DRAFT 2008 FISHERIES STUDIES REPORT

BLUE LAKE PROJECT (FERC NO. 2230) EXPANSION

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EXECUTIVE SUMMARY

Recent energy requirement forecasts conducted by the City and Borough of Sitka Electric Department ("City") have indicated that, in order to assure continued delivery of low cost electrical power, it must expand its electrical generating base. To meet these needs, the City is examining 1) installing a new generating turbine and powerhouse near the existing Blue Lake Hydroelectric Project (FERC No. 2230) powerhouse; and 2) raising the height of Project dam by as much as 83 feet. In this summary and the following report, these actions are called the "Blue Lake Expansion" or simply "Expansion". The Expansion-related actions will require an amendment to the existing FERC license for which the City must conduct specified studies. This report fulfills one element of the FERC amendment application requirements.

The dam raise component of this proposal would significantly affect Blue Lake's inundation area with potential effects on the lake's rainbow trout population. Specifically, Blue Lake rainbows are known to spawn in or near the confluence of several of the lake's major inflow tributaries. Higher reservoir elevations during the trout spawning period could have complex effects including increased access to presently inaccessible stream habitats, seasonal inundation of known spawning areas and effects on existing physical habitat due to sedimentation and erosion.

Through study planning among Stakeholders, it was determined that three primary study areas should be addressed using data and information from existing sources and results of the 2008 studies. These were:

1. **Blue Lake Creek And Tributaries, Spawning, Rearing, And Adult Observations;**
2. **Blue Lake Creek Habitat; and**
3. **Blue Lake Creek Life History**

Objectives and results of these three study components are presented in the following. Detailed results and discussion of the components are in the full report which follows.

BLUE LAKE CREEK and TRIBUTARIES, SPAWNING, REARING, and ADULT OBSERVATIONS

The primary objective of this study element was to document the relative abundance, timing, and location of rainbow trout spawning in several of Blue Lake's major tributaries. This information may help to determine effects of changing reservoir levels at certain times of the year.

Relative Abundance

Trout spawned in relatively equal numbers in Blue Lake Creek, Becky Creek, and Brad Creek (approximately 25% each) with Sheldon Creek contributing slightly less with 17%.

The North Falls and South Falls tributaries contributed significantly less (approximately 6%), but compared to each other also had relatively equal numbers.

In 2005, relative percentages in the major tributaries varied slightly from 2008 with Brad Creek contributing 16% while Blue Lake Creek, Becky Creek, and Sheldon Creek contributed 28%, 20%, and 23% respectively. In the minor tributaries South Falls Creek contributed 11% while North Falls was fairly constant with 2%.

Taking into account yearly fluctuations due to variable environmental factors, results in 2008 were comparable to those in 2005. Overall, the four major tributaries were of relatively equal importance.

Although Blue Lake Creek encompasses a larger drainage area, accessible spawning habitat, like at Becky Creek, Sheldon Creek and Brad Creeks, is limited to a short stream segment below the barrier falls.

Timing

In 2008, spawning runs into the major tributaries took place between late May and the second or third weeks of June. Peak counts occurred between June 9 and June 11.

As in 2005, the timing of the spawning run coincided with water temperatures reaching 6 to 7 C at the interfaces between stream and lake habitat. In 2008, due to unusually cold early water temperatures, the start of the run was more abrupt, the peak of the run was about a week later, and the overall run was prolonged with more fish arriving towards the end of the run.

Location

Spawning was concentrated in and near interface areas at lake and tributary confluence. In the major tributaries, spawning at these interfaces occurred primarily over cobble bars recently overlain with gravel from stream outflows. In Becky, Sheldon and Brad Creeks, some spawning occurred in pools created by large woody debris (LWD) accumulations in the lower stream reaches.

Spawning Substrate

Analysis of substrate sizes suggested that trout generally selected areas where fine to coarse gravel (4-32 mm) comprised at least 20 percent of the substrate. In interface areas, substrate particles of these preferred sizes were usually deposited over larger substrate (> 32 mm), a situation assumed to provide better aeration of redds. Particularly strong substrate size-class preferences were evident in Becky Creek (4-8 mm) and Sheldon Creek (16-32 mm). Spawning was not significantly noted in substrate smaller than 4 mm, even if underlain by cobbles, in any of the studied tributaries.

Emergence

A primary question was whether trout emerged from the gravel prior to the drawdown of Blue Lake reservoir. No emergence was observed in any of the studied tributaries during 2008. To address this question for 2008 conditions, we used degree-day accumulation to estimate the time to emergence based on egg maturation rates (from the literature) at specific temperatures (from 2008 water temperature monitoring data), dated from the range known times of spawning.

This analysis showed that all emergence would take place between August 16 and November 7 under conditions seen in 2008. This time period would be prior to early December when reservoir levels would normally be drawn down.

Tributary Utilization After Spawning

Adult fish counts in the tributaries dropped off after spawning and then increased in late summer. This increase was also true of juvenile fish which had been less prevalent earlier. Rising adult and juvenile fish numbers in late summer appeared to be linked to increased invertebrate activity in the tributaries.

HABITAT

The objective of this study component was to assess the quality of Blue Lake Creek instream habitat with emphases on 1) fish habitat which might become available after the dam raise and 2) habitat in the Reach upstream of the upstream limit of inundation. Habitat analyses in Blue Lake Creek Reaches between the Lower Barrier and the Glacier Lake Creek confluence showed that spawning and adult over-wintering habitat is low. This was evidenced by low sinuosity, high width to depth ratio, few pools, moderate to high channel confinement and high seasonal discharges.

In these Reaches, gravel sizes suitable for rainbow trout spawning were likely flushed from the main channel during high flows and were redeposited in small depositional areas as flows receded. In these same Reaches, summer feeding habitat, evidenced by the more available riffle habitat with adjacent flow refugia, was higher. Spawning habitat upstream from the Glacier Lake Creek confluence was higher than in the Reaches below the confluence, perhaps due to channel type and lower peak discharge in the absence of Glacier Lake Creek inflow.

BLUE LAKE LIFE HISTORY

The objective of this study element was to assess whether significant numbers of rainbow trout completed their life history upstream of the Lower Barrier on Blue Lake Creek, in which case Blue Lake Creek might be a significant source of Blue Lake trout population numbers. Under this objective, we examined 1) whether adult fish moved between Blue Lake and Blue Lake Creek during the period when the Lower Barrier was breached; and 2) whether they utilized the Blue Lake Creek (upstream from the Lower Barrier) habitat year round. We also examined whether juvenile rainbow trout utilized the habitat for rearing.

Movement Between Blue Lake and Blue Lake Creek

Adults

Fish capture, observation and tagging studies in 2008 showed that most adult fish in Blue Lake Creek moved into the area after the Lower Barrier had been breached in August. This was after the majority of spawning was complete. These fish remained in the Creek during the late summer and early fall feeding period when water temperature and invertebrate production were conducive to feeding. Adult trout numbers peaked in late September and then decreased rapidly, as most of the fish migrated back into Blue Lake. Little adult overwintering was demonstrated, likely the result of scarcity of pool habitat which has been demonstrated to be desirable for trout overwintering in streams.

Juveniles

Studies in 2008 documented a small overwintering population of juvenile fish which appear to be slower growing than those found in the Blue Lake. The smaller overall size of these fish at age is likely due to a shorter growing season in Blue Lake Creek than in the Blue Lake. However, variance in length at age and limited sample sizes make data on the origin of these fish inconclusive at this time.

Use of Upper Blue Lake Creek Year Around

Generally, the 2008 studies documented that there is a small year-round juvenile trout presence in Upper Blue Lake Creek, by the capture of juveniles prior to the Lower Barrier being breached. Most of the adult population, however, was thought to be present seasonally and to have migrated from Blue Lake after the Lower Barrier was breached. Spawning evidence and lack of available habitat reduce the likelihood that Upper Blue Lake Creek contributed significantly to the Blue Lake trout population.

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INTRODUCTION and BACKGROUND

The City and Borough of Sitka Electric Department ("City") recently received a new license for the Blue Lake hydroelectric Project (FERC No. 2230, "Project") from the Federal Energy Regulatory Commission (FERC). During the relicensing process, the City's ongoing energy forecasts indicated that, in order to assure continued delivery of low cost electrical power in the face of rising energy needs in Sitka, it must expand its electrical generating base.

Among other alternatives, the City is examining 1) installing a new generating turbine and powerhouse near the existing Blue Lake Project powerhouse; and 2) raising the height of Project dam by as much as 83 feet. Collectively, these actions are called the "Blue Lake Expansion" or simply "Expansion" in this report. The Expansion-related actions will require that the Project's FERC license, reauthorized in 2008, be amended. To obtain the amendment, the City must conduct specified studies supporting the formal application. This report fulfills one element of the FERC amendment application requirements.

The dam raise component of this proposal would significantly affect Blue Lake's inundation area with potential effects on the lake's rainbow trout population. Specifically, Blue Lake rainbows are known to spawn in or near the confluence of several of the lake's major inflow tributaries. Higher reservoir elevations during the trout spawning period could have complex effects including increased access to presently inaccessible stream habitats, seasonal inundation of known spawning areas and effects on existing physical habitat due to sedimentation and erosion.

Because Blue Lake's rainbow trout fishery is an important local and regional biological and recreational resource, the City prioritized fisheries studies in the Lake and inflow tributaries during 2008. Studies were conducted according to a study plan, discussed below, which resulted from extensive consultation with Alaska state and federal resources agencies.

STUDY PLANNING

Study planning for the Expansion-related fisheries surveys began in January, 2008 and evolved over the next several months. The City collaborated with Alaska State and Federal resource agencies, Sitka Tribe of Alaska and members of the Sitka Conservation Society during the study planning process.

The study planning process was complex and resulted in the preparation and review of a series of study plan revisions, some of which were noted only in meeting or field trip minutes, with the result that no final study plan was produced. Because new elements were added during the process, the City distributed a draft report outline to consulting agencies. This report is organized around what the City believes to be the final elements discussed and approved among stakeholders and the Fish Habitat Work Group.

STUDY OBJECTIVE

The overall objective of the 2008 Blue Lake and tributaries fisheries studies was to provide a baseline for analysis of potential impacts of raising the Blue Lake Dam and operating the Project as specified.

STUDY COMPONENTS

The final study elements included the following components, each related to rainbow trout:

1. **Blue Lake Creek and Tributary Spawning, Juvenile and Adult Observations;**
2. **Blue Lake Creek Habitat Analysis; and**
3. **Blue Lake Creek Life History.**

BLUE LAKE CREEK and TRIBUTARIES, SPAWNING, REARING, and ADULT OBSERVATIONS

The primary objective of this study element was to document the location, timing and relative abundance of rainbow trout spawning in several of Blue Lake's major tributaries. Included in this study component were measurements of physical habitat features and stream temperatures associated with spawning. A secondary objective of this component was to note and observe the location, timing and relative abundance of juvenile and adult rainbow trout within the same study areas. Finally, because studies in 2008 did not document trout emergence, Blue Lake temperature monitoring data were used to forecast emergence times based on observed spawning times and degree-day accumulations.

BLUE LAKE CREEK HABITAT ANALYSIS

The objective of this study element was to assess the quality of Blue Lake Creek instream habitat, with emphases on 1) potential fish habitat which might become available after the dam raise and 2) habitat in the reach upstream of the upstream limit of inundation.

BLUE LAKE CREEK LIFE HISTORY

The objective of this study element was to assess whether rainbow trout completed their life history upstream of the lower barrier on Blue Lake Creek. Under this objective, we examined whether adult fish moved between Blue Lake and Blue Lake Creek during the period when the lower barrier was breached and whether they utilized the habitat year round. It also examined whether juvenile rainbow trout utilized Blue Lake Creek for rearing.

METHODS

STUDY TIMEFRAME

Unless otherwise noted, all dates in this report refer to field work done in 2008. Spawning surveys began in April and increased in frequency through June and July. For the remainder of the year, surveys were conducted at least monthly to observe juvenile and adult fish and to better describe overall life history. Surveys were suspended on October 30 and the last fish captures conducted on November 5.

STUDY AREAS

General

Throughout this report, we make reference to various study areas within an overall area which included Blue Lake and its major inflow tributaries, as described in the following (Figure 1). In this report, all units are English. Elevations are relative to mean low sea level and are denoted by the term "El", as in El 425 or El 342. The term "tributary" refers to Blue Lake's inflow tributaries. El 282 which is the 60 ft. foot drawdown level of the current spill level of El 342 is used for comparative purposes in the following tributary length descriptions. Distances along Blue Lake Creek were noted by Stream Mile (SM), the distance upstream from SM 0.0 established at Blue Lake El 290.

Blue Lake Creek, Upper and Lower

Blue Lake creek is Blue Lake's largest tributary with a drainage area of 19.9 square miles, comprising 54 percent of Blue Lake's total drainage area. For the purposes of this report Blue Lake Creek was divided into two segments, Upper and Lower Blue Lake Creek (Figure 2). These segments were separated by a cascade at SM 0.12 which represented a fish passage barrier when Blue Lake reservoir was below El 320 (Figure 2, Figure 4). At higher reservoir elevations, the falls were submerged and did not impede upstream fish passage.

At SM 2.02, a large cascade also impeded upstream migration and marked the limit of rainbow trout migration at any reservoir elevation (Figure 4). In this report, we refer to the cascades at SM 0.12 and SM 2.02 as the "Lower Falls" and "Upper Falls", respectively.

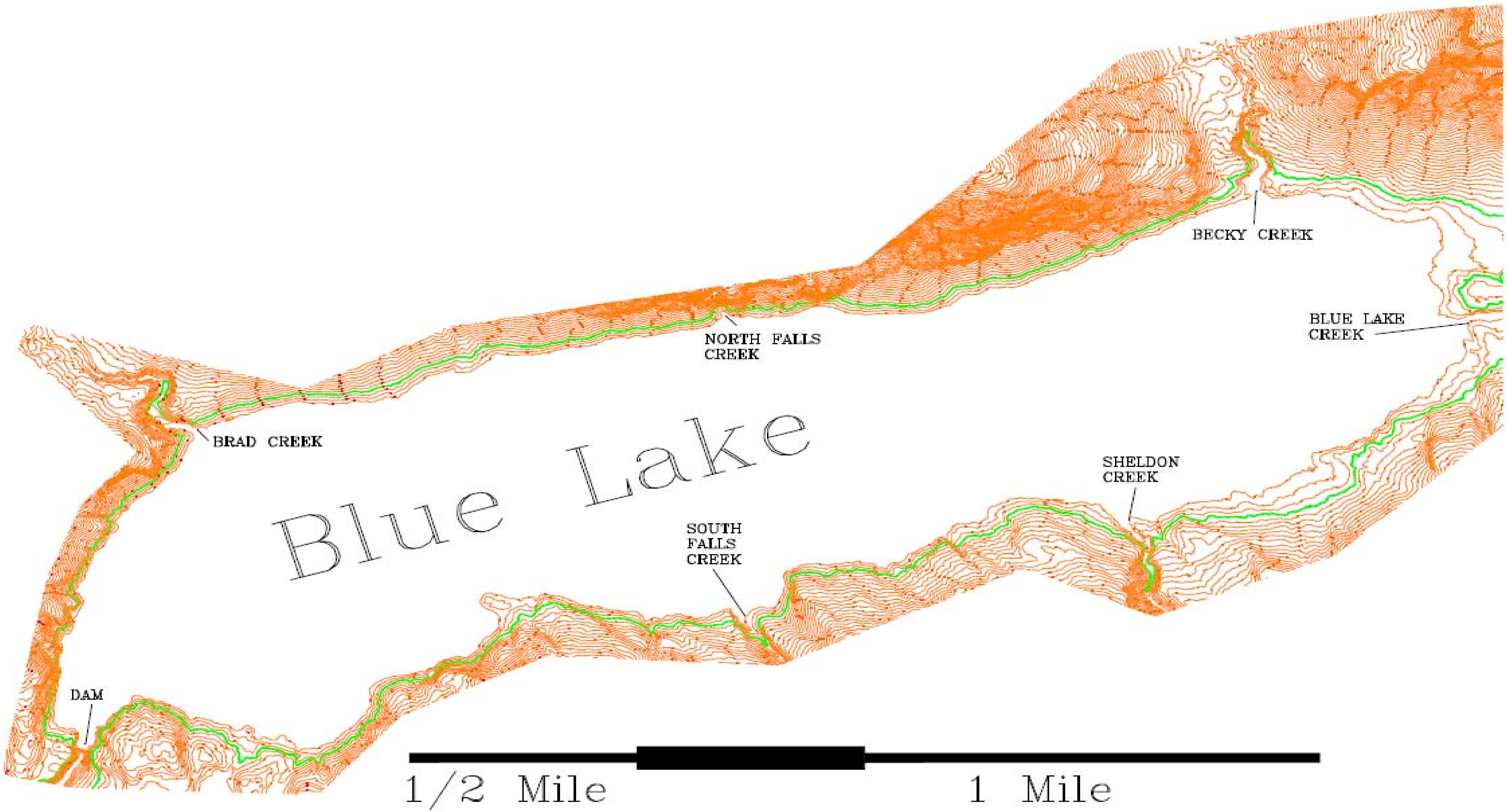


Figure 1. Map of Blue Lake and major tributaries.

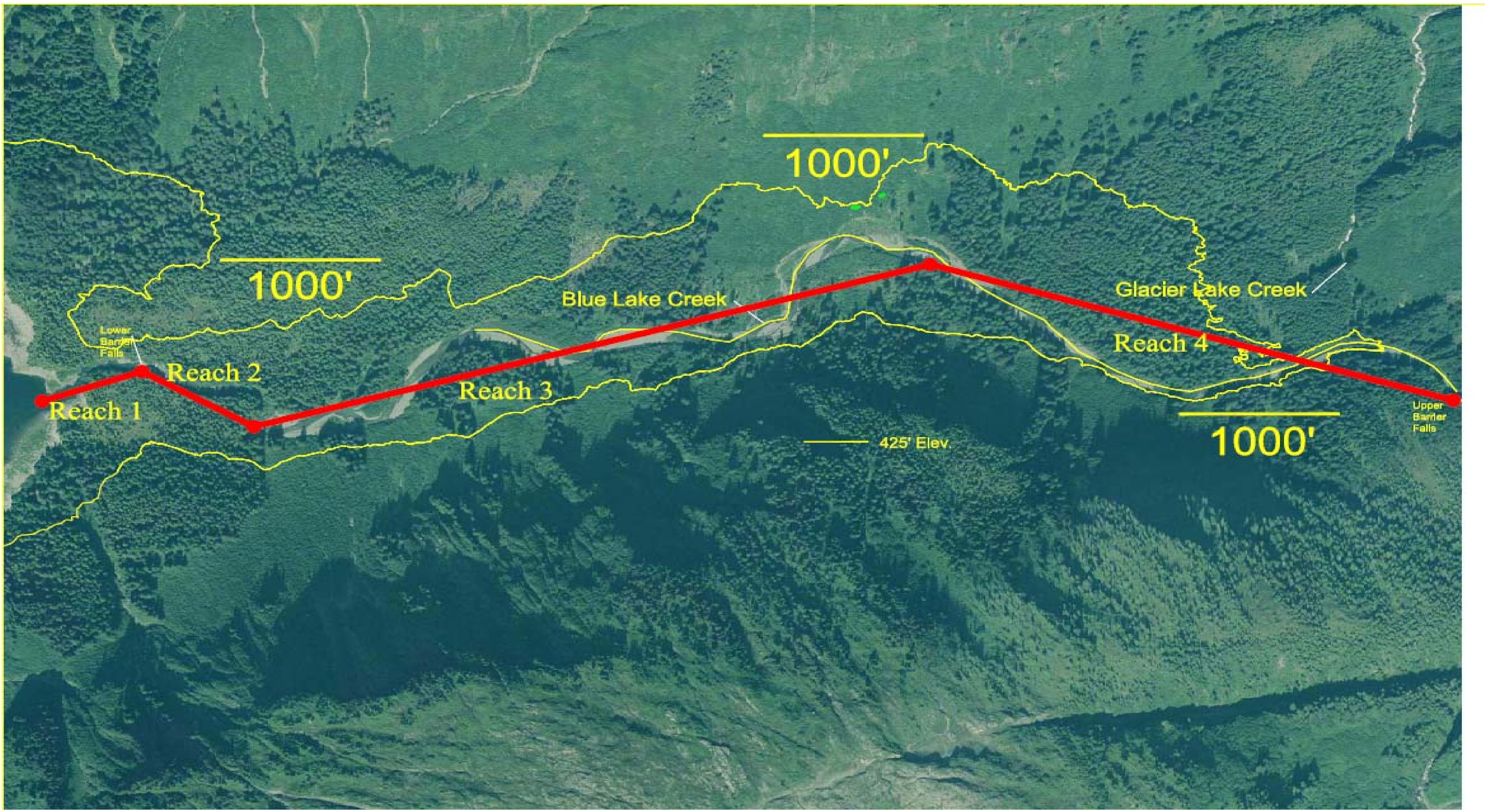


Figure 2. **Blue Lake Creek stream reaches, proposed inundation level and fish passage barriers.**

Figure 3. Blue Lake Creek Lower Falls from Reach 1 SM 0.12 at El 305.

Figure 4. Upper Cascade at Blue Lake Creek S.M. 2.02.

The Lower and Upper Blue Lake Creek segments were further subdivided into "Reaches" within which stream habitat was generally homogeneous (Figure 2). The Lower Blue Lake Creek segment consisted of Reach 1 which extended from SM 0.00 to SM 0.12 at the base of the Lower Falls.

–Upper Blue Lake Creek consisted of Reaches 2-4 which extended from SM 0.12 (the top of the Lower Falls) to SM 2.02 (the bottom of the Upper Falls) (See Figure 2, Figure 5).

Figure 5. Riffle to pool habitat in Upper Blue Lake Creek at S.M. 1.00

Becky Creek

Becky Creek is the second largest Blue Lake inflow tributary with a drainage area of 4.9 square miles, comprising 13 percent of Blue Lake's total drainage area. Becky Creek joins Blue Lake about 3 miles east of Blue Lake Dam (See Figure 1). Becky Creek upstream of its Blue Lake confluence is shorter than Blue Lake Creek, but still offers spawning and rearing habitat from its confluence with the lake to just below a large set of cascades about .41 miles upstream from the Blue Lake confluence at Blue Lake El 282 and .2 miles at Blue Lake El 342.

Sheldon Creek

Sheldon Creek is located about 3 miles east of Blue Lake dam (See Figure 1). Sheldon Creek has a drainage area of 4 square miles, comprising about 11 percent of Blue Lake's total drainage area. Like Brad Creek, Becky Creek and Lower Blue Lake Creek, Sheldon Creek's length between its confluence with Blue Lake decreases with increasing lake level. Sheldon Creek's length is approximately .23 miles at Blue Lake El 282 and reaches its barrier falls by Blue Lake El 342.

North Falls Creek

The North Falls Creek enters Blue Lake's north shore about 1.7 miles from Blue Lake dam (See Figure 1). The name of the site was derived from the presence of a waterfall estimated to be 2000 feet high, located about .05 miles upstream from its confluence with Blue Lake at Blue Lake El 282. North Falls Creek at Blue Lake El 342 reaches its barrier falls.

South Falls Creek

This tributary enters Blue Lake south shore across from the mouth of North Falls Creek (See Figure 1). South Falls Creek was only about .06 miles long at Blue Lake El 282 and is at its fish passage limit at Blue Lake El 342.

Brad Creek

Brad Creek enters Blue Lake on its north shore about 1 mile from the Blue Lake Project dam (See Figure 1). Brad Creek has a drainage area of 3.7 square miles, and is approximately .06 miles long to its permanent barrier at Blue Lake El 282. Like Sheldon Creek, North Falls Creek, and South Falls Creek Brad Creek reaches its barrier by Blue Lake El 342.

BLUE LAKE CREEK STUDY AREAS AND REACHES

Because of the more intensive observations conducted as part of the Habitat and Life History study components, researchers divided Blue Lake Creek into four "Reaches" within which habitat conditions were considered somewhat homogeneous (See Figure 2). Reach 1 was defined as the reach between SM 0.00 and the base of the Lower Falls at SM 0.12. Reach 2 began just upstream of the Lower Falls at SM 0.12 and extended to SM 0.31 Reach 3 extended from SM 0.31 to SM 1.30, and Reach 4 extended from SM 1.30 to SM 2.02 at the Upper Barrier Falls. Blue Lake's confluence with Glacier Creek its major stream tributary was located at SM. 1.94 with Reach 4.

SAMPLING METHODS

Foot/Snorkel Surveys

Snorkel methods were used wherever water depth and velocity did not preclude their use, and all likely holding areas were visually inspected using a mask and snorkel (Northcote and Wilkie 1963, Thurow R.F. 1994). Wherever stream conditions allowed, surveys were conducted upstream to minimize fish disturbance. Surveys were generally conducted upstream to each tributary's' respective barrier falls with the exception of two tributaries. Observation efforts were quantified by recording start and stop locations on hand annotated maps and by GPS coordinates where coverage allowed. Time at the beginning and end of each observation effort was recorded.

Trout locations and other relevant data were noted on detailed maps of the various study areas. Maps were hand annotated daily with GPS coordinates taken at all features and observed fish locations. Researchers recorded lake level, cloud cover, precipitation, time of day at beginning and end of the survey, and other factors on a standardized field form. Data were entered into an Excel spreadsheet in the office, and checked against the original maps and field forms.

Spawning Area Location

Probable spawning areas were identified by noting suitable substrate, sufficient flow, and presence of fish. Confirmed spawning areas were noted by the presence of ripe fish (see sexual maturity methods for characteristics) over suitable substrate, actual spawning activities, or the presence of identifiable redds.

Latitude and longitude were recorded for all fish and habitat areas using Garmin and Magellan 12 channel GPS units. Areas of spawning locations were measured using one of two methods depending upon location. Within stream channels, areas were measured using a tape and /or folding yardstick. Areas at or near a stream's confluence with Blue Lake were marked with GPS-located dive floats. Areas were later calculated using computer-based mapping programs.

Visual "Percent Substrate Composition"

Percent substrate composition (Mullner et al. 2000, Shirazi 1979) was used to characterize substrate in confirmed spawning areas identified in Lower Blue Lake Creek, Becky Creek, and Sheldon Creek. Substrate size categories were assigned using a modified Wentworth scale as described in the US Forest Service Tier III sampling protocol (USFS 2001).

BLUE LAKE AND BLUE LAKE CREEK TEMPERATURE MONITORING

Water temperature was measured in Blue Lake and Blue Lake Creek using both grab-sample and continuous monitoring techniques. Together, these methods provided a record of temperatures sufficient to represent daily temperature patterns throughout the east end of Blue Lake and at the mouths of the major tributaries. Detailed methods for temperature monitoring are documented in a separate temperature monitoring report available during summer or fall 2009.

BLUE LAKE CREEK HABITAT ANALYSIS

To evaluate existing trout habitat in this study area, researchers used a variety of measurements and techniques with the objective of quantifying habitat quality and comparing it to other streams in southeast Alaska. To provide consistency with previous studies and existing literature, many of the measurement techniques were drawn from the US Forest Service Tier III method (USFS 2001). Analysis of the measured values was done using the Tier III criteria as well as those drawn from the literature.

Study Area

The habitat analysis was conducted in Blue Lake Creek Reach 4 from SM 1.34 to SM. 2.02. This study area included a potentially inundated portion of Reach 4 plus a short distance upstream from proposed maximum reservoir elevation at El 425 (See Figure 4).

Study Components

Generally, the Habitat Analysis consisted of 1) **Habitat Quantification,** using various measured stream characteristics; and 2) **Potential Spawning Area** surveys to determine how fish might be using existing habitat within the study area.

Habitat Quantification

Habitat Quantification involved field measurement of several macrohabitat features, including:

- Channel type;
- Sinuosity;
- Gradient;
- Pool:Riffle ratio;
- Large Woody Debris (LWD);
- Width:Depth ratio;
- Incision depth;
- Number and length of macro pools;
- Stream morphology;
- Stream discharge
- Substrate particle size.

Some elements, including sinuosity, gradient, and channel type were obtained both in the field and from aerial photos and maps. The remaining factors were measured in the field according to techniques in USFS Tier III (USFS 2001).

Certain elements, such as discharge, substrate particle size and width:depth ratio were measured along transects placed to represent physical characteristics within a larger area. At these "Tier III Transects", physical factors were measured according to Tier III criteria. The Tier III Transects were located at SM 1.34, 1.50, and 1.94.

For the following elements, specific formulae were used, as described:

- **Sinuosity**

$$P=L_c/L_b$$

Where:
P = Sinuosity;
L_c =Length of the main channel;
Lb=The straight line distance to the point in the basin used to determine the main channel length

- **Slope/Gradient**

Slope (%) = (vertical height/reach length) x 100

- **Incision depth**

$$D=Lx \sin \alpha$$

Where:
D= Incision depth
L= Side slope length
α = Side slope angle in degrees

- **Stream Discharge**

$$Q_n=d_n((b_{n+1}-b_{n-1})/2)v_n$$

Where:

Q_n= discharge for subsection n
d_n= depth at subsection n
b_n=distance along the tape measure from the initial point on the left bank to point n
v_n=mean velocity of subsection n

Total discharge (Q) was calculated by adding all of the Q_n's to get total stream discharge (Q_{total})

Potential Spawning Area Study

The potential spawning area study focused on substrate particle size distribution and proportion both at the Tier III transects, an area at S.M. 1.66 where a full Tier III transect was not possible due to flow, and at higher quality "patches" within certain transects. Patches (Schuett- Hames,et.al 1999) were selected at locations of higher quality spawning gravels which were relatively rare in Upper Blue Lake Creek due to the predominance of medium to large substrate particles.

Substrate particle size distribution was calculated from 100 individual samples measured along the cross-sections and in the patches, using a USGS Gravelometer (US_SAH-97**).**

BLUE LAKE CREEK LIFE HISTORY

Observation/Capture Methods

To determine whether trout completed their life cycles in Upper Blue Lake Creek, several observation and capture methods were applied, as described in the following:

Foot/Snorkel Surveys

Foot and snorkel surveys were conducted to observe rainbow trout activity in Blue Lake Creek in spring, summer, and fall 2008. Observations were conducted throughout Blue Lake Creek to its confluence with Glacier Creek, as permitted by safety and access considerations.

Fish Trapping

Fish were trapped both above and below the Lower Falls with an emphasis on sampling the most likely areas above the barrier falls. Two types of traps were utilized: hoop traps and minnow traps. Hoop traps were initially utilized to target adult and larger juvenile fish and minnow traps to target juvenile fish.

Rod and Reel Sampling

Rod and real sampling took place both above and below the Lower Falls in order to target adult and larger juvenile fish particularly in areas were the use of hoop traps wasn't feasible.

Tagging

To identify adult fish movement between the upper and lower Blue Lake Creek each fish captured >180 mm was marked with an individually numbered tag. To visually distinguish between fish marked in lower Blue Lake Creek in 2004 and 2008 to Upper Blue Lake Creek fish were marked with grey tags in the lower portion to the upper extent of lake inundation and green above these areas.

Scale Sampling

Scale Samples were taken during both sampling Events in order to better characterize the age composition of fish utilizing habitat in upper Blue lake Creek compared to fish captured in 1991 and 2004 from Blue Lake and its tributaries below their respective barrier falls.

Sexual Maturity

All fish captured were examined for sexual maturity to determine length at maturity as well as verifying run timing. More detailed methods are described below.

Study Areas and Dates

Foot/snorkel survey dates are in Table 1, while capture technique survey dates are in Table 2. Foot snorkel surveys as part of both the Spawning and Life History Study began in Upper Blue Lake Creek on April 27 and the last survey was performed on October 30.

Table 1. Upper Blue Lake Creek foot/snorkel dates 2008.

Date	4/27/2008	5/25/2008	6/17/2008	6/25/2008	7/25/2008	8/5/2008	8/10/2008	8/20/2008	8/27/2008	9/25/2008	10/30/2008

Table 2. 2008 Blue Lake Creek life history study capture sampling dates.

Date	Reach 1			Reach 2			Reach 3			Reach 4		
	HT	MT	RR	HT	MT	RR	HT	MT	RR	HT	MT	RR
8-Jul			X									
9-Jul	X	X	X									
10-Jul	X	X	X									
11-Jul	X	X										
14-Jul												X
15-Jul										X	X	
16-Jul							X	X				
17-Jul				X								
21-Jul						X			X			
22-Jul								X				
23-Jul								X				
30-Jul						X			X			X
31-Jul			X									
13-Sep									X			
21-Sep									X			X
23-Sep												X
24-Sep												X
25-Sep				X			X			X		
30-Sep			X									
1-Oct			X			X						
7-Oct			X									
8-Oct			X									
9-Oct			X									
29-Oct								X				
15-Nov								X				

Sampling Methods

Foot/Snorkel Surveys

Snorkel methods were used wherever water depth and velocity did not preclude their use, and all likely holding areas were visually inspected using a mask and snorkel. Wherever current and or depth didn't prevent upstream travel, surveys were conducted in that direction in order to minimize fish disturbance and document smaller size classes (Northcote and Wilke 1963, Thurow 1994). All side channels and tributaries were sampled during the upper Blue Lake Creek surveys.

Trout locations and relevant data including but not limited to size, activity, presence of tags, and temperature were noted on a detailed habitat map of Upper Blue Lake Creek and then transferred and cross checked on a standardized field form.

Researchers recorded lake level, water clarity, cloud cover, precipitation, time of day at beginning and end of the survey, and other factors, on the standardized field form.

Fish Capture

All fish captured were measured for fork length to the nearest mm and inspected for sexual maturity. All fish except for a subset held for handling mortality and tag retention were released immediately in the area of capture. No anesthetics were used during this study.

Sample number, lengths, tag numbers, gear type, and trap number for recaptured and newly captured fish were recorded by date. Other comments including but not limited to mortality status, old or new tag or other scars, physical condition, etc. were also recorded. Location, catch and the number of gear units (rod and reel and trap hours) for each gear type were recorded on trap catch forms and location was also recorded on maps as well as trap catch forms.

Data were entered into an Excel spreadsheet in the office, and checked against the original maps and field forms. Catch per unit effort (CPUE) was determined using the means of ratios approach in order to examine possible factors effecting daily catch rates as well as the total ratio approach for the entire Event.

Fish Trapping

Bait for hoop traps and minnow traps consisted of salmon eggs disinfected in betadine solution. Bait for hoop traps was placed in commercial cup canisters and for minnow traps in perforated film canisters. All traps were marked with individual trap numbers for that day to avoid any confusion and to ensure all traps were retrieved at the end of the sampling period.

Hoop traps were 1.4 m in diameter and consisted of four 0.6-m-diameter steel hoops with 9-cm throats attached to the first and third hoops. Knotless nylon netting with a mesh size of 1 cm covered the hoop traps. Traps were supported horizontally with at least two aluminum bars and willow or alder saplings were often used in conjunction with these due to the necessity of keeping the outside mesh open near current. Due to the necessity of sinking traps in specific locations before being caught in adjacent currents, cobble sized anchors were often utilized.

Minnow traps were 9 in. in diameter, 17 ½ in. long and initially had two 1 in. entrances and consisted of either ¼ or 1/8 inch wire mesh. Traps in lower Blue Lake Creek were connected to floats as well as being tied to shore and traps in the upper creek were primarily tied to shore or other immobile objects.

During the Event 1 (prior to the barrier falls being breached) 6 hoop traps were placed in the upstream-most Reach of Blue Lake Creek (Reach 4) upstream of the barrier falls, for one day. The next day, after checking and clearing the traps, the traps were moved to the next most downstream Reach and left for a day, and so on until all three Reaches had been sampled for one day each. This way, in a three-day period, there was total of approximately 18 trap days in the three Reaches. In Reach 1 (Blue Lake Creek below the barrier plus trapping sites in Upper Blue Lake) six hoop traps were set for three days for a total of 18 trap days per Event to assure equal effort with that in the upstream Reaches.

Due to lack of success, the potential loss of traps to floating avalanche debris in the lower Blue Lake Creek, and the danger of using hoop traps in deep, strong current in the upper creek, hoop trap use was limited to 4 locations during a period of low flow during Event 2. This was done to check for sampling bias and target fish in the 140-160 mm and 160-180 mm size categories for scale samples.

Since the primary objective of minnow trapping was to document presence or absence, and to obtain an adequate number of samples, minnow trapping was more focused and was aimed at seeking a maximum number of fish. During Event 1, all Reaches and the most likely areas were sampled with minnow traps. During Event 2, minnow trapping was focused in Reach 3 due to the availability of higher quality habitat and the lack of previously trapped areas in the other Reaches.

Rod and Reel Sampling

Hook and line fishing was conducted using ultra light to light spin and fly-fishing tackle with tackle choice being determined by fish location, feeding activity, or habitat type sampled. Spin fishing was conducted by casting small (size 10-6 hooks) spoons, spinners, jigs and other lures. Fly-fishing utilized size 22-8 hooks on both wet and dry flies.

To more accurately quantify rod and reel fishing effort, the following protocols were observed:

- Time was recorded at the beginning and end of the rod and reel sampling sessions;
- After moving between areas and not fishing, a new sampling session was initiated;
- All tackle was prepared and checked before the start of sampling;
- Tackle was kept well sorted in clear plastic boxes and spares (lures, flies, leaders, etc.) were kept rigged outside the box to minimize time when lures were lost;

- Snagged lures were broken off and no attempts were made to retrieve lost lures until after the sampling period had ended;
- Fish captured were kept in coolers or five gallon buckets until after sampling for that time period was completed;
- During any delays such as backlashes etc. the clock was stopped and fishing effort suspended until the matter was resolved.
- Sampling sessions were assigned consecutive numbers and location, number of fish captured, and any comments were noted for each numbered session on a trap catch form.

Tagging

Every fish >180 mm was marked with an individually numbered T-anchor fine fabric tag immediately below the dorsal fin. In order to aid in visual identification of fish marked in lower Blue Lake Creek in 2004 and 2008 compared to Upper Blue Lake Creek marked in 2008, fish were marked with grey tags in the lower portion (to the point of current maximum lake inundation) and green in the upper portion. During Event 1, fish were marked with grey tags from S.M. 0.00 to S.M. 0.12 (the Lower Barrier Falls). During 2004 sampling and Event 2, in 2008, fish were marked with grey tags from S.M. 0.00 to S.M. 0.21 (limit of inundation in lower Reach 2). Due to catch rates and access factors, no fish were tagged throughout Reach 2 during Event 1, or in upper Reach 2 (above S.M. 0.21) during either Event. Fish captured in Reaches 3 and 4 were tagged with green tags.

Scale Sampling

After communication with ADF&G, a target of 10 samples from each of the following size classes: 100-120 mm, 120-140 mm, 140-160 mm, 160-180 mm, and greater than or equal to 180 mm, was set to ensure an adequate range of samples. Twenty six scale samples were taken in Event 1 above the barrier Falls and 17 samples in Event 2 for a total of 43 samples.

Scales were taken from the left side of the caudal peduncle immediately above the lateral line, (Brown and Bailey 1949 and 1952, Laasko and Cope 1956), spread along a prerecorded frosted slide, covered with another slide, taped together, and inserted into a scale envelope. Data on the card and frosted slide included: location, date, species, sample number, and fork length.

Sexual Maturity

Sexual maturity was examined using methods adapted from Schwanke and Hubert, 2003. Fish were examined for color, sex, reproductive products, ovipositor extension, kype, abdomen development, and abdomen hardness characteristics. Based on these characteristics, fish were assigned to one of the five following sexual maturity categories: immature, pre spawn, mature, post spawn, or unknown. All fish with any indication of gravidity or any amount of viable gametes were labeled as mature. All characteristics as well as maturity category and sample number, were recorded on custom “dura paper” sheets.

To estimate length at maturity, lengths of pre-spawn, mature and post-spawn fish were combined and noted as fish which had reached sexual maturity. Fish labeled as unknown were discarded from the analysis. Minimum length, maximum length and standard deviation of lengths were then determined for both immature and mature fish.

To estimate run timing, percentages of pre, post, and ripe fish were evaluated relative to the time periods in which they were seen in the stream.

RESULTS

BLUE LAKE CREEK and TRIBUTARY SPAWNING, REARING AND EMERGENCE

Lower Blue Lake Creek and Tributary Spawning

Relative Abundance

Trout spawned in relatively equal numbers in Blue Lake Creek, Becky Creek, Brad Creek, and Sheldon Creek (Figure 6). The North Falls and South Falls tributaries contributed significantly less, but compared to each other also had relatively equal numbers. A total of 159 adult fish were observed at North Falls and a total of 198 adult fish were observed at South Falls both contributing 3% each of the fish observed.

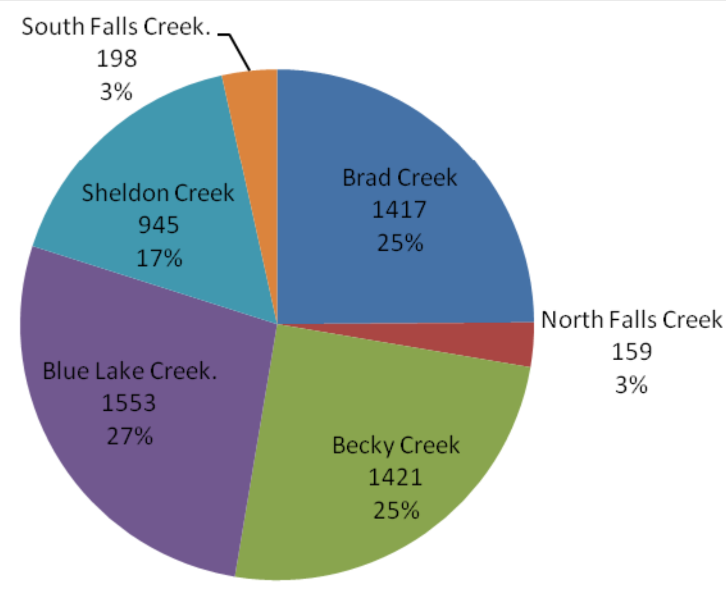


Figure 6. Relative abundance and number of rainbow trout observed in Blue Lake tributaries during 2008 spawning surveys.

Run Timing

Fish numbers in the four major tributaries increased rapidly between May 22nd and 28th. (Table 3, Figure 7).

Table 3. Total number of fish observed in Blue Lake tributaries during 2008 spawning surveys.

Date	Brad Creek	North Falls Creek	Becky Creek	Blue Lake Creek	Sheldon Creek	South Falls Creek
4/27/2008	0	0	0	0	0	0
4/30/2008	0	0	0	0	0	0
5/7/2008	0	0	0	3	0	0
5/13/2008	2	2	0	2	0	0
5/18/2008	6	4	0	0	0	0
5/23/2008	10	4	4	8	0	0
5/28/2008	70	2	3	22	14	0
5/30/2008	80	0	72	57	37	2
6/1/2008	69	2	70	128	42	0
6/3/2008	62	6	42	100	42	7
6/4/2008	82	8	94	141	54	6
6/6/2008	96	5	111	93	59	18
6/9/2008	93	3	169	179	89	22
6/10/2008	115	0	109	99	74	12
6/11/2008	119	11	100	154	67	5
6/13/2008	66	19	72	113	36	8
6/17/2008	89	27	100	62	90	5
6/18/2008	63	14	80	81	87	12
6/19/2008	100	13	74	44	48	21
6/20/2008	75	17	73	84	56	17
06/24/008	70	11	67	46	38	21
6/27/2008	65	7	67	51	35	12
6/30/2008	40	3	68	70	51	13

The bulk of the runs in the major tributaries took place from late May to the second or third weeks of June. Lower Blue Lake Creek, Becky, and Brad had peak counts taking place somewhere between June 9 and June 11. All of the tributaries' confluences except Blue Lake Creek had temperatures had temperatures in the 6.00 to 7.00 C range and the lakes had warmed to about 8.00 C (Figure 5, Figure 6). Sheldon Creek was the exception with a peak count of 90 fish on June 17th, but also had a count of 89 fish on June 9th. After the first three weeks of June numbers showed a general decline until July 2 (Table 3, Figure 4).

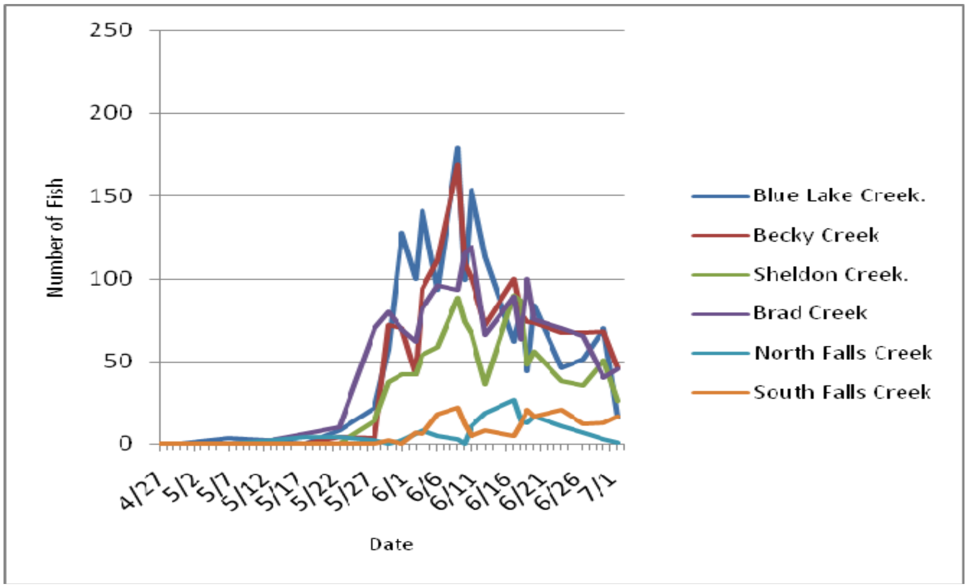


Figure 7. Rainbow trout observed in Blue Lake tributaries during 2008 spawning surveys.

In North Falls and South Falls Creeks, numbers began to rise about June 1, peaking on or about June 6. In South Falls Creek there were two peaks during June, and numbers had not decreased significantly by July 2 (Figure 7).

Water temperature

Water temperatures at the tributary confluences increased rapidly beginning on May 18 and continuing into June (Figure 8). Lake temperatures rose to over 7C by May 28, while tributary confluence temperatures remained at or below 7C until early June (Figure 8, Figure 9). Both lake and confluence temperatures had an overall decrease in temperature around June 6 (Figure 5, Figure 6).

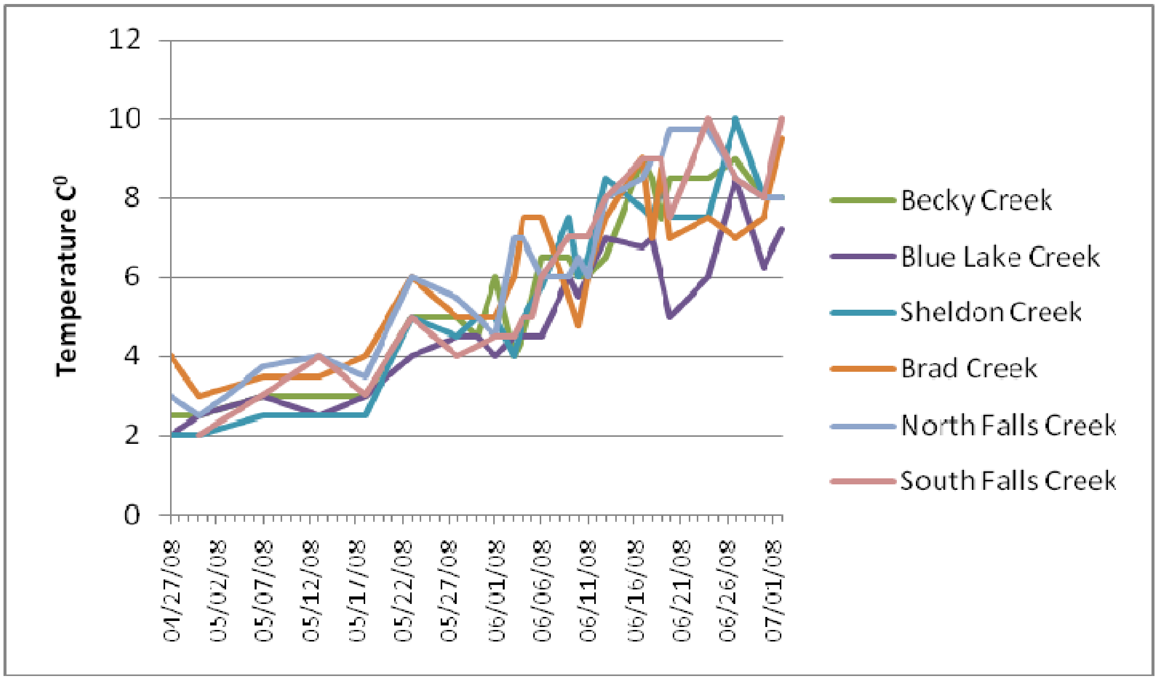


Figure 8. Tributary confluence temperatures during 2008 Blue Lake spawning surveys.

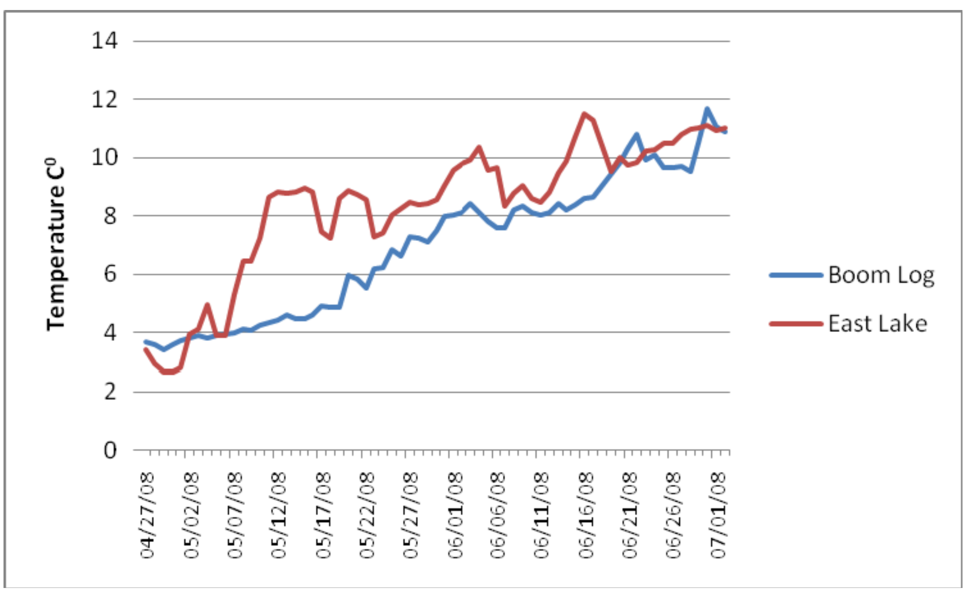


Figure 9. Daily mean lake temperatures during 2008 Blue Lake spawning surveys.

Location in tributaries of spawning activities

Spawning in the major tributaries was concentrated in and near interface areas at lake and tributary confluences (Table 4). Spawning at these interfaces occurred primarily over cobble bars recently covered with gravel from alluvial deposits. In Becky, Sheldon and Brad Creeks, some spawning occurred in small cascade pools created by large woody debris (LWD Pool) that had accumulated where their respective valley gorges meet the reservoir at higher reservoir levels. Like run timing and abundance, these generalizations varied according to whether it was a major or minor tributary with a greater percentage of fish observed at the smaller tributary's respective interfaces.

Table 4. Percent relative fish location and number of redds within major tributaries during spawning surveys.

Tributary	Interface		Creek		LWD Pool		Above LWD Pool	
	% Fish	# Redds	% Fish	# Redds	% Fish	# Redds	% Fish	# Redds
BL Creek Reach 1	61%	100	36%	0	n.a	n.a	n.a	n.a
Becky Creek	38%	85	20%	0	32%	2	10	0
Sheldon Creek	72%	11	11%	0	14%	0	3	n.a.
Brad Creek	68%	0	3%	0	30%	0	n.a.	0
North Falls Creek	76%	n.a	24%	n.a	n.a	n.a	n.a	n.a
South Falls Creek	99%	n.a	1%	n.a	n.a	n.a	n.a	n.a

Stream habitat in North Falls and South Falls Creeks was limited even at lower reservoir elevations. South Falls Creek was largely inaccessible due to avalanche debris.

Percent Substrate Composition

Analysis of substrate sizes in known spawning areas (assumed to be preferred) suggested that trout generally selected areas where fine to coarse gravel (4-32 mm) comprised at least 20 percent of the substrate (Figure 7). Particularly strong substrate size-class preferences were evident in Becky Creek (4-8 mm) and Sheldon Creek (16-32 mm) which contained some stream spawning, but these preferences were both within the 4-32mm range. In the interface areas, substrate particles of these preferred sizes were usually deposited over larger cobbles (> 64 mm), a situation assumed to provide better aeration of redds. Spawning was not significantly noted in substrate smaller than 4 mm, even if underlain by cobbles, in any of the studied tributaries.

It was hypothesized that interfaces consisted of a layer of cobble on which preferred size gravel was deposited seasonally as a result of the runoff cycle.

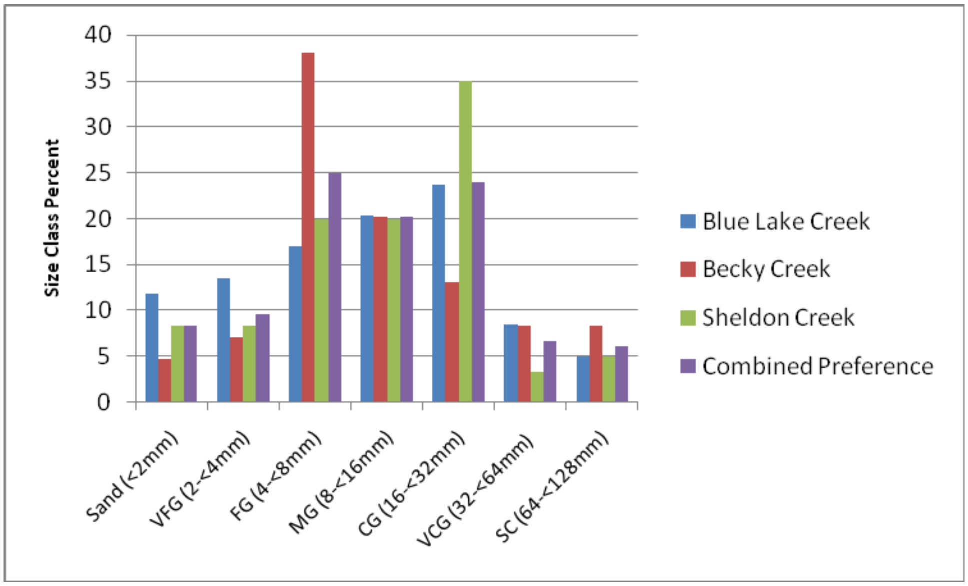


Figure 10. Percent substrate composition at spawning locations.

Incubation and Emergence

No emergence was observed in 2008. To predict hatching and emergence timing in the various tributaries, Accumulated Temperature Units (ATU) (Behnke 1992, Leitritz and Lewis 1980) were used. The "stream" tributary temperature logger data were used to calculate daily temperature accumulations. Degree days used were 330 for hatching and 630 for emergence (Behnke 1992). Three dates relative to the earliest spawn, the peak spawn, and the last date surveyed were used with the stream data logger temperatures which provided the coldest possible temperatures that fish could spawn and eggs would incubate in and thereby providing a range of the last possible dates of incubation and emergence in 2008 (Table 5).

Table 5. Predicted latest dates of hatching and emergence by tributary.

Tributary	Begin		Peak		End	
	Hatch	Emerge	Hatch	Emerge	Hatch	Emerge
Blue L. Creek. R1	8/18/2008	10/11/2008	8/24/2008	10/18/2008	9/5/2008	11/7/2008
Becky Creek	8/10/2008	9/25/2008	8/15/2008	9/30/2008	8/27/2008	10/16/2008
Sheldon Creek	8/10/2008	10/11/2008	8/12/2008	9/17/2008	8/23/2008	9/28/2008
North Falls Creek	7/16/2008	8/16/2008	7/25/2008	8/25/2008	8/5/2008	9/3/2008

The North Falls, with a greater influence of warmer lake water, had the earliest hatch-emergence dates with hatching taking place primarily in July and emergence in August. Reach 1 of Blue Lake Creek, with a greater influence of cold water, had the latest dates with hatching occurring primarily in mid August to the first week of September and emergence taking place from mid- October to early November. Becky Creek and Sheldon Creek timing fell roughly between these two extremes. All emergence was predicted to occur prior to typical reservoir drawdown, leaving post-emergent fish free access to Blue Lake.

Adult Fish Distribution After Spawning

Adult fish numbers in the various tributaries decreased after spawning as fish returned to the lake in early July. In late July and early August all of the major tributaries except Brad Creek had an increase in fish numbers as fish returned to feed on insect hatches (Table 6).

Fish observed in Becky, Sheldon and, Brad Creeks were concentrated at the interfaces as they ascended until they reached each tributary's barrier falls (Table 7). Blue Lake Creek fish had reached the Lower Barrier Falls by July 8. Fish not holding at the interfaces tended to be "cruising" around the inundated gorge areas (Table 8). Adult fish at the minor tributaries of North and South Falls followed these patterns to a lesser extent

Table 6. Adult rainbow trout observed in major tributaries during snorkel surveys after July 2, 2008

Date	Blue Lake Creek R1	Becky Creek	Sheldon Creek	Brad Creek	North Falls Creek	South Falls Creek
7/8/2008	25	n.a.	n.a.	n.a.	n.a.	n.a.
7/9/2008	n.a.	31	31	n.a.	n.a.	10
7/10/2008	n.a.	n.a.	n.a.	41	5	n.a.
7/14/2008	18	43	n.a.	n.a.	4	14
7/17/2008	n.a.	n.a.	41	n.a.	n.a.	n.a.
7/22/2008	55	n.a.	n.a.	n.a.	n.a.	8
7/23/2008	30	40	63	32	4	n.a.
7/28/2008	n.a.	38	n.a.	n.a.	n.a.	n.a.
7/29/2008	n.a.	n.a.	38	40	6	4
8/5/2008	n.a.	n.a.	21	n.a.	n.a.	n.a.
8/7/2008	45	77	67	36	4	15
8/10/2008	40	58	53	34	3	11
8/20/2008	n.a.	61	46	37	4	7
8/27/2008	27	36	38	31	6	7
9/5/2008	20	46	21[1]	25	2	20
9/18/2008	14	21	22	35	6	9
10/6/2008	18	14	15	31	8	9

Table 7. Percent of adult rainbow trout observed below, at, and above the interface (Creek) at major tributaries.

Tributary	Below Interface	Interface	Creek
BL Creek Reach 1	n.a.	n.a.	n.a.
Becky Creek	6%	75%	19%
Sheldon Creek	3%	85%	11%
Brad Creek	8%	85%	7%

Table 8. Percent of adult rainbow trout observed away from barrier falls (Gorge) and at barrier falls after reaching permanent barrier falls at major tributaries.

Tributary	Gorge	Barrier
BL Creek Reach 1	n.a.	n.a.
Becky Creek	21%	79%
Sheldon Creek	19%	81%
Brad Creek	10%	90%

Juveniles

Juvenile fish observations were concentrated in August and September with later observations thought to relate to invertebrate activity (Figure 11, Table 9, Table 10).

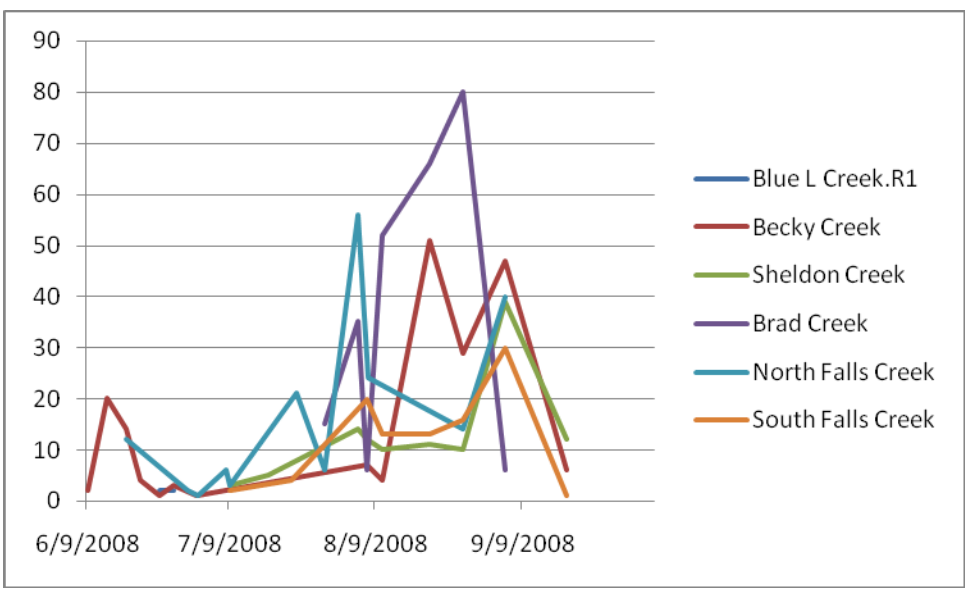


Figure 11. Timing trend of juvenile rainbow trout <180 mm observed in Blue Lake tributaries during 2008 snorkel surveys.

Table 9. Total number of juvenile rainbow trout <180 mm observed in Blue Lake tributaries during 2008 snorkel surveys.

Date	Blue Lake Creek R1	Becky Creek	Sheldon Creek	Brad Creek	North Falls Creek	South Falls Creek
6/9/2008		2				
6/13/2008		20				
6/17/2008		14			12	
6/20/2008		4				
6/24/2008	2	1				
6/27/2008	2	3				
6/30/2008					2	
7/2/2008		1			1	
7/8/2008					6	
7/9/2008			3		3	2
7/10/2008						
7/14/2008						
7/17/2008			5			
7/22/2008						4
7/23/2008					21	
7/28/2008						
7/29/2008				15	6	
8/5/2008			14	35	56	
8/7/2008		7	12	6	24	20
8/10/2008		4	10	52		13
8/20/2008		51	11	66		13
8/27/2008		29	10	80	14	16
9/5/2008		47	39	6	40	30
9/18/2008		6	12			1
10/6/2008						

Table 10. Number of juvenile rainbow trout observed on days with invertebrate activity versus days without.

Tributary	Invertebrate Activity		No Activity	
	# Fish	# Days	# Fish	# Days
Brad Creek	206	3	54	11
Sheldon Creek	51	2	67	7
Becky Creek	127	4	66	6
North Falls Creek	157	6	28	5
South Falls Creek	92	5	7	4
Total	633	20	222	33
% Observed	74%		26%	

BLUE LAKE CREEK HABITAT ANALYSIS

General Characterization of All Blue Lake Creek Reaches

Habitat characterization of all Blue Lake Creek Reaches showed distinct differences among the Reaches (Table 11). Generally, Reach 1, depending on reservoir elevation, was a steep, narrow boulder-strewn reach from normal low reservoir level (approx. EL

272) to the base of the lower barrier falls. Reach 2, prior to inundation of its lower section at higher lake levels, was similar to Reach 1 with more habitat diversity in the upper section. Reach 3 was a much less confined lower gradient area with a generally wider, shallower canyon and presence of braiding. Reach 4 varied in an upstream direction, but with a generally higher gradient and more confined channel than Reach 3.

Table 11. Summary of Blue Lake Creek initial habitat characterization descriptions

Reach	1	2	3	4
Stream Mile	0.0-0.12	0.12-0.31	0.31-1.3	1.3-2.02
Physical Location	Lake to lower Barrier Fall	Lower Barrier Falls to Braided Channel	Braided Channel to Confined Channel	Confined Channel to Upper Barrier Falls
Length (miles)	0.12	0.19	0.99	0.72
Grade (%)	1%-3%[1]	2.3%	0.10 %	0.65%
Sinuosity	1.1	1.3	1.3	1.1
Confinement	High	High	Moderate to Variable	Moderate to High
Stream Bank Description	Very stable bedrock and boulder controlled[1]	Very Stable bedrock and boulder controlled	Depositional (inc. old alluvial) and organic materials	Depositional and organic materials
Width to Depth	Low	Low	Variable	Moderate[2]
General Description	Varies with lake elevation	Pool to riffle, rapids and cascade, lower area varies w/ lake elevation.	Braided with longitudinal and diagonal bars, riffles dominated with small scour pools associated with boulders and LWD	Channel side bars, longer stretches of riffles

[1]Dependent on lake elevation
[2]Narrows with increasing elevation and stream miles

Specific Habitat Factors, Blue Lake Creek Reach 4

The following results were for Reach 4 between El 400 and El 425:

Sinuosity

With a value of 1.1, Reach 4 lies below the <1.2 threshold which is normally considered low (Rosgen 1994, 1996) and is more often found in association with steeper more confined channel types.

Gradient/Slope

With a value of .65% Reach 4 has a value that is considered low and is more often found in association with channel types that have a higher sinuosity (Rosgen 1996).

Discharge

Stream discharge was 155 cubic feet per second (cfs). This lies at the low end of the flow spectrum for the system which was determined to have a mean monthly flow of 238 cfs, a maximum monthly flow of 3834 cfs and a minimum monthly of 5 cfs.

Pool: Riffle Ratio

Pool:Riffle ratio in Reach 4, on a linear basis, was about 1:12. This is considered biased towards the riffle side with a one to one ratio being considered optimum for rainbow trout (Fortune and Thompson 1969; Thompson and Fortune 1970). Riffles and other fast water types are important for summer feeding particularly when water temperatures rise to about 5 C while pools are critical winter habitat during cooler periods.

Large Woody Debris

Reach 4 contained 451 total pieces of LWD and 90 key pieces of LWD. This is a good count for a stream with this channel type. Large accumulations and key pieces tended to be concentrated at current pool features or areas of active stream bank erosion. Most key pieces tend to be horizontal or lateral in orientation to the stream bank and perpendicular pieces were only located at pools at SM. 1.50, and S.M 1.64. Lateral and horizontal orientations compared to perpendicular tend to reduce the area of scouring creating smaller slow water habitats (Flosi and Reynolds 1994).

Width: Depth Ratio

Reach 4 had a mean width to depth ratio of 37. This is in the high range with <12 being considered low and >12 being considered moderate to high (Rosgen 1994, 1996).

Incision Depth

Transect incision depths ranged from .3 m to 3.00 m with an overall mean of .86 m. Incision depths at other areas, particularly at higher stream elevations, appeared to be much greater, making the overall data set appear biased due to lack of samples (Table 12).

Table 12. Incision depths taken at Tier III transects.

Bank Side Location	Tier III Transect		
	1	2	3
Downstream Right Bank	0.65m	0.33m	3.00m
Down Stream Left Bank	0.36m	0.30m	0.51m

Potential Spawning Area Analysis

All Transects had smaller patch areas within their boundaries that were proven to be composed of greater percentages of smaller higher quality spawning material in the 8-32 mm range that rainbow trout are able to move easily (Table 13, Figures 13, 14, 15, and 16). Patches tended to have medians near the middle of this range consisting medium to coarse gravels while all transects except three had medians (D_{50}) in the small cobble range.

Table 13. Square area, percent particle size less than 8, 16, and 32 mm, and median particle size of substrate at potential spawning study areas.

Study Area	m^2	% < 8 mm.	% <16 mm	%<32 mm	D_{50} [1]
Transect 1	853.44	0	1	8	73.5
Patch 1	4.32	21.1	41.3	63.3	20.6
Transect 2	777.24	0	1	4	88
Patch 2	1.62	7	33	66	23.9
Patch 3	7.76	15	38	76	16.1
Transect 3	716.28	7	10	27	62
Patch 4	5.33	19	62	83	12.4
Patch 5	4.16	6.9	37	63	21.3

[1] Median diameter in mm.

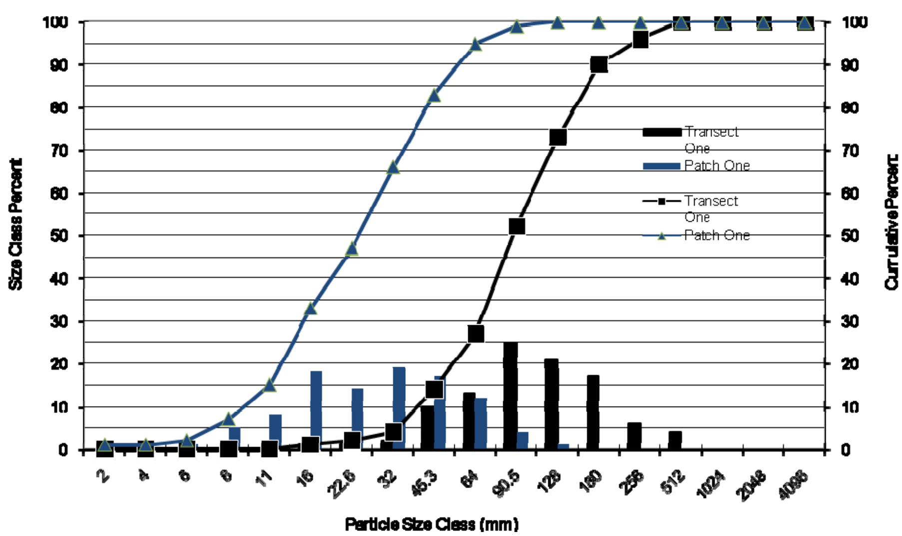


Figure 12. Transect one and patch one size class percent (bar graph) and cumulative frequency percent distributions.

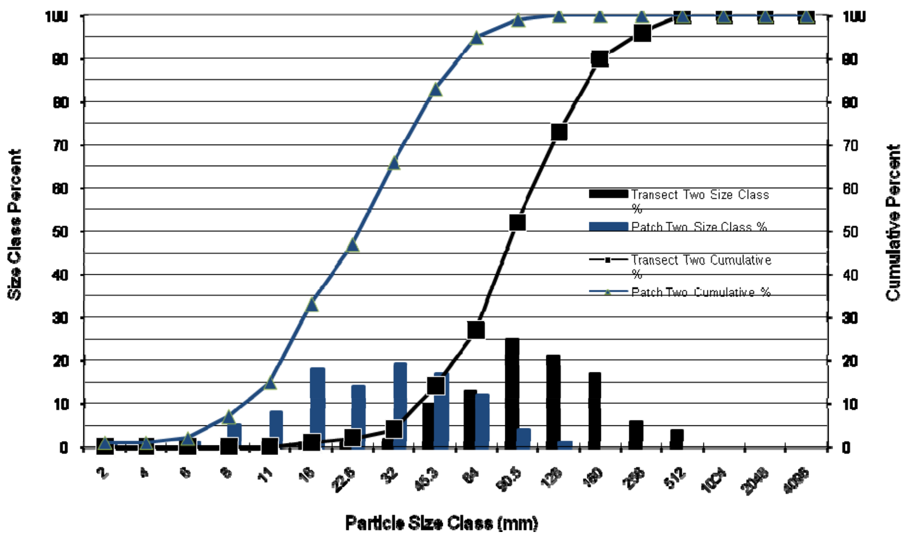


Figure 13. Transect two and patch two size class percent (bar graph) and cumulative frequency percent distributions.

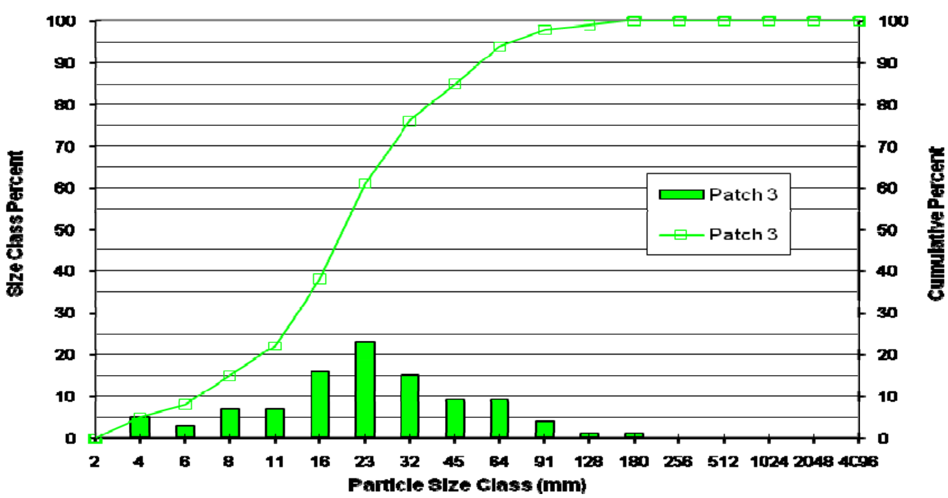


Figure 14. Patch three size class percent (bar graph) and cumulative frequency percent distributions.

Patches also had close to if not all of their percent particle size sizes and percent cumulative distributions within 64 mm while transects were not within these size classes (Figure 12, Figure 13, Figure 14, Figure 15,). Sizes greater than 64 mm. have been shown to be unsuitable for rainbow trout spawning (Cochnuer et. al 1986, Corning and Elliot 1987, Raleigh 1984, Shirazi et al 1979, Schuett-Hames 1999)

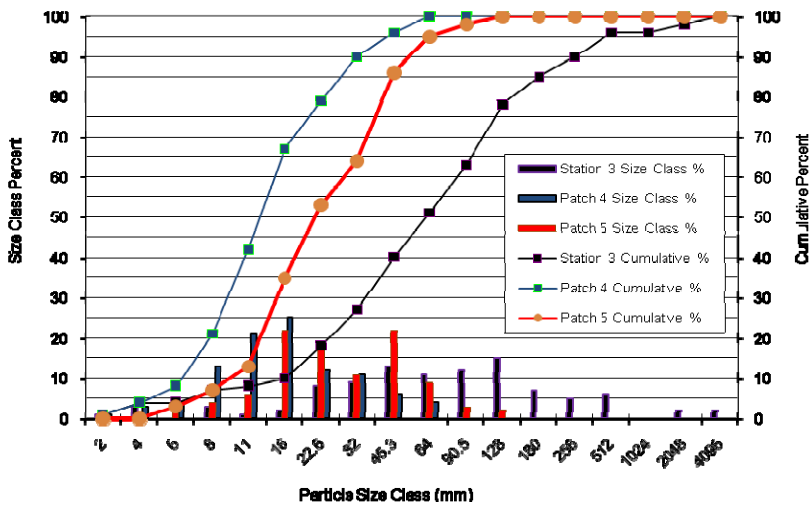


Figure 15. Transect three and patches four and five size class percent (bar graph) and cumulative frequency percent distributions

Transect Three which was located above the Glacier Creek confluence contained greater percentages of suitable spawning gravel in two distinctive well sorted patches. This was most likely due to the overall lower flows that it experiences reducing bed load transport of suitable spawning gravels.

BLUE LAKE CREEK LIFE HISTORY

Overall it appears that there was little overwintering of adult rainbow trout above the barrier particularly in the larger size classes. Some juvenile and smaller rearing fish were found in this area, primarily in Reach 3, prior to the lower barrier falls being breached but we were unable to tell if they originated from the lake or were bred in the upper stream. Juvenile fish captures and sightings below the barrier falls were limited. Fish tagged in the lake and below the barrier falls were found to move up into the lake, but by this time spawning is limited to an increasingly small portion of the population.

Foot and Snorkel Surveys

Adults

Snorkel observations of adult fish were extremely low prior to the Lower Barrier being breached and increased in August. From April 27 until July 25, zero to two fish greater than 180 mm in length were observed during surveys (Table 14). Fish greater than 180 generally began to increase after August 5 as the Lower Barrier appeared to become increasingly surmountable and water temperatures rose (Table 14, Figure 16) Figure 17.

Table 14. Number of rainbow trout > 180mm. and tags observed during Upper Blue Lake Creek surveys.

Date	Total >180mm	#GreyTags	# Green Tags
4/27/2008	0	0	0
5/25/2008	0	0	0
6/17/2008	2	0	0
6/25/2008	0	0	0
7/25/2008	1	0	0
8/5/2008	14	0	2
8/10/2008	9	0	2
8/20/2008	74	11	2
8/27/2008	97	7	2
9/25/2008	143	10	19
10/30/2008	9	1	2

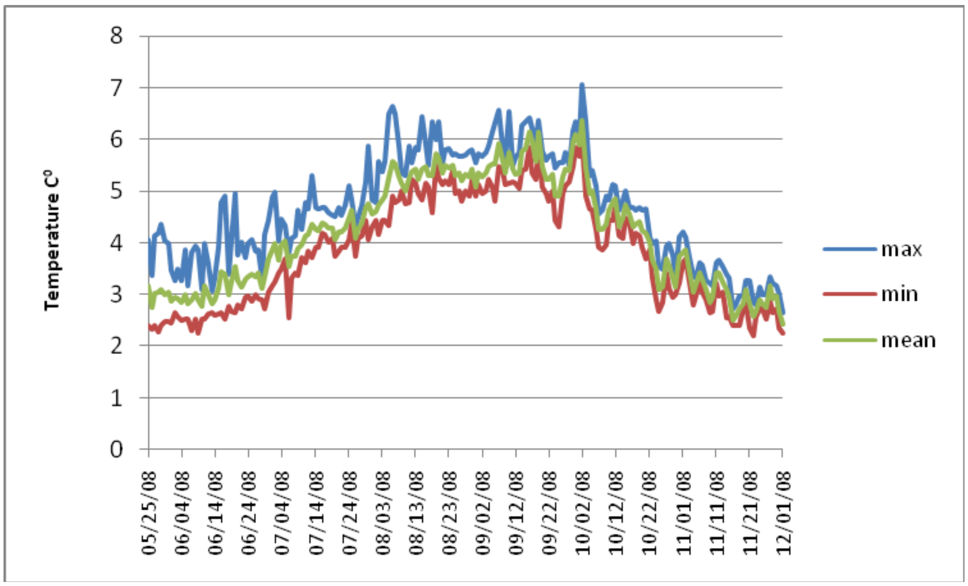


Figure 16. Maximum (max.), minimum (min.) and mean daily temperatures at S.M. 1 Reach 3 in Upper Blue Lake Creek.

Figure 17. Lower Barrier at S.M. 0.12 Blue Lake Creek on August 5, 2008 El 322.

By August 20 the Lower barrier Falls were totally inundated and trout tagged with grey tags (tagged below the Lower Barrier Falls) were observed throughout the stream to the Upper Barrier Falls.

Figure 18. Lower Barrier at S.M. 0.12 Blue Lake Creek on August 20 at El 330.

With 100% tag retention during all tests, the August 27 decrease in grey tags observed and the subsequent increase on September 25 in tags observed is most likely due to Event 2 marking.

Table 15. Number of rainbow trout > 180mm. and tags observed during snorkel surveys in Reach 1 of Blue Lake Cr. in 2008.

Date	Total >180	# Grey	# Green
7/8/2008	25	n.a.	n.a.
7/14/2008	18	n.a.	n.a.
7/22/2008	55	n.a.	n.a.
7/23/2008	30	n.a.	n.a.
8/7/2008	45	7	0
8/10/2008	40	4	0
8/27/2008	27	2	0
9/5/2008	20	0	0
9/18/2008	14	2	0
10/6/2008	18	6	4

Tag observations were lower overall in Reach 1 below the Lower Barrier Falls due to depth and visibility and only four green tags were observed below the barrier falls in Reach 1 on October 6 indicating outmigration (Table 15).

Spawning areas

Only one redd was observed with two actively spawning fish over it on August 5 at a pool just below the Upper Barrier Falls and above the point of proposed maximum inundation.

Other potential spawning areas and percent substrate composition examinations for Reach 4 are covered in the habitat analysis portion of the paper.

Juvenile

Two factors appeared to influence juvenile fish observations: water temperature in all size classes and the breaching of the falls in the larger size classes.

Little juvenile fish activity was observed prior to August 5. On August 5, as average stream temperatures rose to above 5.0 C (See Figure 16), juvenile fish observed increased and on August 20 as the lower barrier falls became completely breached a dramatic increase was noted particularly in the larger size classes(>120) (Table 16). On September 25, fish observations dropped dramatically during a temperature drop and counts remained low on October 30 as stream temperatures decreased. During the last two surveys, all juvenile fish observed where associated with cover.

Table 16. Total juvenile rainbow trout observed by date and size class in Upper Blue Lake Creek Reaches 2-4 during snorkel surveys in 2008.

Date	<100	100-120	120-140	140-160	160-180	Total Juv.
4/27/2008	0	0	0	0	0	0
5/25/2008	0	0	1	0	0	1
6/17/2008	0	0	1	0	0	1
6/25/2008	0	0	0	0	1	1
7/25/2008	0	0	0	0	0	0
8/5/2008	1	16	10	8	5	40
8/10/2008	1	10	16	10	10	47
8/20/2008	0	13	42	73	57	185
8/27/2008	26	28	37	41	58	190
9/25/2008	0	3	10	2	0	15
10/30/2008	2	3	7	0	0	12

Reach 2 had the fewest juvenile fish observations with 17. Reach 3 had the most observations with 313, and Reach 4 had 162 juvenile fish observations. As in the other tributaries and lower Blue Lake Creek, no emergence was observed (Table 17).

Table 17. Total number of juvenile rainbow trout observed by Reaches and size class in Upper Blue lake Creek during snorkel surveys in 2008.

Reach	<100	100-120	120-140	140-160	160-180	Total
2	0	1	7	5	4	17
3	18	50	86	88	71	313
4	12	22	31	41	56	162

Fish Capture

Adults

In Reach 1, adult fish captures decreased after the Lower Barrier was breached and captures in the Reaches above the Lower Barrier increased substantially. Both daily CPUE's and Event CPUE's followed the same trend, indicating an increased presence of adult fish in the upper Reaches. The 2008 grey series of tags were recaptured in all Reaches. Hoop trap catches were low prior to breaching and no adult fish were captured during limited trapping after breaching. In the following section, Event 1 includes sampling efforts prior to the Lower Barrier being breached while Event 2 includes sampling efforts after the Lower Barrier was breached.

In Reach 1, adult fish captures decreased between Events, the number of 2008 grey tags recaptured increased in response to added tagging, while the number of 2004 population study grey tags decreased (Table 18). No 2008 green tags were recaptured in Reach 1 below the Lower Barrier. All CPUE's where high in Reach 1, decreased between Events, and daily CPUE's varied substantially (Table 19).

Table 18. Adult rainbow trout (>180mm.) captured, tagged, and recaptured in Reach 1 of Blue Lake Creek 2008.

Reach	Event	# Captured	# Tagged	Recaptures			Other and Comments
				2004 Grey	2008 Grey	2008 Green	
1	1	168	159	3	3	0	2 Mortalities, 1 escapee
1	2	110	99	1	6	0	2 Mortalities, 2 escapees

Table 19. Daily minimum, daily maximum, daily mean, and Event catch per unit effort (CPUE) of adult rainbow trout in Reach 1 of Blue Lake Creek 2008.

Reach	Event	Gear Type	Daily Minimum CPUE	Daily Maximum CPUE	Daily Mean CPUE	Event CPUE
1	1	Rod & Reel	3.29	8.67	5.87	5.78
1	1	Hoop trap	0.01	0.07	0.03	0.03
1	2	Rod & Reel	2.00	7.72	3.78	4.07

Fish captured in Reach 2 increased from zero to 15 captures between Events with one 2008 recapture tagged in Reach 1 during Event 2. All fish were captured in the lower portion of Reach 2 which was inundated by high reservoir levels at the time (Table 20). Little cover was available in this lower portion of Reach 2, and adult fish were observed coming into the area from below the lower barrier falls. Daily CPUE's in Reach 2 increased and ranged from low to fairly high due to fish moving in and out from Reach 1, and Event CPUE's were close to average (Der Hovanisian 1994) (Table 21).

Table 20. Adult rainbow trout (>180mm.) captured, tagged, and recaptures in Reach 2 of Blue Lake Creek 2008.

Reach	Event	# Captured	# Tagged	Recaptures			Other and Comments
				2004 Grey	2008 Grey	2008 Green	
2	1	0	0	0	0	0	
2	2	15	14	0	1	0	All captures in area of lake inundation

Table 21. Daily minimum, daily maximum, daily mean, and Event catch per unit effort (CPUE) of adult rainbow trout in Reach 2 of Blue Lake Creek 2008.

Reach	Event	Gear Type	Daily Minimum CPUE	Daily Maximum CPUE	Daily Mean CPUE	Event CPUE
2	1	Rod & Reel	0.00	0.00	0.00	0.00
2	1	Hoop trap	0.00	0.00	0.00	0.00
2	2	Rod & Reel	0.00	3.50	1.45	1.67

Only five adult fish were captured in Reaches 3 and 4 prior to breaching, including a recapture from the previous day's sampling above the Lower Barrier Falls (Table 22). After breaching, the number of fish captured in Reaches 3 and 4 were similar and each had a recapture of a fish tagged below the Lower Barrier Falls prior to breaching (Table 22).

Table 22. Adult rainbow trout (>180mm.) captured, tagged, and recaptured in Reaches 3 and 4 of Blue Lake Creek 2008.

Reach	Event	# Captured	# Tagged	Recaptures			Other and Comments
				2004 Grey	2008 Grey	2008 Green	
3	1	2	2	0	0	0	
3	2	22	20	0	1	0	1 Mortality
4	1	3	2	0	0	1	
4	2	24	23	0	1	0	

After the Lower Barrier was breached, daily CPUE's also increased substantially in Reaches 3 and 4 and were fairly high with Reach 4 having the highest overall catch rates (Table 23).

Table 23. Daily minimum, daily maximum, daily mean, and Event catch per unit effort (CPUE) of adult rainbow trout in Reaches 3 and 4 of Blue Lake Creek 2008

Reach	Event	Gear Type	Daily Minimum CPUE	Daily Maximum CPUE	Daily Mean CPUE	Event CPUE
3	1	Rod & Reel	0.00	0.00	0.00	0.00
3	1	Hoop trap	0.01	0.01	0.01	0.02
3	2	Rod & Reel	0.00	4.00	2.04	2.44
4	1	Rod & Reel	0.17	0.33	0.25	0.22
4	1	Hoop trap	0.01	0.01	0.01	0.01
4	2	Rod & Reel	1.46	5.33	3.67	2.67

Juveniles

Juvenile capture rates were lower for both hoop traps and minnow traps below the Lower Barrier compared to above the Lower Barrier during Event 1 (Table 24, Table 25). Reach 3 had the highest catch rates with a low overall daily mean 0.06 for hoop traps (Table 24) and much higher rates for minnow traps (Table 25). Due to higher quality rearing habitat, minnow trapping was focused in Reach 3. The decreasing daily CPUE means of 0.07, 0.05, and 0.04 in Reach 3 were likely in response to trapping moving out of the highest quality habitat available as these locations were targeted first (Table 25).

Table 24. Juvenile hoop trap captures and daily ratio of the means CPUE's below (Reach 1) and above the Lower Barrier Falls (Reach 2, 3, 4,).

Reach	Date	# Captured	Daily CPUE	Comments
1	7/9/2008	0	0.00	
1	7/10/2008	1	0.01	
1	7/11/2008	2	0.01	
Reach 1 subtotals		3	Mean =0.01	
2	7/17/2008	7	0.05	
3	7/16/2008	8	0.06	
4	7/15/2008	5	0.03	
Reach 2,3,4, subtotals		20	Mean = 0.05	

Table 25. Event 1 juvenile minnow trap captures and daily ratio of the means CPUE's below and above the Lower Barrier Falls.

Reach	Date	# Captured	Daily CPUE	Comments
1	7/9/2008	2	0.01	10 traps
1	7/10/2008	1	0.004	9 traps one lost
1	7/11/2008	0	0.00	9 traps
Reach 1 subtotals		3	Mean = 0.01	
3	7/16/2008	23	0.07	14 traps
3	7/22/2008	20	0.05	16 traps
3	7/23/2008	9	0.04	11 traps
4	7/15/2008	2	0.01	9 traps
Reach 3,4, subtotals		54	Mean = 0.04	

During Event 2, hoop trap use was limited to a low water period to target fish in the size ranges from 140-180mm in order to attempt to obtain scale samples. Catch rates for minnow trapping in Reach 3 were initially consistent with Event 1 and dropped in response to weather, temperature and the concentration of trapping in two connected tributaries targeting larger size classes (Table 25, Table 26).

Table 26. Event 2 juvenile minnow trap captures and daily ratio of the means in Reach 3 above the Lower Barrier Falls.

Reach	Date	# Captured	Daily CPUE	Comments
3	10/29/2008	32	0.05	26 traps
3	11/5/2008	3	0.01	20 traps
Reach 3 subtotals		35	Mean = 0.03	

Reaches 1, 2 and 4 had insufficient data to draw any conclusions on juvenile length frequencies. Due to variable growth rates in Reach 3, length frequencies alone were inconclusive in determining age and growth (Figure 19). This variation in growth rates was supported by scale analysis.

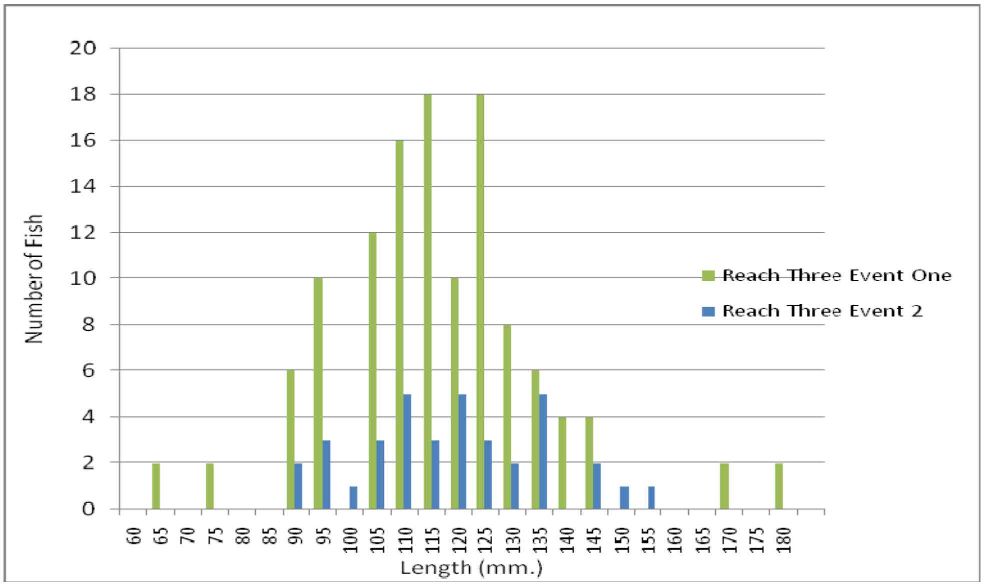


Figure 19. Comparison of Event 1 and Event 2 juvenile length frequencies in Reach 3.

Scale Sampling

A summary of scale samples by age class and length for both Events as well as a comparative sub sampling aged by the same reader from previous year's sampling are contained in Appendix 1 and reader's interpretations of 1991 and 2004 lake data are in Appendix 2.

Fish from previous year's lake studies and those taken after the Lower Barrier had breached began entering the spawning population as three year olds to four year olds (3+) and most of the population was sexually mature by age five (Appendix 2). Fish growth slowed after age three, and fish older than five proved difficult to age due to limited samples and slow growth. 5-10% of the scales from all the studies and multiple areas are missing a first year annulus which has been linked to late emerging fish that have little or no growth occurring in their first year (Appendix 2, Romey 2003).

Growth rates appeared highly variable both in the lake and in the stream (Appendix 1, Appendix 2) especially in regards to age 2 and 3 fish. This was evident in age 2 fish in 2008 whose lengths tended to be grouped according to where they were caught. Single fish similar in size to the Reach 2 (R2) and Reach 4 (R4) groups were located in boulders adjacent to the main stream at S.M. 0.4 (Figure 20). Larger lengths (>130mm) were from a mixture of habitats and areas (Figure 20).

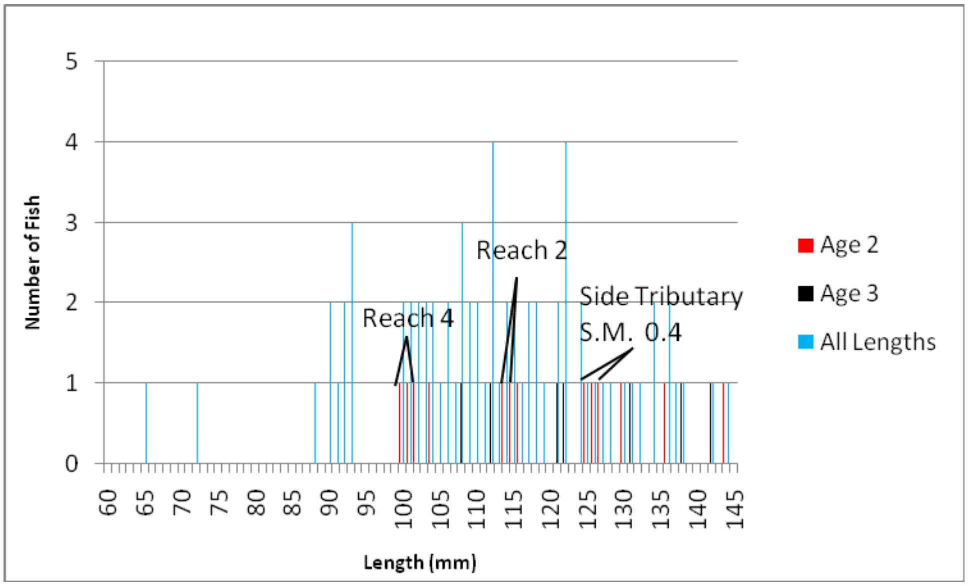


Figure 20. Comparison of Event 1 age two and age three scaled length frequencies.

Scale data suggests that the smaller age classes evident in Upper Blue Lake Creek prior to the Lower Barrier breaching tend to be slower growing than those in other areas of Blue Lake. Comparing mean, median, minimum and maximum lengths, fish that were sampled in age class 2 in Blue Lake Creek appeared to be almost one year class smaller than fish sampled in the lake in late May 1991 (Table 27).

Table 27. Comparison of length at age data of 2004 population study fish vs. 2008 study fish in Reaches 3 and 4 prior to the Lower Barrier Falls being breached.

Length	Age 2		Age 3	
	1991	2008	1991	2008
Mean (mm)	136	121	160	132
Median (mm)	132	121	156	127
Minimum (mm)	121	100	126	126
Maximum (mm)	168	144	194	184
Sample Size	13	14	10	8

Two age four fish with respective lengths of 178 and 196 mm where captured prior to the Lower barrier breaching (Appendix 1). After the Lower Barrier was breached, the lengths of the age 4 class increased.

During Event 2 in 2008, fish from the age classes four and older appeared to be larger compared to similar age classes from 2004, even when accounting for the later capture date. (Table 28, Appendix 1).

Table 28. Comparison of length at age data of 2004 population study fish vs. 2008 study fish in Reaches 3 and 4 after the Lower Barrier Falls have been breached.

Length	Age 4		Age 5		Age 6	
	2004	2008	2004	2008	2004	2008
Mean (mm)	225	293	243	314	264	341
Median (mm)	226	290	259	316	253	341
Minimum (mm)	180	265	180	295	240	341
Maximum (mm)	276	328	272	330	309	341
Sample Size	22	4	4	3	4	1

Sexual Maturity

Comparisons between Event 1 maturities above and below the lower barrier falls are limited due to the lack of larger size classes captured in the upper reaches. During Event 1, 100 percent of the mature fish captured in Reaches 3 and 4 were ripe males which were smaller in both minimum and maximum lengths (Table 29, Table 30) than all other mature captures. Only 4 fish of unknown maturity were captured in these Reaches indicating a scarcity of mature females (Table 31).

Table 29. Summary of sexual maturity length, sexual composition, and state of ripeness data for Event 1.

Reach	Maturity	n=[1]	Length mm.			% Sexual Composition			% State of Ripeness		
			min	max	stan dev.[2]	female	male	unknown	Ripe	Pre	Post
Reach 1	mature	107	167	412	38.34	47	31	22	22	5	78
	immature	5	69	162	35.50	0	0	5			
Reach 2	mature	0									
	immature	6	93	131	14.05						
Reach 3	mature	15	105	178	21.15	0	100	0	100	0	0
	immature	44	65	196	20.88	0	11	89			
Reach 4	mature	1	267	267		0	100	0	100	0	0
	immature	8	101	185	29.34	0	0	100			

[1] n= number of fish included in sample
[2] Standard deviation

Table 30. Summary of sexual maturity length, sexual composition, and state of ripeness data for Event 2.

Reach	Maturity	n=[1]	Length mm.			% Sexual Composition			% State of Ripeness		
			min	max	stan dev.[2]	female	male	unknown	Ripe	Pre	Post
Reach 1	mature	95	241	403	30.00	20	9	70	3	0	97
	immature	0									
Reach 2	mature	14	280	398	33.81	7	0	93	0	0	100
	immature	1	112	112		0	0	100			
Reach 3	mature	20	179	365	44.07	25	15	60	5	0	95
	immature	27	90	135	13.65	4	4	92			
Reach 4	mature	21	232	383	37.22	24	19	57	5	0	95
	immature	1	144	144		0	0	100			

[1]n= number of fish included in sample
[2] Standard deviation

Table 31. Number of rainbow trout by Event and Reach whose sexual maturity was unknown.

Event 1		Event 2	
Reach 1	72	Reach 1	15
Reach 2	1	Reach 2	1
Reach 3	2	Reach 3	11
Reach 4	1	Reach 4	3

The percentage of ripe fish observed dropped in all Reaches between Events and were 3-5 % in all Reaches during Event 2. State of ripeness in Reach 1 decreased from 22 percent ripe and 5 percent pre spawn during Event 1 to three percent ripe and zero percent pre-spawn during Event 2.

The number of females to males decreased substantially between the two Events in Reach 2 while the number that couldn't be sexed due to lack of identifiable characteristics increased (Table 29, Table 30). In response to the increased number of larger size classes captured, unknown sexual maturity increased in the upper Reaches after the Barrier was breached.

During Event 2, lengths of mature fish in the inundated and upper Reaches of Blue Lake Creek were fairly consistent with the upper Reaches having a slightly smaller proportion of the largest size classes (Figure 20) and a greater percentage of females (Table 29, Table 30).

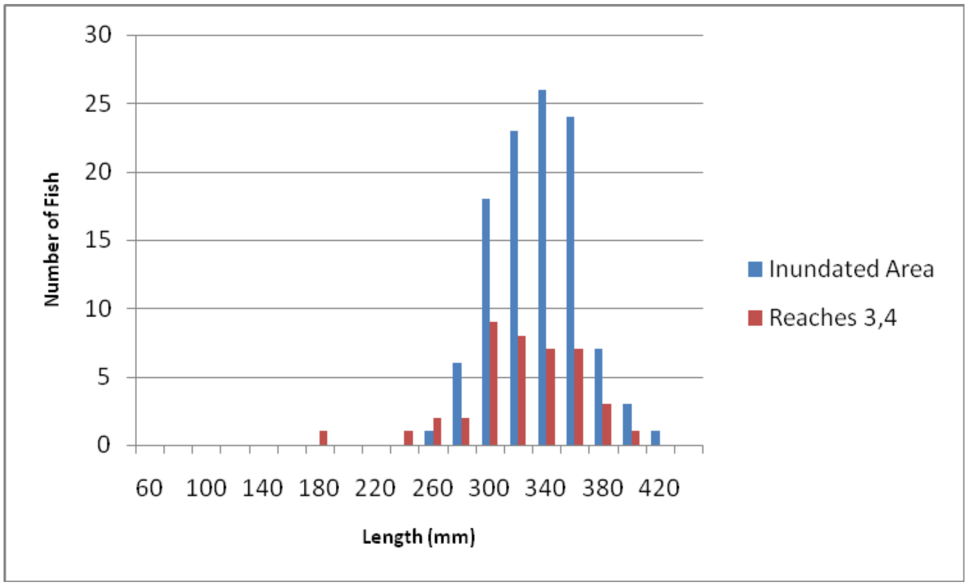


Figure 21. Comparison of length frequencies (20 mm bin) of mature fish during Event 2 between the reservoir inundated area (Reaches 1, 2,) and the upper Reaches (3, 4).

DISCUSSION

BLUE LAKE CREEK and TRIBUTARY SPAWNING, REARING AND EMERGENCE

Overall Percent Abundance

Results of the 2008 observations showed relatively equal abundance of trout during the spawning season in the four major tributaries, Blue Lake Creek, Brad Creek, Becky Creek and Sheldon Creek. This result generally reflected abundance seen in 2005 studies, although those studies were not conducted to specifically document relative abundance among various tributaries (See Figure 3, Figure 22). The most notable difference was at South Falls Creek which comprised 12 % of the fish in 2005 compared to 3% in 2008. The most plausible reason for this is access difficulties in 2008 due to large accumulations of avalanche debris during portions of the spawning run (Figure 22).

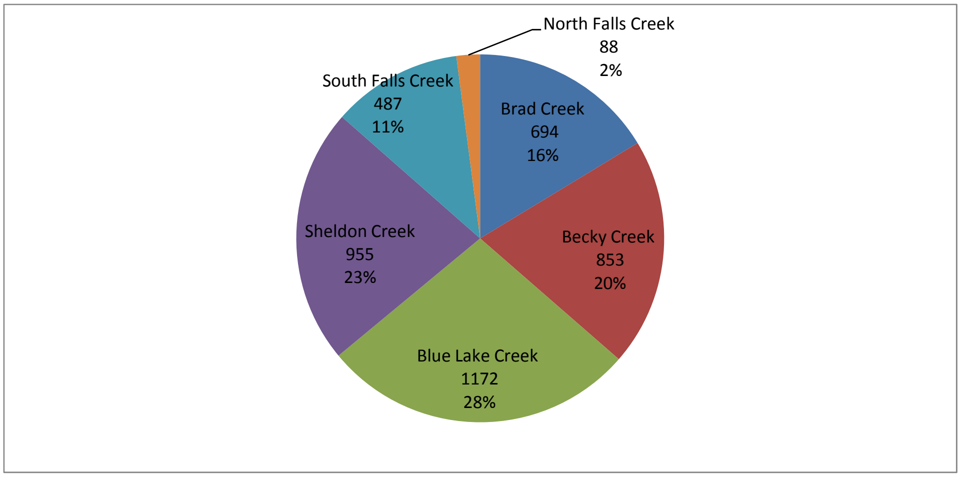


Figure 22. Relative percent abundance and total number of rainbow trout observed during Blue Lake spawning surveys in 2005.

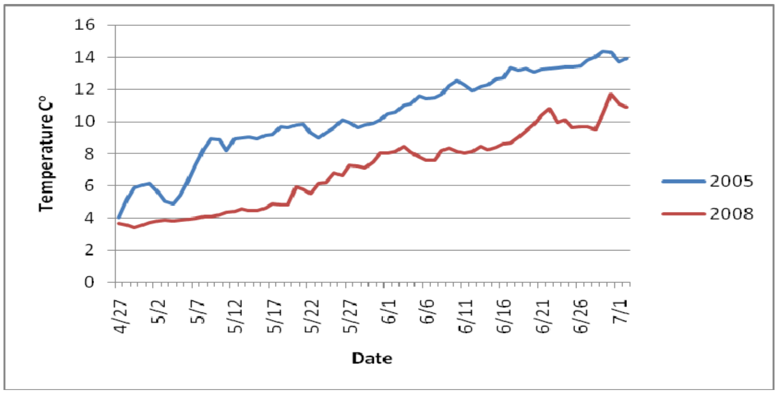
Blue Lake Inlet had a smaller contribution to the overall spawning in both 2005 and 2008 then would be expected in relation to its drainage size (Figure 18, Figure 14). Due to the lack of mature females overwintering above the Lower Barrier Falls, accessible spawning habitat, like at Becky Creek, Sheldon Creek and Brad Creeks, is primarily limited to a short stream segment below barrier falls.

Figure 23. South Falls Creek avalanche debris on June 19, 2008.

Run Timing

Due to a late warming and overall colder temperatures in 2008 compared to 2005, there were slight variations in run timing between the two years (Figure 24). Unusual temperatures have been known to alter the timing of migration (Reiser and Bjorn 1979).

Figure 24. Comparison of 2005 to 2008 lake surface water temperatures at the Boom Log.



In 2005 the run increased more gradually in late May peaked first week of June and decreased rapidly by June 11(Figure 25). There was a more abrupt early in-migration in 2008 than in 2005 (See Figure 7, Figure 25, CBS 2005a) and fish numbers in 2008 peaked around June 11 (See Figure 7, Table 3). In 2008 the run was more prolonged with a larger numbers of fish observed later into the run (See Table 3, Figure 7).

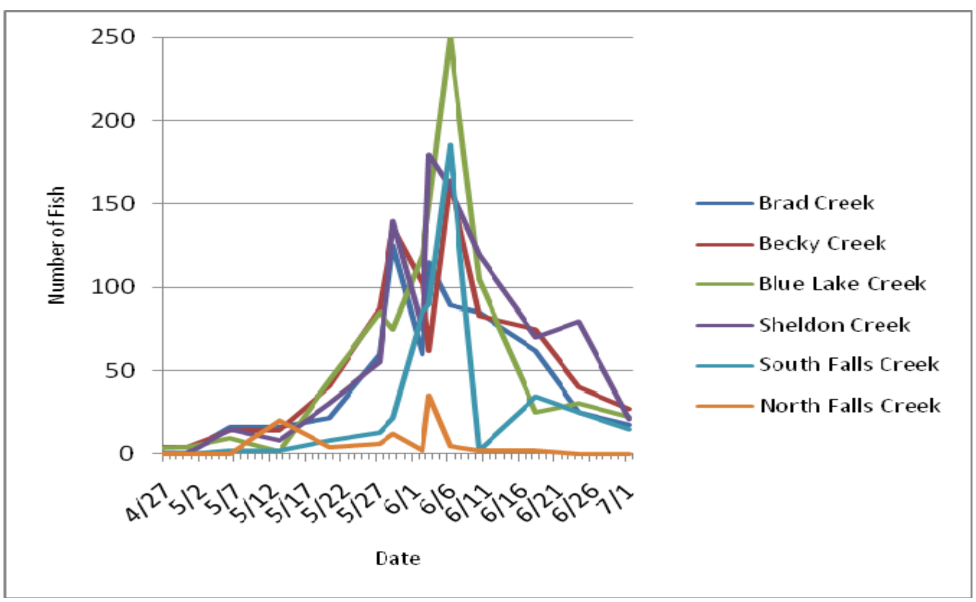


Figure 25. Rainbow trout observed at Blue Lake tributaries during 2005 spawning surveys.

Location of Spawning Areas

As in 2005, the majority of spawning activity in 2008 occurred at the stream-lake interface where a mixture of tributary and lake water temperatures created areas at or near that thought to be preferred by spawning rainbow trout (Behnke 1992, Whitesel et al. CBS 2005).

In 2008 the preferred locations in Becky Creek, Blue Lake Creek, and Sheldon Creek were over old bars that had been overlain by gravel the origin of which appears to be alluvial deposition located adjacent to the stream.

All of these overlain areas in the interface were composed primarily of gravels in the 4-32mm range with the limiting substrate appearing to be cobble (>64mm) which has been determined to be larger than rainbow trout can move (Cochnuer et. al 1986, Corning and Elliot 1987, Raleigh 1984, Shirazi et al 1979, Schuett-Hames 1999). Spawning at Brad Creek in 2008 was at the interface but was more concentrated at the valley mouth similar to areas at Becky and Sheldon in 2005 (CBS 2005a).

It is hypothesized that within the valley gorges, spawning location over bars which are higher in aspect is less critical. This is possibly due to the gorges' incised bedrock features providing a more concentrated inter gravel flow and upwelling. In 2008 upwelling would have been more pronounced through the bars compared to other available areas with suitable substrate and optimum temperatures.

Percent Substrate Composition

Much of the literature places the optimum rainbow trout spawning substrate size in the 4-8mm range with suitability dropping to approximately half that by 32mm (Cochnuer et al. 1986, Corning and Elliot 1987, Sando 1981), and 64mm is often considered the size limit that spawning rainbow trout can move during redd construction (Cochnuer et al. 1986, Corning and Elliot 1987, Raleigh et al. 1984, Shirazi et al. 1979, Schuett-Hames 1999). Our percent substrate composition results were similar with more inter-creek variability between fine gravel to coarse gravel substrates (4 to32 mm). This indicates that rainbow trout in Blue Lake are fairly opportunistic in their substrate preference contingent upon it consisting of predominately fine to coarse gravel and containing low percentages of substrates greater then 32mm.

Emergence

Emergence was not observed in 2008 most likely due to the fact that most of the spawn occurred in areas where emergent fry would be in immediate reach of an expansive area of highly suitable early rearing habitat. During 2005 the lake-stream interface was at or within the tributaries' respective valleys. This created a greater likelihood that emergence would be observed in low velocity side areas within the stream valley prior to finding a more suitable rearing area downstream.

In 2005, emergence was observed as early as July 30th at North Falls Creek and near lakeshore spawning areas and by August 2nd at Brad Creek and Becky Creek. Except for one pool in Becky Creek, warmer lake temperatures eventually influence all available spawning areas to the base of each tributary's respective barrier falls. This influence creates more temperature units (daily degrees centigrade greater then 0^o) enabling faster maturation. This is displayed by the earlier maturation dates at North Falls Creek compared to Reach 1 of Blue Lake Creek.

Even when utilizing the coldest available daily mean temperatures, all emergence would occur prior to these areas being uncovered by decreasing reservoir levels in late fall and early winter.

Adult Utilization

Adult fish counts dropped off after spawning and then increased again in late summer. It's generally concluded that fish spawn near the tributary confluences and then adults and juveniles move back out into the lake until late summer when a portion return to the tributary mouths to feed on invertebrates emanating from the tributaries until winter. Adults appear to overwinter in the lakes. Movement back to lakes after spawning is characteristic of lake and reservoir dwelling forms of rainbow trout (Lindsey et al. 1959). Movement back into tributaries in order to feed and then back into areas of thermal refugia has also been documented in Alaska (Meka 2000 et al.,) as well as the use of lakes for over wintering (Palmer 1998, Northcote 1997).

Juvenile Rearing

Compared to the overall population, few juvenile fish were observed, particularly in the major tributaries. Like adults, juvenile utilization in the tributaries was linked to increased invertebrate activity in late summer and early fall. Juvenile catches during the 2004 population study were highest in the relatively shallow areas at the southeast end of Blue Lake and to a lesser extent in other shallow areas along the margin of the lake.

BLUE LAKE CREEK HABITAT ANALYSIS

Blue Lake Creek Fish Habitat

Results of the habitat analyses show that fish spawning, pool, and adult over wintering habitat upstream of the barrier is low while summer feeding habitat in the form of faster water types with adjacent flow refugia is higher. While rainbow trout will utilize areas near faster water with pools or cobble and larger type substrates acting as flow refugia during peak feeding in the summer, optimum trout habitat for all seasons has been described as having a pool-to-riffle ratio of 1: 1 (Fortune and Thompson 1969; Thompson and Fortune 1970).

With a low sinuosity more associated with steeper, more confined channel types (Rosgen 1994), high flows in Reach Four appear to move key pieces of large woody debris into non perpendicular positions near the stream margins or onto gravel bars which reduce scour pool formation. This reduction biases the pool:riffle ratio towards riffles and other fast water types. Pools that are formed by non perpendicular key pieces scour less of the channel width and tend to be shallower (Flosi and Reynolds 1994). Pools are utilized year round by juvenile and adult rainbow trout, and are critical habitat during low temperatures in winter when they are used extensively (Raleigh et al 1984, Chapman and Bjornn 1969; Everest 1969; Bustard and Narver 1975a,b). Bustard and Narver (1975) also surmised that the amount winter habitat may be the major limiting factor of salmonid densities.

Potential Spawning Area Analysis

Available spawning areas above the Lower Barrier Falls are currently limited since tailouts and riffles contain larger then optimum substrate sizes for trout spawning (Cochnuer et al. 1986, Corning and Elliot 1987, Sando 1981). Gravel substrates were more prevalent in depositional areas adjacent to the main flow created by LWD and or bedrock features, in side tributaries, deep in the pools and in the deep runs just below the Upper Barrier Falls. With few pools, moderate to high confinement, a large width:depth ratio and high flow rates, spawning gravels in the size range suitable for rainbow trout appear to get flushed out from the main channel and other areas with suitable flow below Glacier Creek and tend to be limited to relatively small depositional areas.

BLUE LAKE CREEK LIFE HISTORY

Overall it appears that there was little overwintering of rainbow trout above the Lower Barrier, particularly in the larger fish size classes. Some juvenile and smaller rearing fish were found in this area, primarily in Reach 3, prior to the Lower Barrier breaching, but we were unable to tell if they originated from the lake or were bred in the upper stream. Juvenile fish captures and sightings below the Lower Barrier falls were limited. Fish tagged in the lake and below the Lower Barrier were found to move into the Upper Creek, but by this time spawning was limited to an increasingly small portion of the population.

Adult Utilization

The area above the Lower Barrier contained few deep pools critical for adult winter habitat and long stretches of faster water habitats. Faster water habitats with adjacent flow refugia or shear zones are utilized primarily during optimum feeding periods. Fish that ascend after the Lower Barrier is breached appear to descend back down to the lake as optimum temperatures and feeding behavior decrease. In winter, adult rainbow trout in lotic systems have been shown to move into large deep pools (Lewis 1969), and if this habitat is unavailable trout tend to move downstream during or proceeding winter (Bjorn 1971). The use of lakes by wintering rainbow trout has been documented (Northcote 1997). The apparent late summer in-migration and late fall out migration in Upper Blue Lake Creek appears linked with summer feeding behavior and then the scarcity of large deep pools necessary for winter holdover of larger size class fish. This leaves few adult fish able to utilize spawning areas in Upper Blue Lake Creek when the Lower Barrier is again exposed and impedes in-migration.

Juvenile Rearing

It was shown that there was an overwintering population of juvenile fish in Upper Blue Lake Creek. We are unsure of what the contributions of fish spawning above the falls are to this population. Two factors appeared to influence juvenile fish observations and captures: water temperature in all size classes and the breaching of the falls in the larger size classes (>140mm).

During winter, juvenile rainbow trout exhibit hiding behavior in larger substrate ranging from medium cobble to boulders in areas of slower flows, in pools with woody debris, or other similar microhabitats (Everest 1969, Cambell and Neuner 1985). Since it was unlikely that fish <140 mm would have been able to ascend the Lower Barrier (see Figure 16), the initial increase of juvenile fish on August 5 is likely due to a habitat transition out of hiding areas into feeding areas in response to warmer water temperatures (Chapman and Bjorn 1969, Cambell and Neuner 1985). Warming temperatures also contribute to a greater amount of insect drift which enables efficient feeding at areas of flow refugia adjacent to faster flows. This trend of moving from summer habitat to winter habitat has also been observed downstream in Blue Lake's outlet of Saw Mill Creek.

We are less certain about the larger juvenile size classes (140 to 180mm) that appeared to increase after the falls were breached. Some of the overall lack of data is most likely due to gaps in the age class structure at this size. However it appears from snorkel surveys that some fish in the 140-180 size range move in to feed from below the Lower Barrier. It is hypothesized that due to their larger size, fish in this size class would have more limitations in their use of interstitial spaces for winter hiding behavior and would be more likely to migrate downstream in search of winter habitat.

Colder water temperatures that occur later into the year in Upper Blue Lake Creek could delay transition to summer feeding behavior limiting the growing season as well as contributing to slower growth rates. It appears that the growing season in Upper Blue Lake Creek is comparatively short. Emerging from hiding behavior at 5 C would limit the growing season to approximately 3-4 months compared to 6-7 months in the lake. During this short growing season, fish would also have overall slower growth due to cooler temperatures (Morton 1962, Leitritz and Lewis 1980). This is suggested by scale analysis in the two and three year old age classes in the upper creek appearing slower growing then those in sampled in 1991 in the lake (See below).

Scale Analysis

Scale analysis encompassing a large range of habitats, areas, and years with limited samples makes definitive conclusions difficult. Therefore at this time it is unknown what the exact contributions of various physical habitat factors affecting growth are, but low water temperature is likely the most critical factor in Upper Blue Lake Creek due to its affects on other biological processes.

The influence of relatively warmer ground water upwelling into off channel habitats has been shown to be beneficial in stream salmonid production particularly in winter habitat limited systems (Bustard 1996, Cunjack 1996). The side tributary at SM. 0.40 which contained the largest sizes at age two is indicative of this relationship (See Figure 19).

The shorter length of two year and three year old fish captured in 2008 prior to the Lower Barrier breaching compared to those sampled in 1991 in the lake suggest slow growth and a shorter growing season. Both have been linked to temperature (Haskell 1955, Behnke 1992, Persons 1992).

Lack of first the year's annulus in 5 to 10% of scale samples for all areas and years was likely due to spawning and egg incubation occurring in upper areas at cooler water temperatures which led to later emergence dates. This left little time for growth prior to the onset of winter and could lead to decreased survival (Romey 2003).

Due to the lack of larger age classes (4+) captured prior to the Lower Barrier breaching, and the difficulty in ageing these fish, we are unable to make any comparative inferences at this time.

We are unsure of the reason behind the older age classes sampled in 2008 after the Lower Barrier is breached appearing slightly larger at age than those sampled in 2004. Possible reasons include variable growth rates between areas and years.

Sexual Maturity

Due to variances in stock characteristics and the inherent subjectivity involved, trout sexual maturity studies based on external morphological characteristics have been shown to be problematic (Bangs 2008). To account for these difficulties, fish were often labeled as unknown for either sexual maturity or sexual composition. Unknown sexual maturity decreased in Reach 1 as handlers became more familiar with the characteristics of the stock while unknown sexual composition increased during Event 2 as gametes and spawning characteristics decreased. yet fish still had characteristics indicating previous spawning activities (see Table 29, Table 30, and Table 31).

Although fish labeled as unknown for either sexual maturity or sexual composition reduced data points were able to draw some inferences out of the sexual maturity study.

With a lack of mature females and the presence of small mature males in the upper Reaches of Blue Lake Creek prior to the Lower Barrier Falls being breached it appears that juvenile females leave the upper Reaches prior to maturation. Males are known to mature earlier (Behnke 2002, Quinn 2005) even as early as parr at age 1 (Quinn 2005). Rainbow trout residing in lakes and reservoirs are known to have similar life history pattern to steelhead trout (Raleigh et al. 1984) and Blue Lake rainbow trout are originally derived from Sashin Lake strain of steelhead trout (Der Hovanisian 1994, Chadwick 2004). Non-anadromy is often largely or entirely a male trait in salmonids (Quinn 2005). It appears that most Upper Blue Lake Creek female trout, which would mature at a larger size than males, leave due to 1) winter habitat constraints, 2) a hereditary basis for downstream migration, or 3) a combination of both factors.

The length frequencies of mature fish were similar between the lake inundated area and Upper Blue Lake Creek captured after the Lower Barrier was breached. This is different than our scale data which indicated that the 2008 fish above the Lower Barrier were larger at age then fish sampled in 2004. This is possibly due to differential growth rates between years or habitats as well as the seasonally later capture date.

The percentage of ripe fish observed dropped in all Reaches between Events and was 3-5 % in all Reaches during Event 2. Even without taking into account the late and extended run timing due to colder than normal temperatures, this left few in-migrating fish able to utilize spawning habitat above the Lower Barrier.

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APPENDICES

Appendix 1. Summary of comparative scale samples for 2008, 2004, and 1991.

	July 2008 Event 1	Aug-Nov 2008 Event 2	Late May 1991	Early July 2004 Event 1	Late July 2004 Event 2
Age 1					
n=	0	1	3	0	0
Min		135	79		
Max		135	97		
Median		135	82		
Mode		n.a.	n.a.		
Age 2					
n=	14	4	13	3	0
Min	100	142	121	184	
Max	144	147	168	195	
Median	120.5	143	132	187	
Mode	n.a.	142	132	n.a.	
Age 3					
n=	8	2	10	25	4
Min	126	154	126	180	187
Max	184	179	194	246	262
Median	172	166.5	156	201	200
Mode	n.a.	n.a.	148	201	200
Age 4					
n=	2	4	0	18	4
Min	178	265		180	238
Max	196	328		253	276
Median	187	290		218.5	257
Mode	n.a.	n.a.		n.a	n.a
Age 5					
n=		3		4	0
Min		295		180	
Max		330		272	
Median		316		259	
Mode		n.a.		259	
Age 6					
n=		1		3	1
Min		341		240	245
Max		341		309	245
Median		341		260	
Mode		n.a.		n.a.	
Age 7					
n=		1		1	0
Min		362		260	
Max		362		260	
Median		362		260	
Mode		362		n.a.	
Age 9+					
n=					1
mm=					333

Appendix 2. Draft Blue Lake rainbow trout age analysis.

Blue lake rainbow trout age analysis

I examined rainbow trout scales, collected from Blue Lake near Sitka in 1991 and 2004. I concentrated on counting circuli between annuli to see if I could establish growth patterns that can be used as general guidelines for aging these fish consistently and with a maximum degree of accuracy. The 1991 scales were mounted on slides and viewed with an EYECOM 3000 microfiche reader and the 2004 scales were digitized and viewed on a computer screen. The inability to zoom in on scales with the microfiche reader hampered accurate counting of circuli past age 3 on many fish, especially slower growing, mature fish.

The number of circuli developed before the first annulus varied from 4 to 11 for the Blue Lake samples. A small fraction of the samples (5 to 10%) did not have a defined first annulus based on the generalization that circuli to the first annulus should not exceed the number of circuli between the first and second annuli. Circuli between the first and second annuli varied between 10 and 21 with an average of 14 to 15 circuli. Third year growth ranged from 6 to 21 circuli with an average of 13-14 circuli. The number of circuli formed on the scales between the third and fourth annuli varied widely, from 7 to 24, reflecting the recruitment of some of the fish into the spawning population and possible habitat selection (littoral versus pelagic zones) of the fish being sampled. Habitat selection could also explain the variation of growth observed during the second and third years of growth. The number of circuli formed during the fifth year of growth was lower than the previous three years of growth ([illegible] to 11). The lower number of circuli and the presence of spawning checks on many fish at age 5 indicates that by age 5 most of the rainbow trout in Blue lake are sexually mature. Analysis of older age classes proved to be fairly difficult and numbers of older fish were limited. Examination of scales from these older fish indicated that growth was very slow. In most cases, only 3 to 5 circuli were observed and some cases there appeared to be only 1 or 2 circuli separating spawning checks. The oldest fish I assigned an age to was 10 years old.

Some observations I feel are valid for the Blue lake rainbow trout population are;
1. I found that the range of circuli per annulus varied widely on fish over fish over 3 years of age due to variation in growth rate and age at maturity.
2. Unlike other rainbow trout examined from Southwest Alaska (Minard and Dye Special Publication No. 98-[illegible]), I do not feel that counting each spawning check as two annuli is justified for Blue lake rainbows.
3. Blue lake rainbow trout are generally late spawners. There was little or no plus growth after the spawning check on the scales of fish sampled in late July Also, Karl Wolfe has sampled many fish in July with ripe gametes present.
4. In addition to the littoral and pelagic habitats found in Blue Lake, there are also several fairly sterile inlet streams feeding Blue lake that rainbow trout are utilizing, which may affect their growth rate.
5. Some years showed better growth than others, 1990 and 2003 generally produced more circuli at a given age than other years.
6. There should be an effort made to collect scales from a wide range of lengths and ages of trout from the different habitats present in the system. Having reference collections

would provide training tools and help us monitor the Blue Lake trout population for changes that may occur with the planned dam revisions..