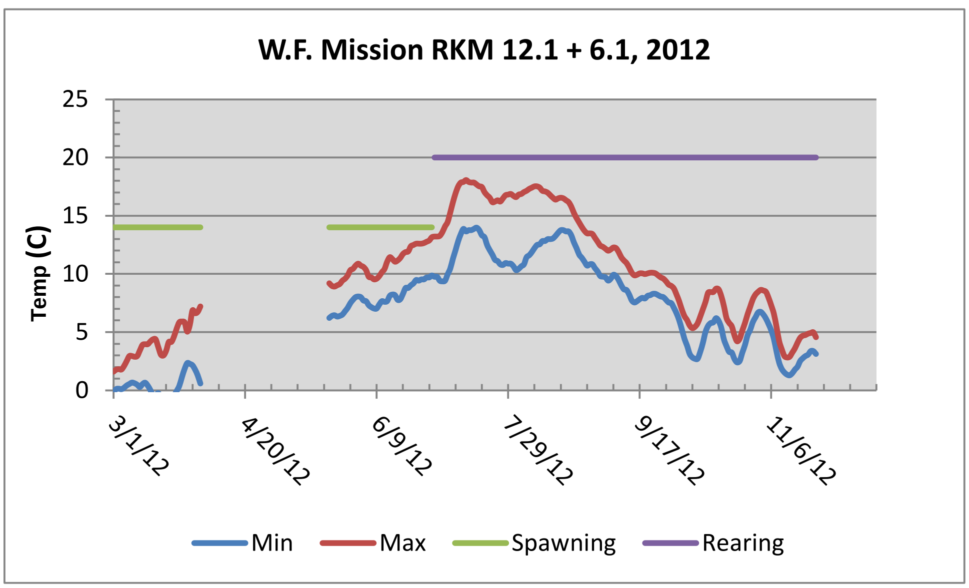


Figure B-37: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

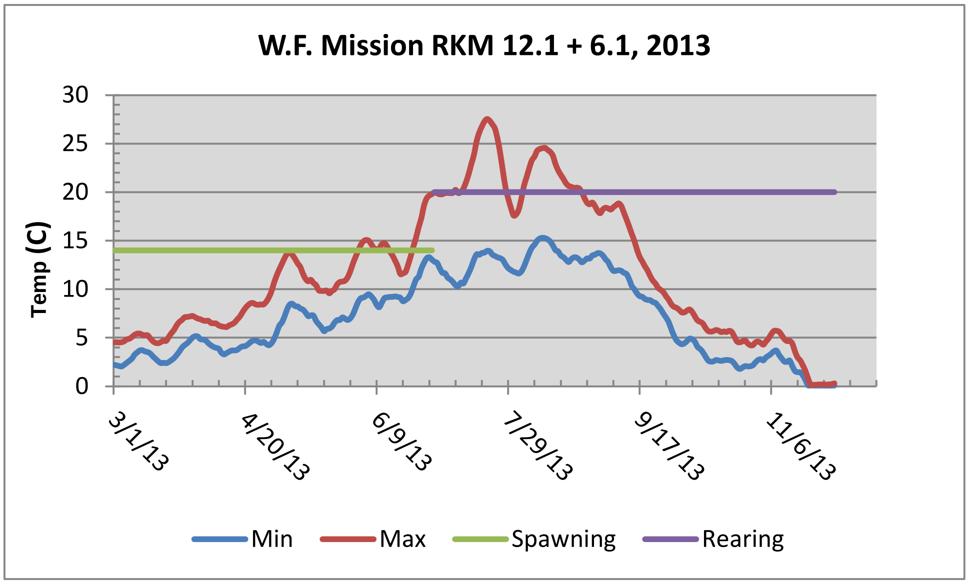


Figure B-38: Average weekly maximum/minimum temperature profiles of Mission Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

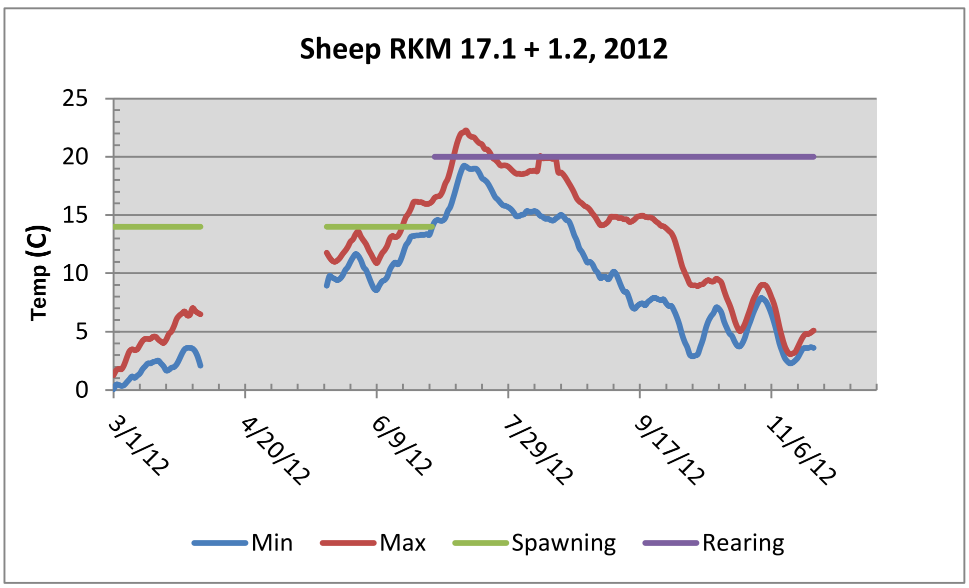


Figure B-39: Average weekly maximum/minimum temperature profiles of Sheep Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

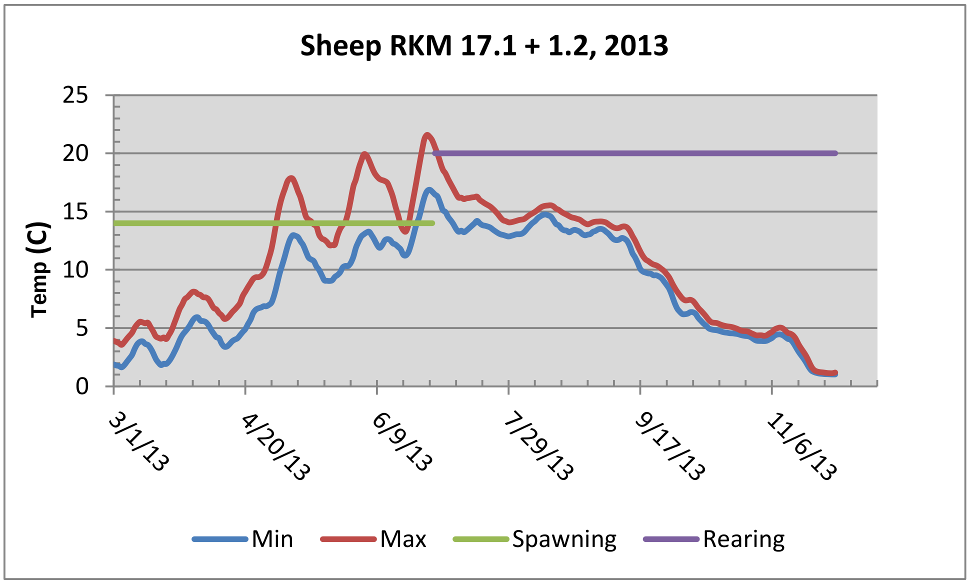


Figure B-40: Average weekly maximum/minimum temperature profiles of Sheep Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

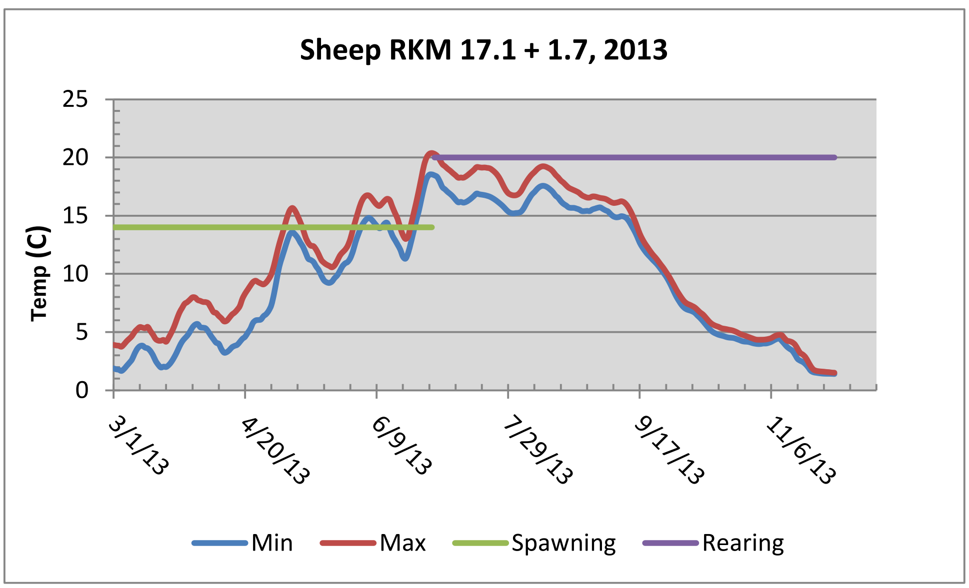


Figure B-41: Average weekly maximum/minimum temperature profiles of Sheep Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

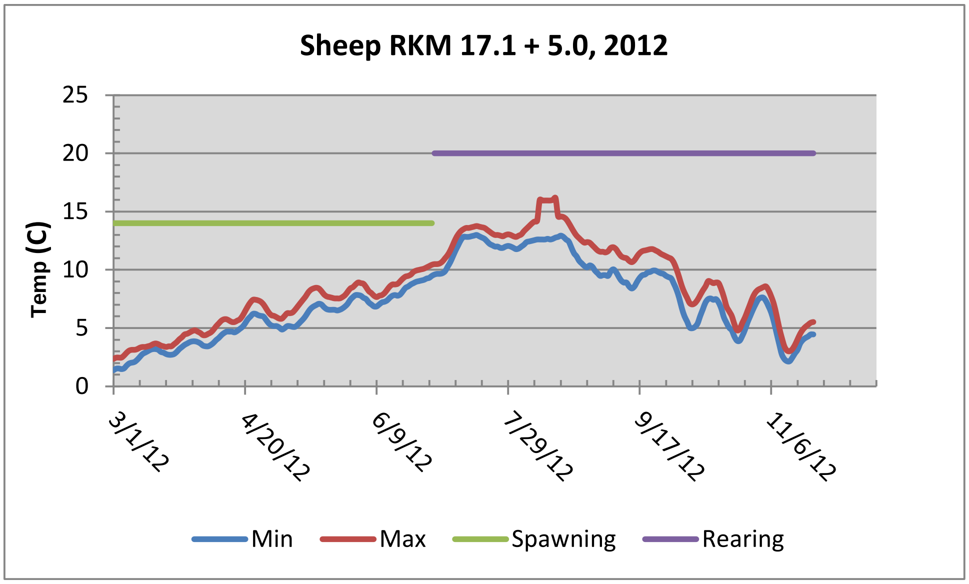


Figure B-42: Average weekly maximum/minimum temperature profiles of Sheep Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

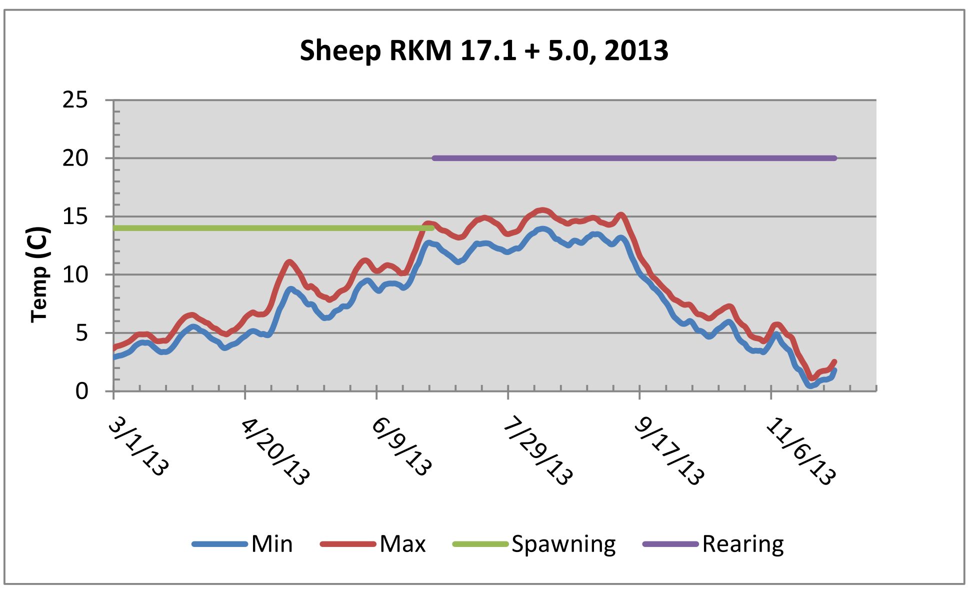


Figure B-43: Average weekly maximum/minimum temperature profiles of Sheep Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

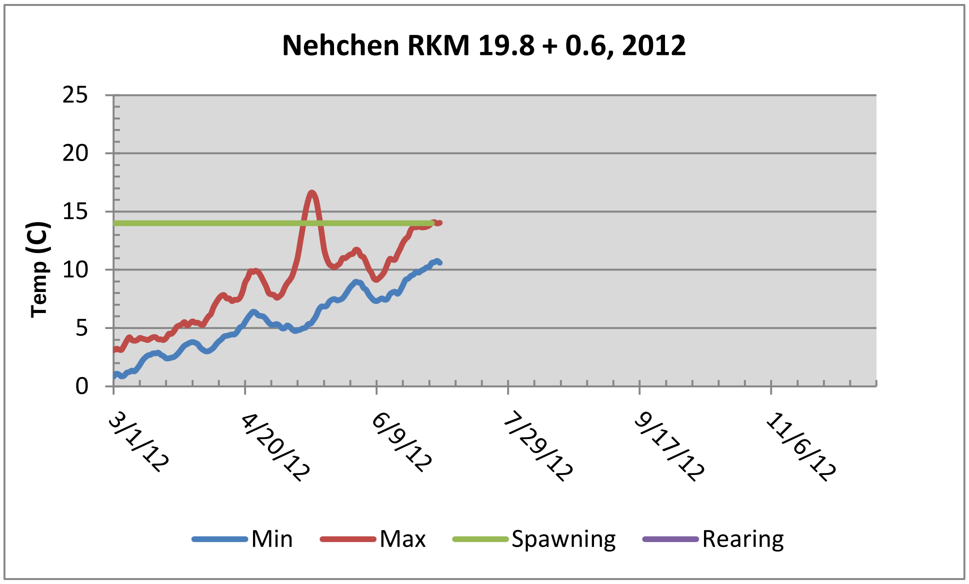


Figure B-44: Average weekly maximum/minimum temperature profiles of Nehchen Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

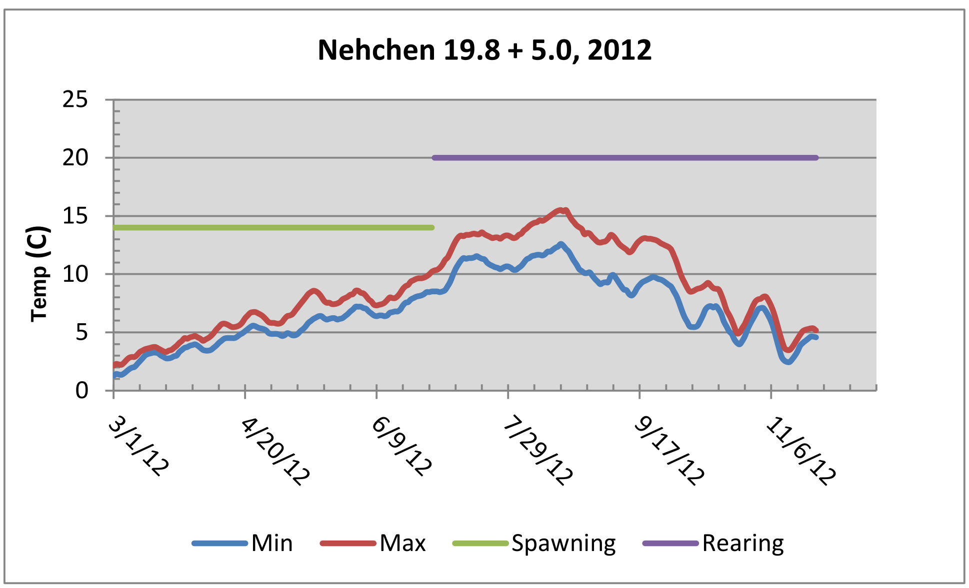


Figure B-45: Average weekly maximum/minimum temperature profiles of Nehchen Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

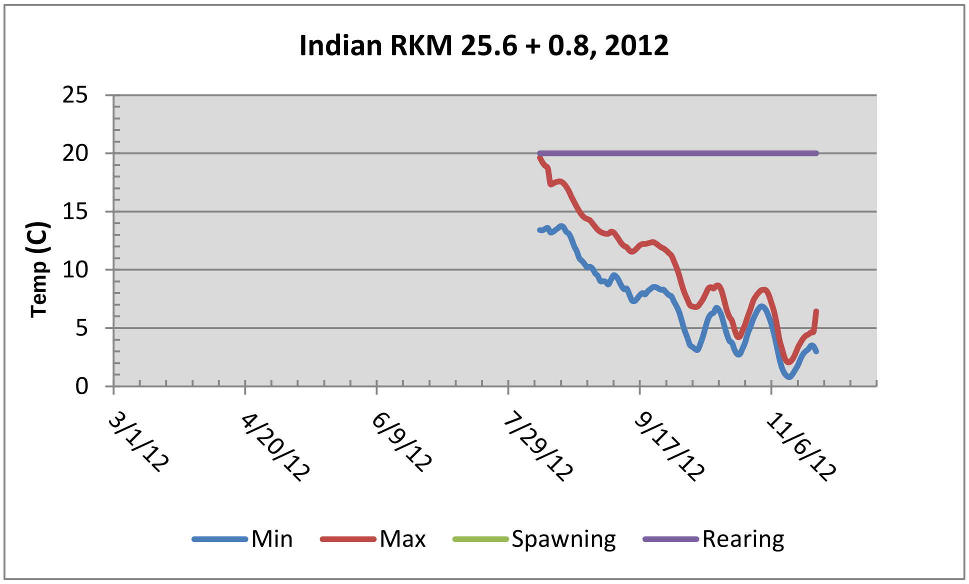


Figure B-46: Average weekly maximum/minimum temperature profiles of Indian Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

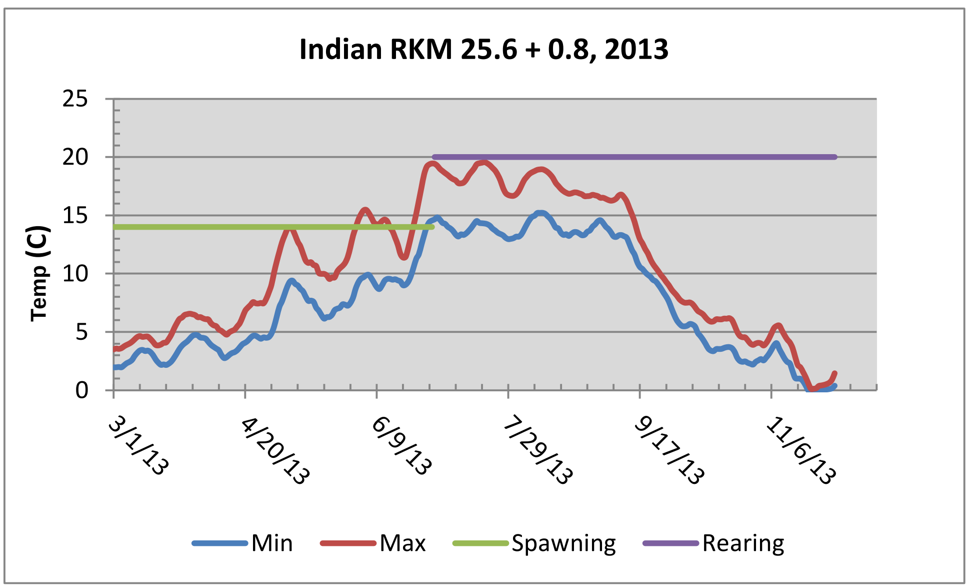


Figure B-47: Average weekly maximum/minimum temperature profiles of Indian Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

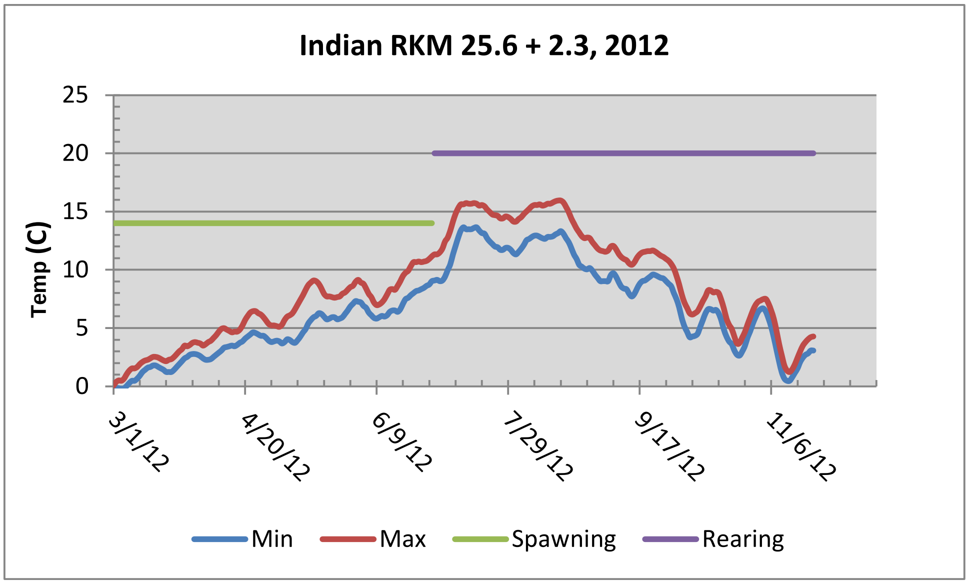


Figure B-48: Average weekly maximum/minimum temperature profiles of Indian Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

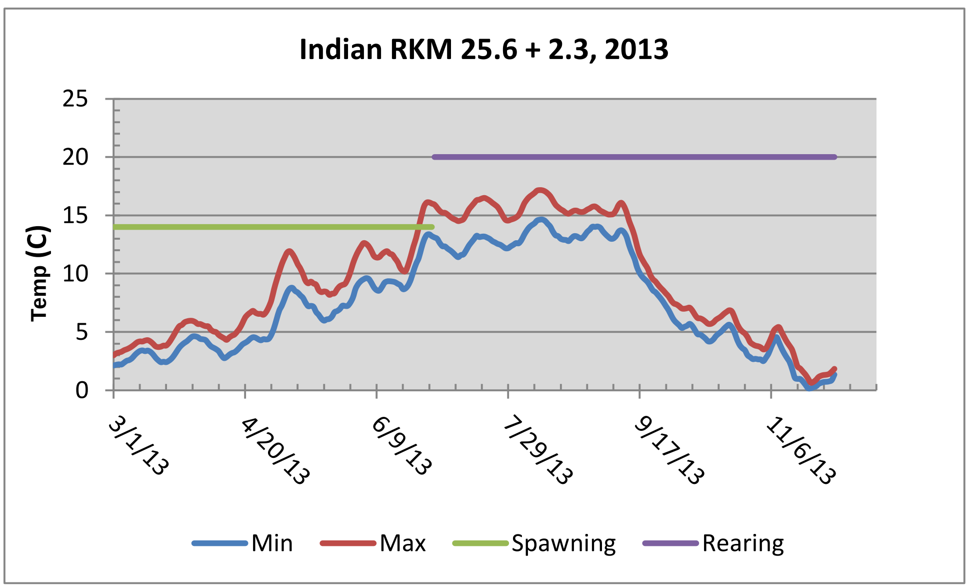


Figure B-49: Average weekly maximum/minimum temperature profiles of Indian Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

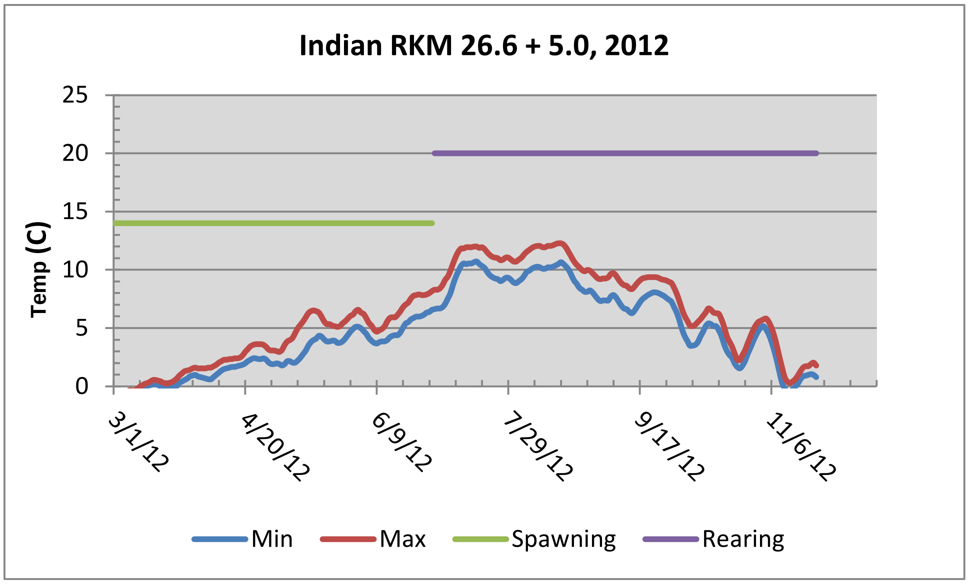


Figure B-50: Average weekly maximum/minimum temperature profiles of Indian Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

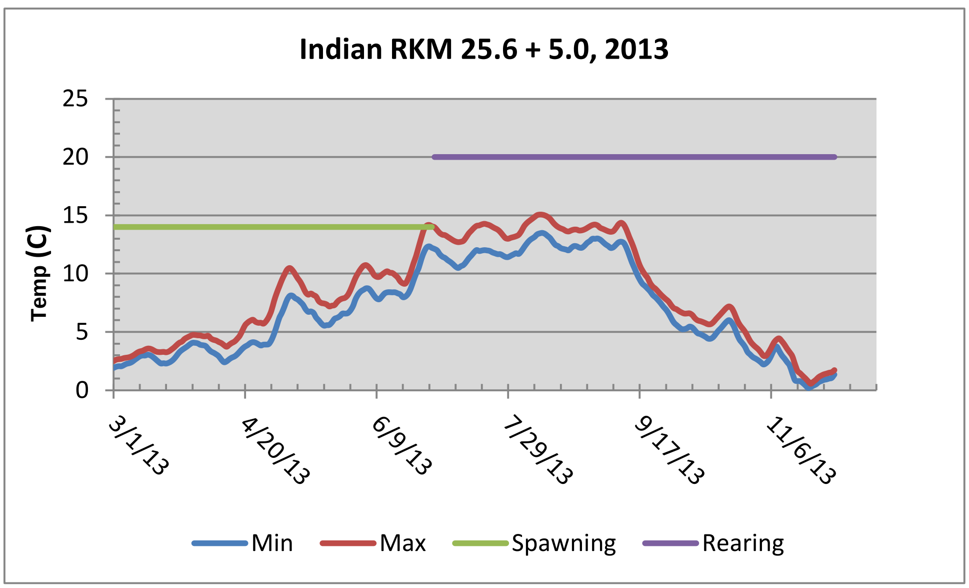


Figure B-51: Average weekly maximum/minimum temperature profiles of Indian Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

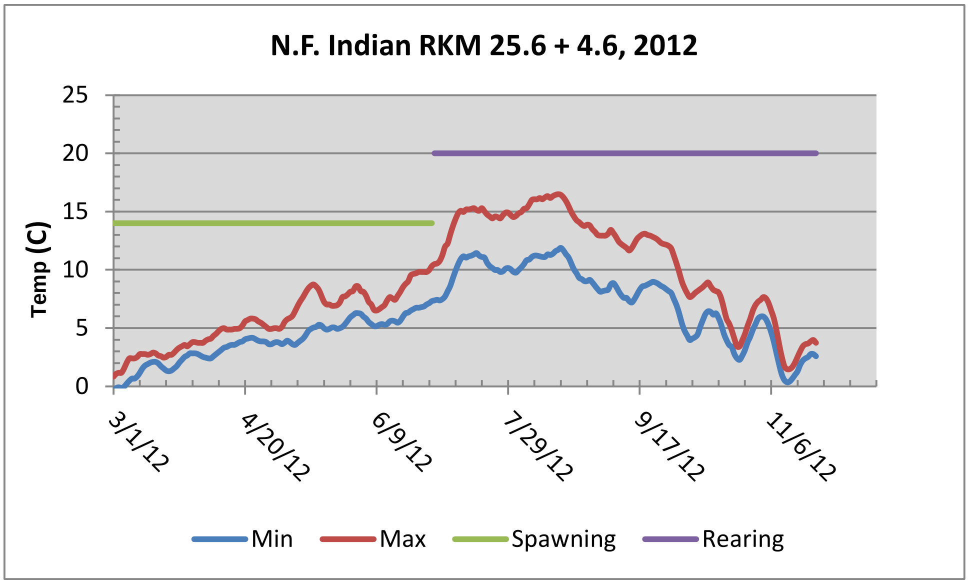


Figure B-52: Average weekly maximum/minimum temperature profiles of N.F. Indian Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

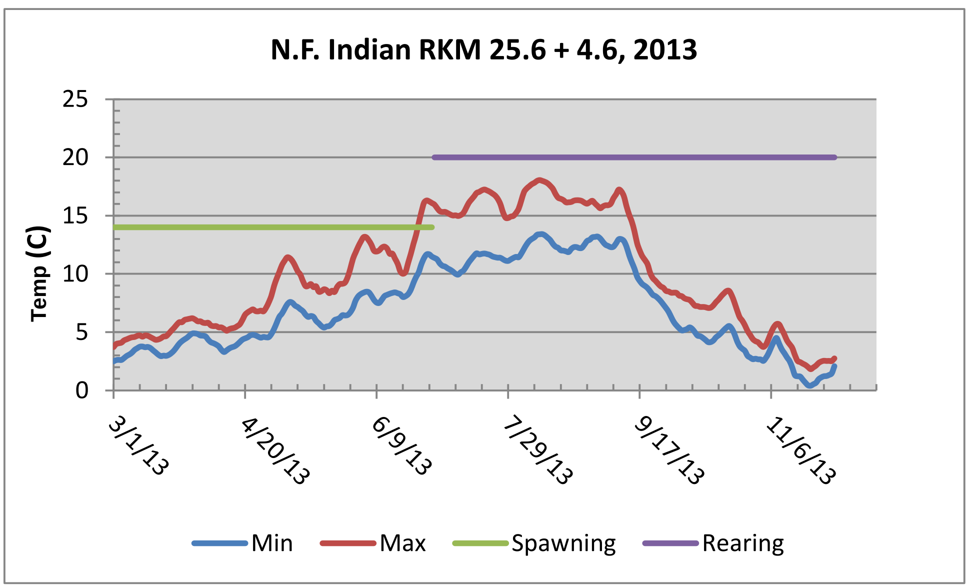


Figure B-53: Average weekly maximum/minimum temperature profiles of N.F. Indian Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

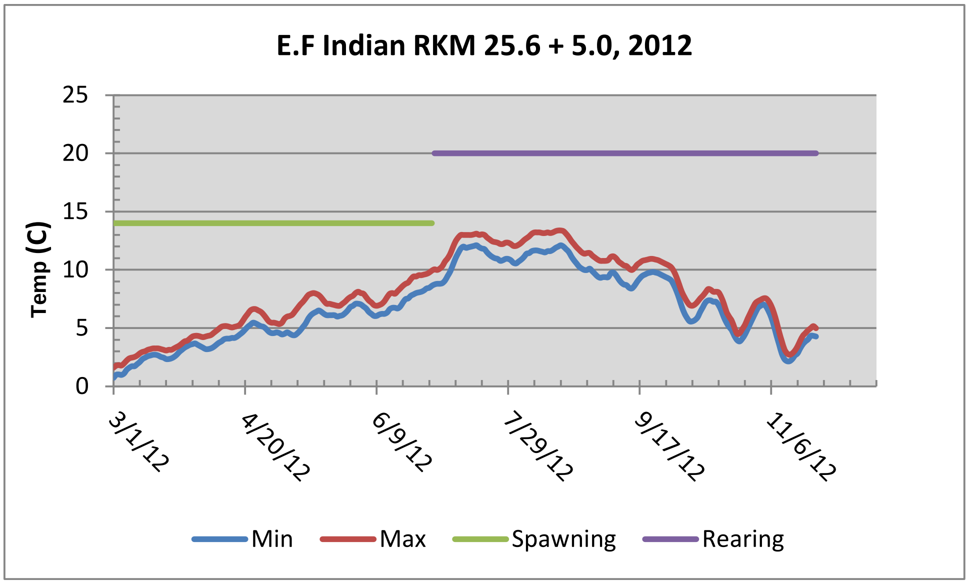


Figure B-54: Average weekly maximum/minimum temperature profiles of E.F. Indian Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

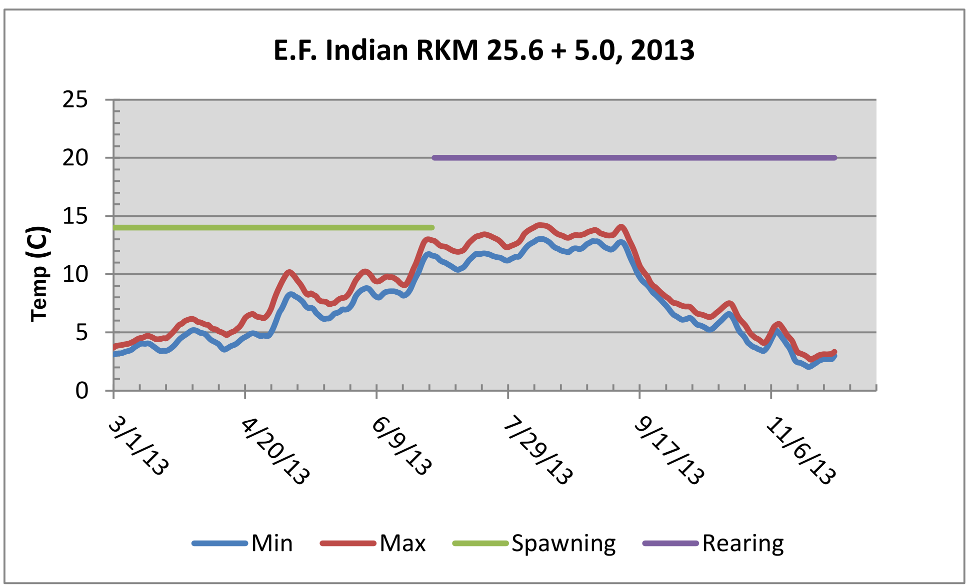


Figure B-55: Average weekly maximum/minimum temperature profiles of E.F. Indian Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

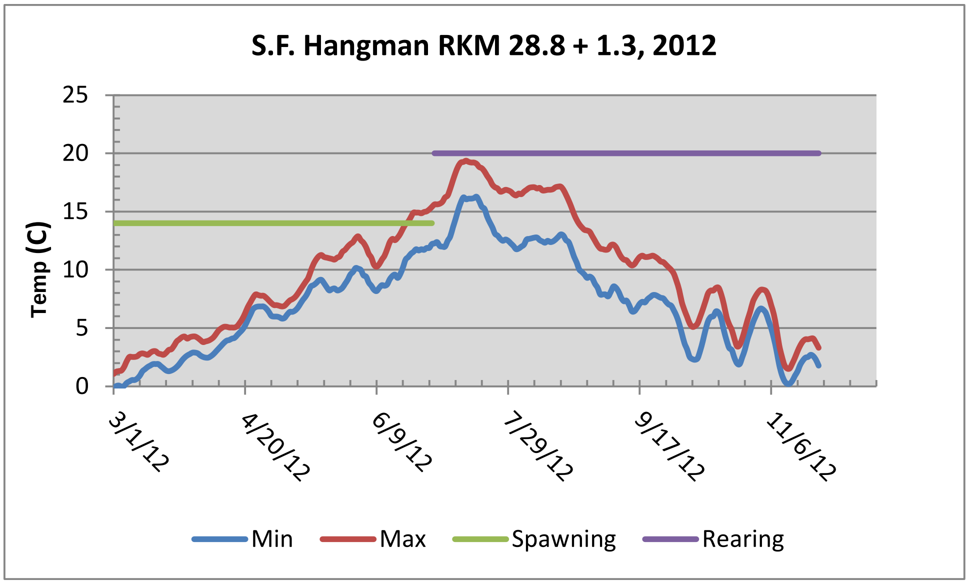


Figure B-56: Average weekly maximum/minimum temperature profiles of SF Hangman Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

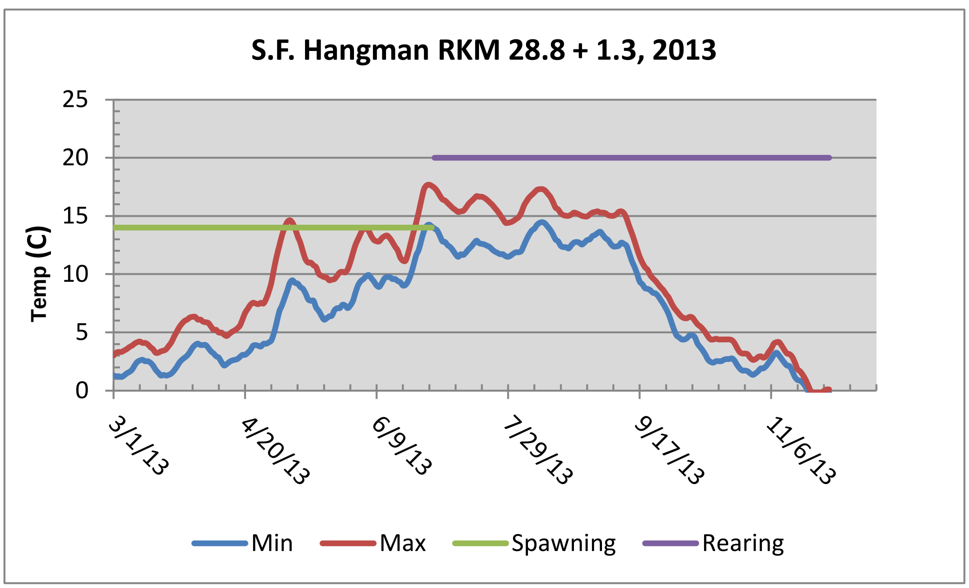


Figure B-57: Average weekly maximum/minimum temperature profiles of SF Hangman Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

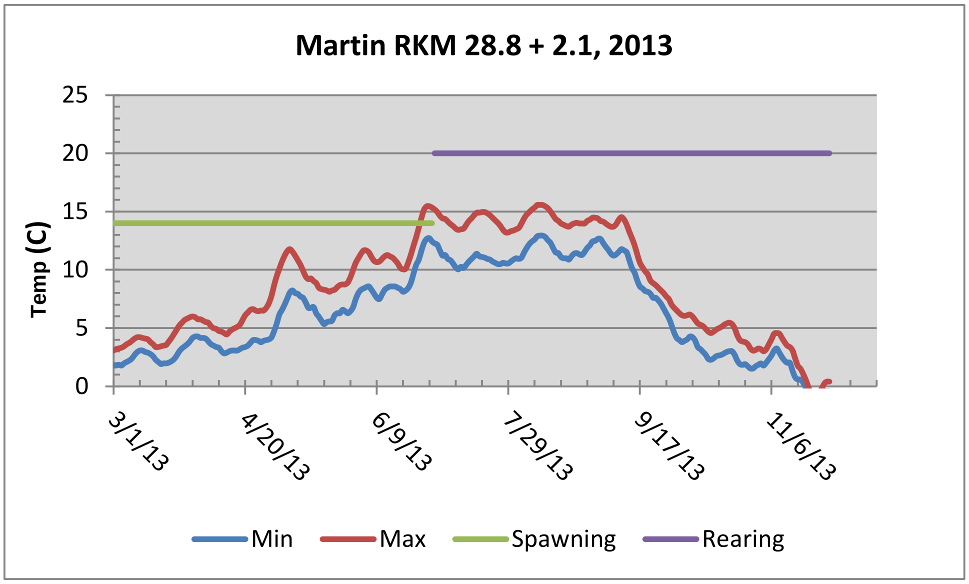


Figure B-58: Average weekly maximum/minimum temperature profiles of Martin in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

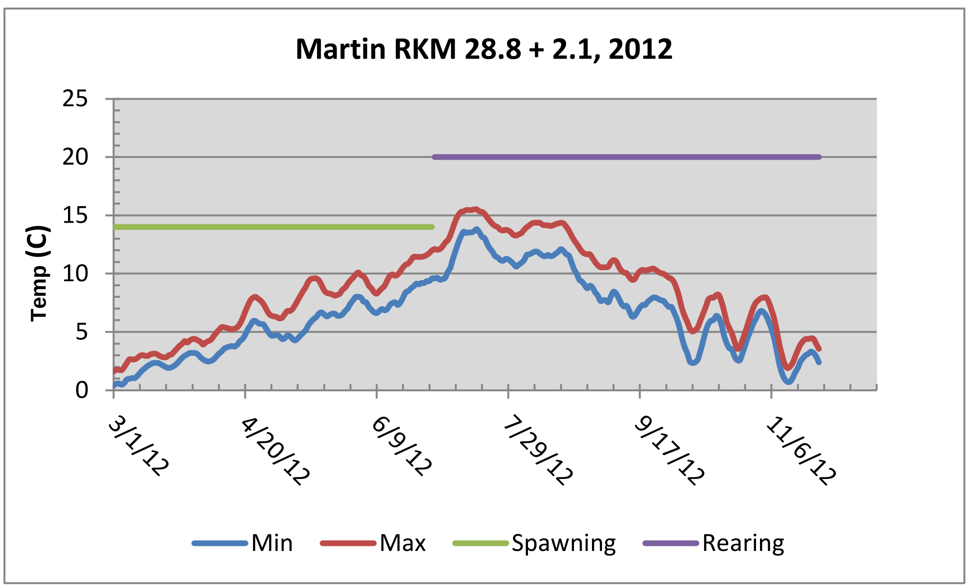


Figure B-59: Average weekly maximum/minimum temperature profiles of Martin Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

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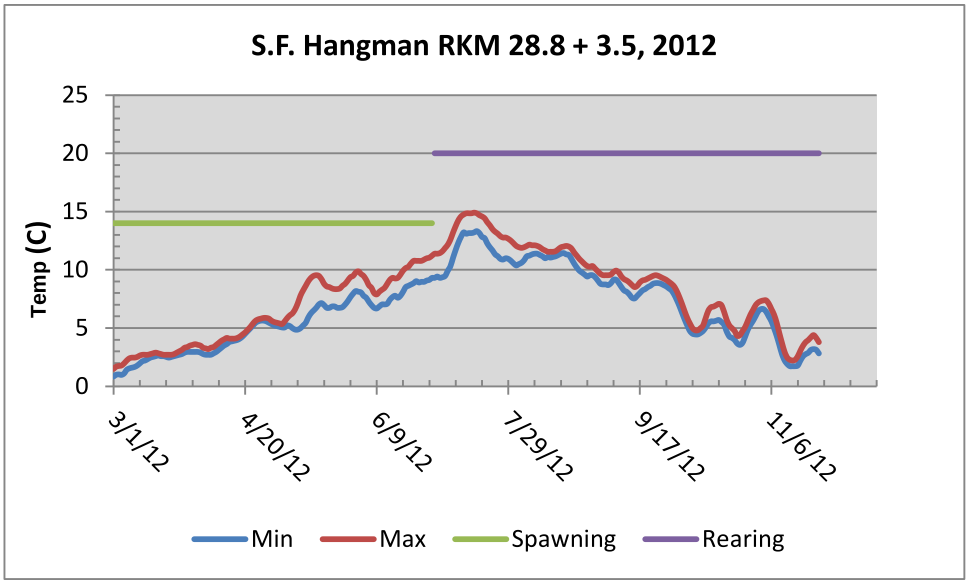

Figure B-60: Average weekly maximum/minimum temperature profiles of SF Hangman Cr. in 2012 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

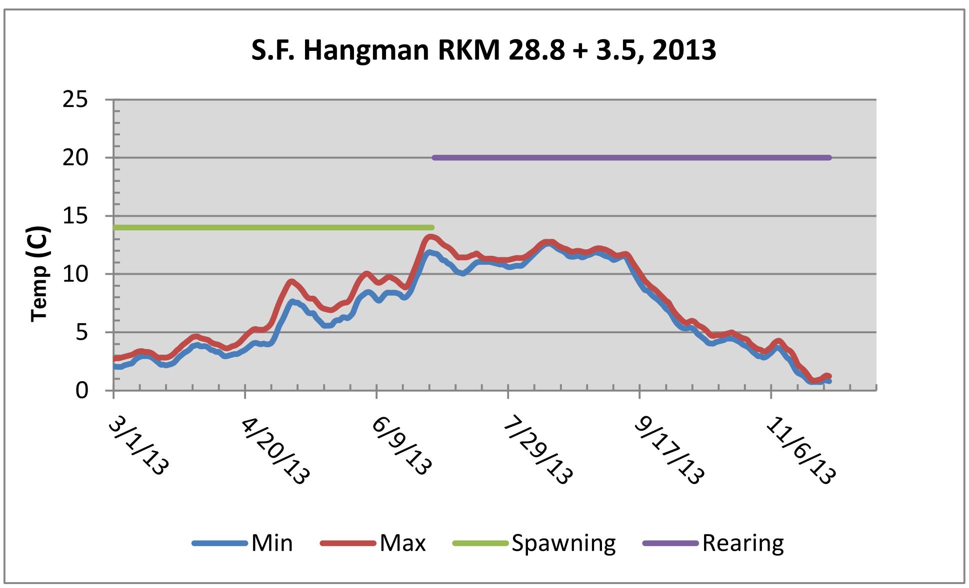

Figure B-61: Average weekly maximum/minimum temperature profiles of SF Hangman Cr. in 2013 marked with optimum/critical ranges for salmonids. Purple line estimates rearing limit temperature, and the green is the beneficial uses limit set by IDDEQ for salmonid spawning.

7.1.3 Appendix C: Thermal Refugia in Pools

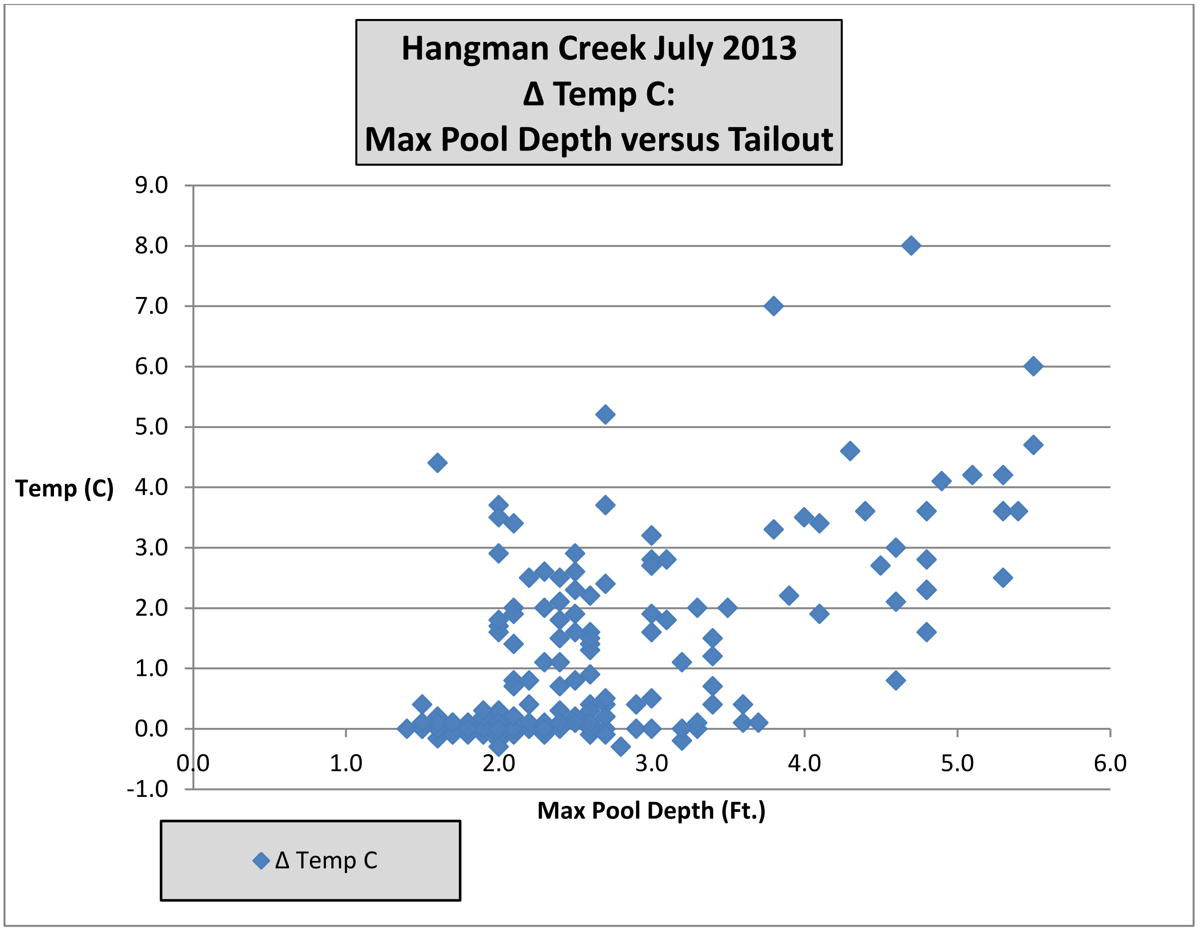

Figure C1. Longitudinal survey of temperature differences between max depth of pools and their tailout habitat completed in July 2013 on Hangman Creek

7.1.4 Appendix D: Repeated Measures Analysis Output

Table D1. Repeated measures statistical test output showing no significant difference between paired treated and control groups (p-value = 0.147).

```
Effects coding used for categorical variables in model.

Categorical values encountered during processing are:
TREAT$ (2 levels)
   C, T
Number of cases processed: 4

Dependent variable means
```

	Y09	Y10	Y11	Y12	Y13
	20.500	20.250	15.500	6.000	15.250

```
Univariate and multivariate Repeated Measures Analysis

Between Subjects
```

Source	SS	df	MS	F	P
TREAT$	168.200	1	168.200	5.357	0.147
Error	62.800	2	31.400		

```
Within Subjects
```

Source	SS	df	MS	F	P	G-G	H-F
a	551.500	4	137.875	4.128	0.042	0.176	0.096
a*TREAT$	193.300	4	48.325	1.447	0.304	0.352	0.333
Error	267.200	8	33.400				

```
Greenhouse-Geisser Epsilon:       0.2583
Huynh-Feldt Epsilon       :       0.5513
```

7.2 Photos

7.2.1 Indian Creek LWD Additions

7.2.2 Migrant Trap Before and After Photos

Although effective at capturing fish during lower flows, these chicken-wire framed trap panels were difficult to maintain, especially during times of high runoff. Upper picture is the upriver migrant trap; lower picture is the downriver migrant trap.

The new trap style is designed to be more fish-friendly, is much easier to install annually, and to maintain during periods of high runoff. These traps are designed to capture upstream and downstream migrant fish.

8 Acknowledgements

We wish to thank the Coeur d'Alene Tribe for the support given to this project, and to the Northwest Power and Conservation Council, Upper Columbia United Tribes (UCUT), and Bonneville Power Administration for funding and technical guidance. The following agencies were instrumental as partners and sources of data: Idaho Department of Environmental Quality, Idaho Dept. of Lands, Benewah County Conservation District. Special recognition is afforded to Tribal staff that provided technical assistance and data gathering, including Glen Lambert, Todd Johnson, Jon Firehammer, Gerald Green, Dan Jolibois, Stephanie Hallock, Angelo Vitale, Berne Jackson, and finally to tribal elder, Felix Aripa, who continues to support and inspire all of us.