Ecology & Geomorphology of Streams:

A Study of Juvenile Salmonid Habitat in Select Scott River Tributaries

Sponsored by
the University of California Presidential Chair in Undergraduate Education and
the Roy Shlemon Chair in Applied Geosciences

August, 2003

A Study of Juvenile Salmonid Habitat in Select Scott River Tributaries

Final Report

Submitted August, 2003
Fieldwork completed June, 2003

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ECOLOGY AND GEOMORPHOLOGY OF SELECT SCOTT RIVER TRIBUTARIES

INTRODUCTION

Background

The field of watershed science is inherently multidisciplinary, involving a broad array of physical, biological and social sciences. Traditional hierarchical undergraduate and graduate education programs that train students necessarily emphasize in-depth study within a specific discipline. This focused education is vital to producing professionals with useful technical and analytical skills. However, most students who pursue careers in watershed science and related fields rarely work solely within their discipline. Rather, their work is inevitably integrated with other professionals addressing related issues with different skill sets. The ability to work closely and collaboratively with professionals from different backgrounds is fundamental to success in this field.

This course introduces advanced undergraduate and graduate students to multidisciplinary study of stream ecology and geomorphology. The goal of this course is to bring students together from the fields of biology, ecology, geosciences and engineering to collaborate in addressing issues in river, stream and watershed management and restoration. The students form multidisciplinary research teams that evaluate existing information about a chosen watershed or issue. This is then followed by field studies in the watershed that address gaps in understanding or information. The hallmark of this course is its multidisciplinary nature and its hands-on, field-based approach. Each student comes to the course as an “expert” in his or her discipline. They are then required to teach the other team members the basic concepts and methods of their discipline, particularly field techniques. In this way, the students teach their peers, much as it will be in life after their university experience.

This is the second year that this course has been taught. To review the results of the first year’s course, which focused on juvenile salmonid habitat in the Copper River watershed of Alaska, go to: www.watersheds.edu/copper

Research Question

This report contains the results of this year’s stream ecology and geomorphology study. The focus of this year’s effort was on the Scott River of Siskiyou County in northern California—a tributary to the Klamath River (Figure 1).

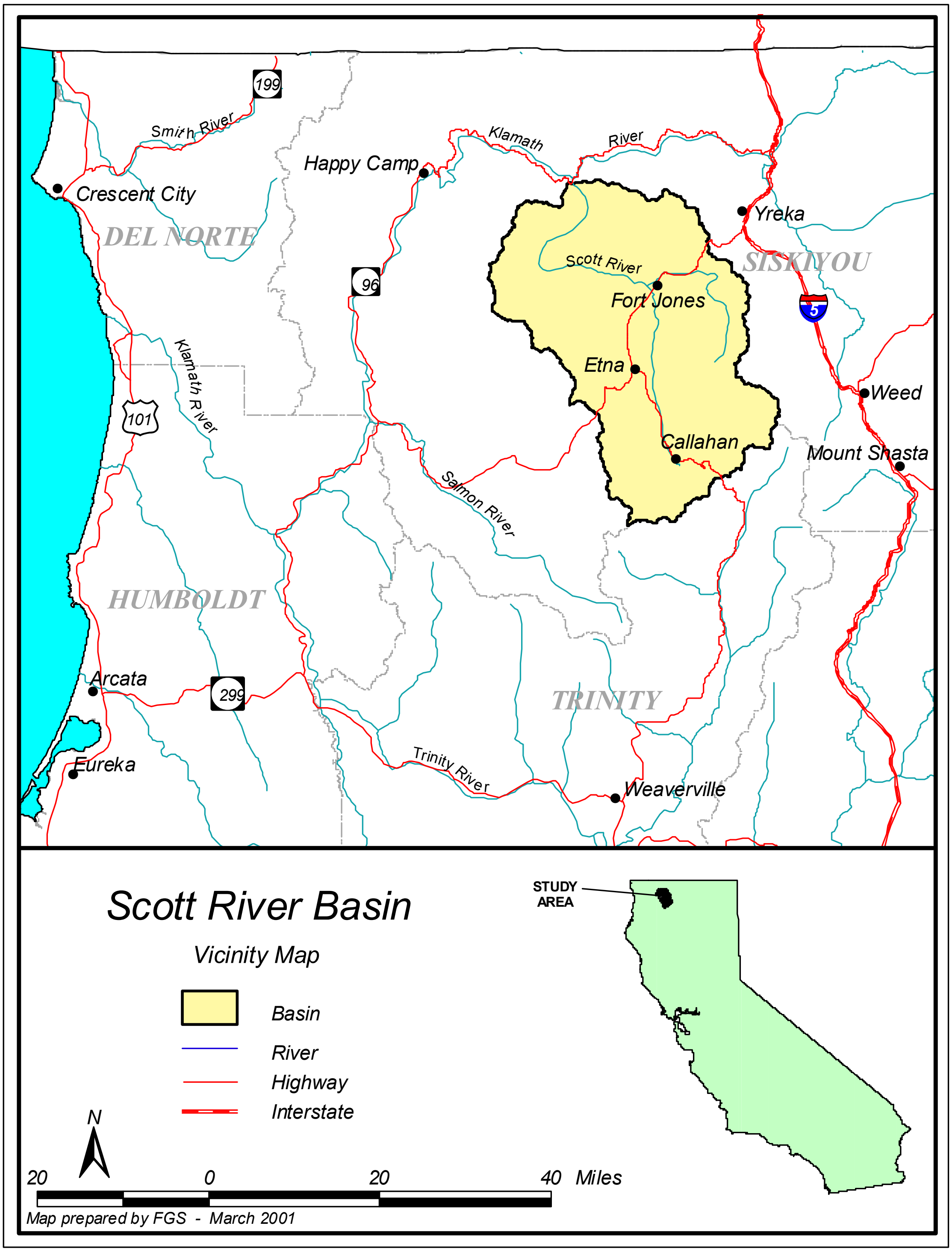


Figure 1. Geographic Location of Study Area.

Figure 1. Scott River Location Map.

The Klamath River watershed has been much in the news over the past two years. Water wars are nothing new in the American west, but the issues affecting the Klamath are particularly acute and complex. The interests of farmers, loggers, hydroelectric suppliers, commercial and sport fisheries, wildlife refuges, several large state and federal bureaucracies, and the multiple Native-American tribes that depend upon the Klamath system have all been impacted by the federal listing of the Lost River and Shortnose suckers in the upper watershed, and the state and federal listing of the coho salmon in the lower watershed (NRC, 2002). This year's course examined one component of this controversy—limitations on coho and steelhead abundance within tributaries to the Scott River.

Recent reviews have demonstrated the significant decline of coho salmon in California over the past 40-50 years (CDFG, 2002). Many factors have contributed to this decline, including ocean conditions, fisheries, dams, water diversions, hatchery operations, and degradation of spawning and rearing habitat. Restoration of coho to large populations requires understanding and addressing all of these factors. The federal and state-listed Southern Oregon/Northern California Coast Coho Ecologically Significant Unit (SONCCC ESU) occurs within most tributaries of the middle and lower Klamath River watershed, below Iron Gate Dam. Within the Scott River watershed, coho are known to spawn and rear in tributaries to the mainstem Scott (CDFG, 2002). The quality of spawning and rearing habitat within these tributaries has been rated as fair to poor (CDFG, 1994, 2002). However, limited specific information exists about habitat conditions in the Scott River, and how these conditions may limit overall coho production.

The students in this course focused their efforts on evaluating rearing conditions for salmonids in general, and for coho specifically, within four tributaries to the Scott River. From north to south, these include 1) Mill Creek and its tributary Emigrant Creek, 2) French Creek, 3) Sugar Creek, and 4) East Fork of the Scott River (Figure 2). As outlined below in the Methods section, emphasis was placed on the lower gradient reaches of these creeks where surveys have documented coho spawning over the past two years (Maurer, 2003). However, to provide an overall watershed context, reaches were surveyed or evaluated in the upper, steeper-gradient portions of the watershed as well. This effort also revealed some of the impacts of upper watershed land use on habitat quality in lower watershed sites. Surveys were conducted from June 16-25, 2003.

Important Caveats

It is important for readers of this report to note that this is a class exercise, not a scientific study of coho in the Scott River. Students conducted all of the work, including data gathering, synthesis and analysis. Because this was a training exercise for students from highly variable backgrounds, data and conclusions of this report should not be used as a precise measure of coho habitat suitability in the watershed. Moreover, this study was conducted during optimal conditions for coho following an unusually cool, wet spring in the

Scott Valley. Unseasonably high flows and cool water temperatures persisted during the surveys. The greatest information about limiting factors associated with poor habitat quality are likely to come from surveys during the late summer/early fall, when high ambient air temperatures and reduced baseflow conditions persist.

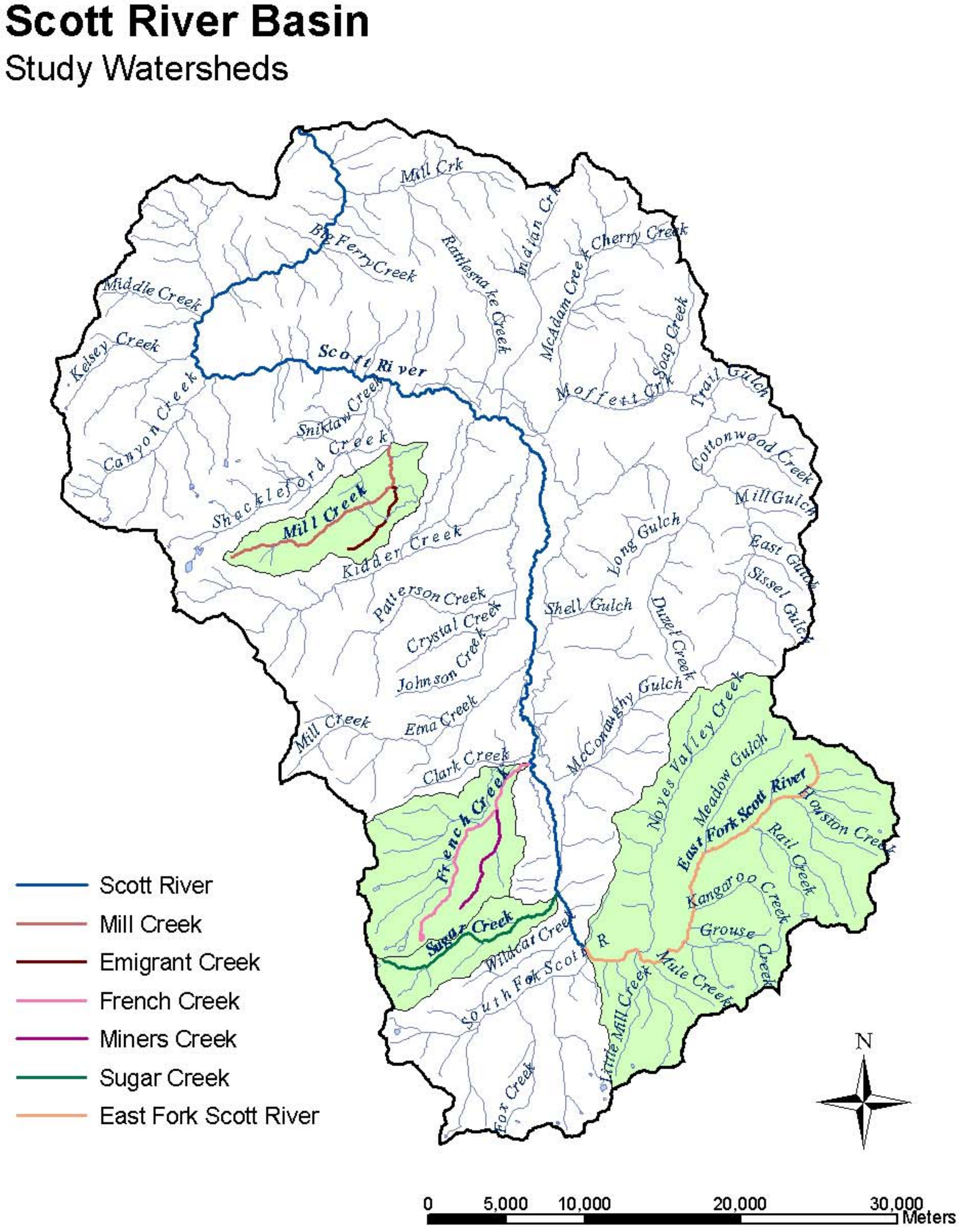


Figure 2. Study Watersheds.

METHODS

In an effort to evaluate stream conditions for rearing of juvenile coho salmon within the tributaries of the Scott River watershed, an integrative approach was employed that evaluated not only a wide range of small-scale site specific parameters, but also the larger-scale watershed context within which each study site lay. This type of spatial hierarchical analysis has been shown to provide a broader understanding of how processes and conditions at one spatial scale control and affect the processes and conditions at a smaller scale (Frissell et al, 1986; Imhof et al, 1996). For example, watershed-scale characteristics such as geologic rock type and vegetative cover directly affect the nature of reach-scale stream habitats, such as the amount of sand in pools and water temperature. Consequently, resource agencies have incorporated these concepts into their stream monitoring and evaluation programs in an attempt to better understand the impacts of land use and management activities on stream habitat conditions (Davis et al, 2001; Fitzpatrick et al, 1998; Lazorchak et al, 1998).

The methods utilized in this course combined techniques primarily from the U.S. Geological Survey's National Water Quality Assessment Program (USGS NAWQA) (Fitzpatrick et al, 1998), the U.S. Forest Service's Field Guide to Stream Channel Reference Sites (USFS) (Harrelson et al, 1994) and the Environmental Protection Agency's Rapid Bioassessment Protocol (EPA RBP) (Barbour et al, 1999) with the specific intent of evaluating several factors that may limit coho rearing success. Those factors included stream habitat availability (channel structure and flow conditions), degree of in-stream sedimentation, water temperature, and relative abundance of food sources (macroinvertebrates). Although many other limiting factors exist for coho rearing success, time limitations associated with this class precluded further analysis.

Sample Reach Selection

Stream surveys were conducted in four tributary watersheds with a known history of coho spawning (Maurer, 2003), specifically, Mill and Emigrant creeks, French Creek, Sugar Creek and East Fork Scott River. Using GIS data provided by the California Spatial Information Library (http://gis.ca.gov/) each watershed was divided into two general sections based on topography, geology and vegetative cover type: an upper watershed dominated by steep slopes, bedrock geology and alpine plant communities, and a lower watershed primarily composed of shallower slopes, alluvial deposits and extensive riparian species. Within these two sections, stream segments were selected for more detailed field study based on landowner approved access. The one exception to this approach was Mill and Emigrant Creeks, where field study was limited to the lower portions of the creeks where access was granted.

For the field study portion of the class, students were divided into interdisciplinary teams of four people and assigned to a watershed. Each team consisted of a student with an academic background in geology, hydrology/engineering, fisheries and aquatic ecology, respectively. Once in the field, each team completed a reconnaissance of their selected stream segments to assess the overall character of the stream habitat and the diversity of the channel morphology. Each segment was classified into geomorphic reach types based on the classification of Montgomery and Buffington (1997). Portions of the stream segments were delineated as one of six reach types based on the dominant geomorphic processes exhibited: bedrock, cascade, step-pool, plane-bed, riffle-pool and dune-ripple. Once the range of reach types present in each segment was determined, each team identified representative sample reaches of a single reach type to survey in detail. Although the number of surveyed reaches varied by watershed, in general at least three different sample reaches were identified in the lower segments of each watershed. Details on the specific survey methods used to characterize each sample reach are described below. Due to time constraints, emphasis was placed on surveying sample reaches in the lower segments of the watershed where coho spawning has been documented. However, stream reconnaissance and reach characterizations were completed in the upper segments of each watershed, and if time allowed, representative sample reaches were identified and surveyed to provide a detailed comparison between habitat availability in the lower and upper watershed.

Sample Reach Surveys

In order to address the specific limiting factors for coho rearing described above, each representative sample reach was characterized using a variety of techniques selectively chosen from the diverse array of USFS, USGS and EPA RBP protocols. Specifically, sample reaches were characterized according to USGS NAWQA protocols (Fitzpatrick et al, 1998), habitat quality was assessed and macroinvertebrates were sampled following the EPA RBP approach (Barbour et al, 1999), channel morphology and substrate texture were surveyed in accordance to USFS Stream Channel Reference Site techniques (Harrelson et al, 1994), and relative fish abundance was determined by snorkel surveys. Standardized datasheets were used by each team in the field and are included in the appendices. Details on each survey technique and the associated datasheet are provided below.

Reach Characterization

Based on the ‘reach’ form used in the USGS NAWQA protocols, a ‘reach characterization’ datasheet was used to document the physical conditions and characteristics of the sample reach (refer to class website). The physical characterization included a description of stream origin and type, documentation of general land uses, indication of the presence or absence of erosional and depositional features, a summary of riparian and instream vegetation features and measurements of discharge and water quality. These data not only delineated the general condition of instream and riparian habitat, but helped to describe the factors influencing the biological condition of the stream.

In order to assess the overall quality of the physical in-stream habitat for biota such as fish and macroinvertebrates, we used the rapid qualitative assessment approach of EPA RBP. Various habitat parameters, such as substrate quality, extent of riparian vegetation, flow characteristics and habitat diversity among others, are evaluated and ranked on a scale of 0 to 20 for each sample reach. Scores increase as habitat quality increases. The habitat assessment forms differ slightly for high-gradient versus low-gradient reaches in order to reflect the coarser substrates inherent to high-gradient streams. Examples of each form are shown on the class website.

The data from the reach characterization and the habitat assessment were then compared between the four study streams to provide a general overview of the physical condition of each stream system. To document the site specific physical characteristics of each sample reach, the entire sample reach was hand sketched on a standard ‘reach sketch’ form (see class website). Although not to scale, the reach sketch provides a snapshot of the current condition and character of the sample reach. Specific details such as log jams, pieces of large woody debris, extent of riparian vegetation, and proximity of pools to undercut banks among others can be documented and later referred to as conditions within the reach change.

Geomorphic Survey Techniques

The geomorphic characteristics of each sample reach were evaluated using the USFS protocols described by Harrelson et al (1994) and recorded on newly created datasheets in order to standardize data collection (see class website for examples). Two cross-section profiles were surveyed in the two most dominant habitat types found within the sample reach. For example, if a sample reach was predominantly riffles and pools, then one cross-section would be surveyed in a representative riffle and one in a representative pool. Data was recorded on the 'Channel Morphology Survey Datasheet' specific to Cross-section Profiles (see class website). A longitudinal profile of the channel bed and water surface through the full length of the sample reach was also surveyed and recorded on a form similar to the cross-sections. Sediment conditions were recorded on the 'Sediment Characterization Datasheet', and included an assessment of the sediment quality, the percent and type of organic material and the distribution of sizes of inorganic material. To determine the grain size distribution through the reach, a Wolman-style pebble count was completed at each cross-section. From this data, D_{16} (i.e. 16% of the total sediment sizes are finer than the D_{16} grain size; representative of the fine sediment fraction), D_{50} (median grain size) and D_{84} (representative of the channel bed roughness) were calculated to provide a more complete picture of the range of sediment sizes deposited throughout the reach.

Macroinvertebrate Survey Techniques

Benthic macroinvertebrates were sampled following the EPA RBP protocols for a single habitat (Ch.7, Barbour et al, 1999). Samples were focused in riffles or runs where macroinvertebrate abundance and diversity is usually highest due to the prevalence of coarse substrate material. A D-frame dipnet was used to collect three sub-samples in three riffles or runs throughout the reach. One kick was completed for 90 seconds at each sub-sample site, and samples were preserved in ethyl alcohol for post-processing following the field effort. Data was recorded on a newly created 'Macroinvertebrate Survey Datasheet' that included information collected in the field (such as local velocity, depth and temperature at the kick site) and information collected during the post-processing of samples. Sub-sample locations were also delineated on the reach sketch form for that sample reach. Post-processing involved sorting the macroinvertebrates and identifying individuals to order and genus. An example datasheet is shown on the class website.

Fish Survey Techniques

Relative fish abundance and diversity in each sample reach was qualitatively evaluated using a snorkel survey of the entire reach length. One or two snorklers would float the reach calling out numbers and approximate size classes of fish observed to a data recorder on the bank. Species, count data, condition and any information on habitat were recorded on the 'Fish Survey Datasheet' (see class website). Surveys ranged in time from one to several hours depending on the length and habitat complexity within the reach. In some cases, locations of large numbers of fish were delineated on the reach sketch form in order to document the spatial distribution of fish relative to habitat type throughout the sample reach.

In addition to the snorkel surveys, one sample reach on each study creek was electro-fished in partnership with California Fish and Game biologists. The electro-fishing effort, although only completed in one sample reach, provided a good validation of the species diversity observed during the snorkel surveys, as well as an opportunity to record individual fork lengths, and thus determine the relative size distribution of different fish species. When graphed, the size data provide a quantitative evaluation of the age classes of each species present within the creek.

Survey Data

The raw data collected within each study watershed is included in the Appendices. Each Appendix is associated with one study watershed, and includes the following data for each survey reach in order: pictures taken in the field, electronic copies of the reach characterization, habitat assessment and reach sketch forms, plots of the cross-section and longitudinal profiles, and graphs of the surface grain size distribution. The raw data for the fish and macroinvertebrate surveys are provided in excel files available both on the final report CD and on the class website.

MILL AND EMIGRANT CREEK

Introduction

Mill creek and one of its tributaries, Emigrant creek, drains the eastern slopes of the Marble Mountains Wilderness Area (Figure 2). Together the streams flow through the Quartz Valley and join Shackleford Creek before draining into the Scott River north of the Quartz Mountains. These creeks differ from one another in that they are very dynamic in response to changing climate, geology, and anthropomorphic conditions. Both creeks showed considerable ability to provide rearing habitat for juvenile salmonids.

Watershed Characteristics

The northeast-facing Mill/Emigrant watershed covers 51.0 square kilometers of the west side of the Scott valley. Mill Creek is the primary tributary to Shackleford creek and Shackleford creek is a tributary to the Scott River. Emigrant Creek is a tributary to Mill

Creek, and the confluence of the two lies roughly 3km south of the Shackleford confluence (Figure 2). A summary of various watershed characteristics is shown in Table 1.

Watershed Characteristics	**Mill/Emigrant Creek**
Watershed Area (km^2)	51.013
Watershed Perimeter (km)	37.248
Watershed Aspect	northeast
Watershed Elevational Range (m)	855 to 2129
Stream Elevational Range- Mill (m)	855 to 1974
Stream Elevational Range- Emigrant (m)	884 to 1245
River Distance on Scott (km)	40
Stream Order- Mill	3
Stream Order- Emigrant	2
Stream Length- Mill (km)	15.1
Stream Length- Emigrant (km)	5.2
Length of all Streams in Wtrshd (km)	41.2
Drainage Density (km per km^2)	0.81

Table 1. Watershed Characteristics of Mill and Emigrant Creeks.

The majority of Mill Creek is under private ownership and management except for the headwaters, which are largely in the Marble Mountain Wilderness Area (under USFS management). In the upper Mill watershed, the dominant vegetation type is mixed conifer, consisting of ponderosa pines, white fir, cedar, and other subalpine conifers. Presumably, historical logging took place on the National Forest land; however, due to limited time and access, a field visit to the upper reaches of the watershed was forgone and the status of logging and its impacts on Mill Creek were not observed. Figures 3 and 4 show specific vegetation cover and geology types throughout the watershed.

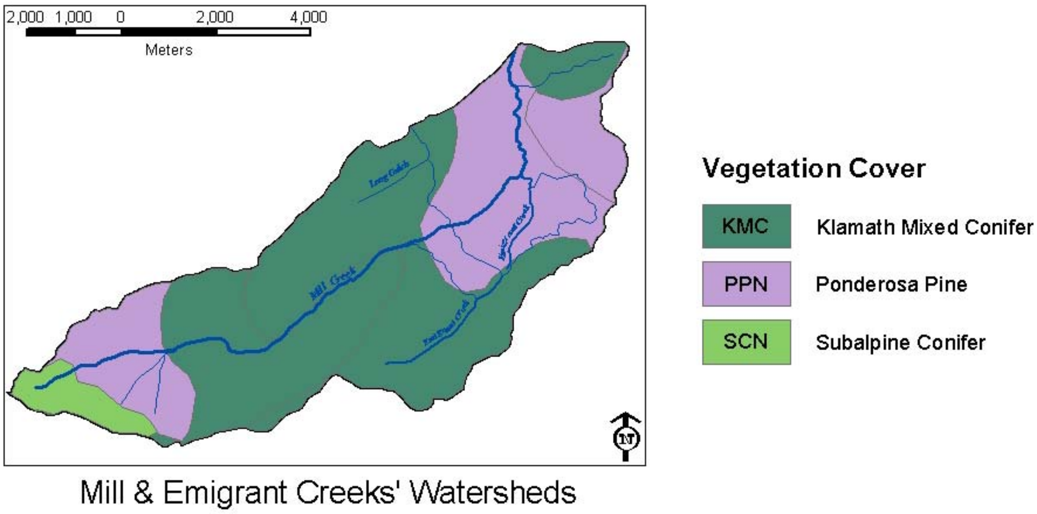


Figure 3. Vegetation types in the Mill/Emigrant Creek watershed.

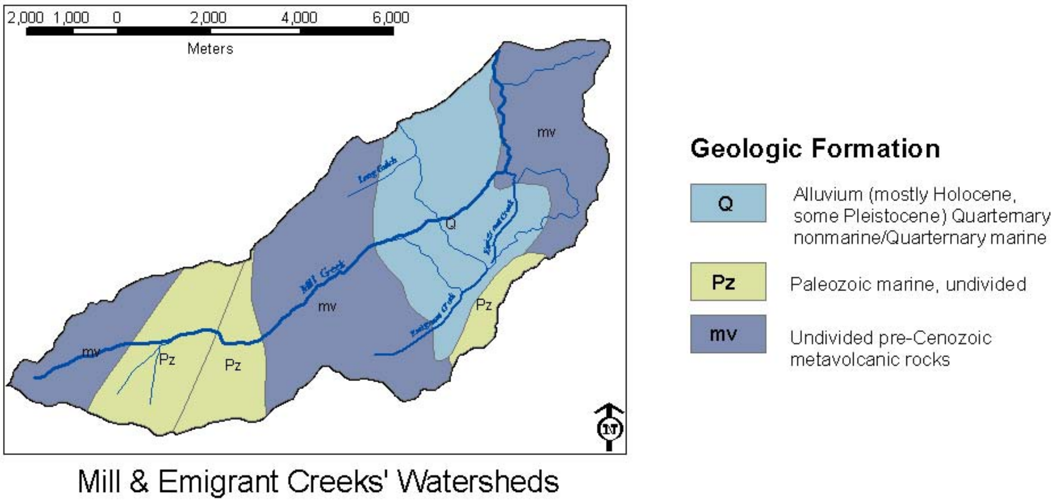


Figure 4. Geology of the Mill/Emigrant watershed.

The land surrounding Emigrant creek is entirely under private ownership and land management. Current land use in the lower watershed and in the Quartz Valley is dominated by various types of agriculture including, pasture, ranching, and hay farming. There are several cattle crossings along Emigrant creek as well as a road crossing on Mill creek. In addition, a majority of the land immediately beside the creeks is fenced off to prevent cattle intrusion. Based on conversations with various landowners in the area, historic placer mining occurred on both Mill and Emigrant creeks, but yields were not profitable and the practice was abandoned. Figure 5 is an overview of land use and ownership on Mill and Emigrant creeks.

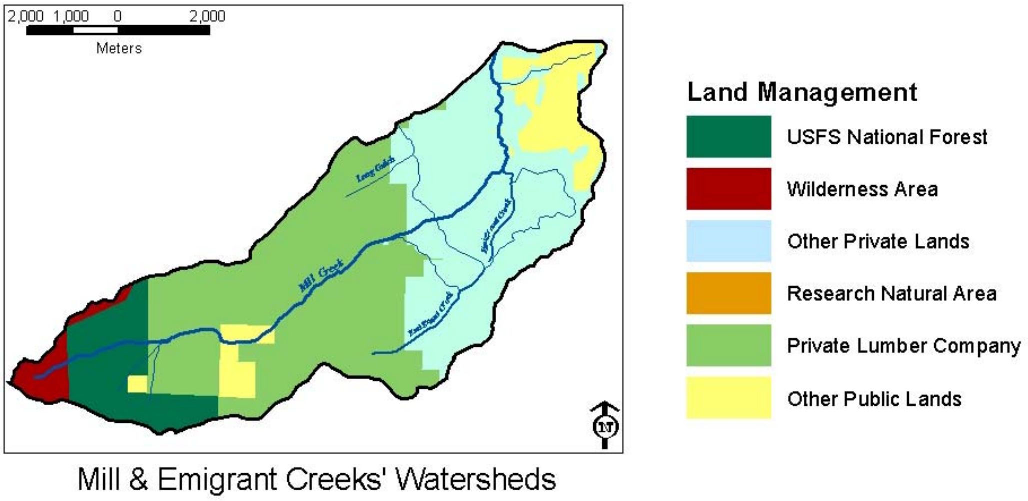


Figure 5. Land use and management in the Mill/Emigrant watershed.

Mill Creek

Several distinct reach types were delineated along Mill Creek according to channel morphology and vegetation influence. The geomorphology of Mill Creek below the confluence with Emigrant Creek is dominated by alternating riffle-pool sequences interspersed with occasional runs. The lower creek is a perennial system of non-glacial montane and spring-fed origin. There is no evidence of any significant erosional features and generally in-stream sedimentation is low. An extensive, continuous riparian buffer zone extends for more than 5 channel widths on either side of the channel. Riparian vegetation is established and is dominated by alder with some cottonwoods. Moderate willow encroachment into the channel is occurring and slight amounts of rooted emergent aquatic vegetation are present. There is one diversion present along the stream in the form of a cobble jetty/dyke extending into the channel diverting water into a culvert on the right bank. Downstream from the diversion is the fish-screened return operated by a paddle wheel.

Mill creek above the confluence with Emigrant creek is similar, with established riparian vegetation. The left bank has an extensive riparian buffer zone of more than five channel widths; however, on the right bank riparian vegetation is limited due to a rip-rap embankment that follows the channel edge. Several springs provide cold inflow into this part of the creek making it perennial. However, a short distance above the confluence, the input of springs and presence of significant riparian vegetation end. A braided, cobble dominated channel and flood plain opens up and both riparian and instream vegetation disappear completely. Several side and overflow channels exist. Scattered ponderosa pines and dry grasses are present further out past the flood plain. Alternating riffle-run habitats with a mixture of small and large cobble dominates the stream morphology. Pools in this section of Mill Creek were seldom, and occurred generally from scour around vegetation. It should be noted that during the survey period, this portion of Mill creek began to dry up and flows receded upstream. Above the braided section, the character of Mill creek changes again as riparian vegetation returns in the form of herbacious plants with scattered cedars, ponderosa pines and black oaks close to the creek. The uppermost section had flow during the whole sampling period. The habitat is predominately riffle-pool habitat with some LWD present in the channel. The channel system in the upper section is anabranched rather then braided due to the presence of permanent islands between channels with established vegetation.

Emigrant Creek

Near the confluence with Mill creek, Emigrant creek is dominated by alternating pool and run habitats. There is a great deal of LWD in the channel, which creates a variety of plunge and scour pools throughout the lower reaches. This part of the creek is deeply entrenched as seen from the undercut banks. There is continuous established riparian vegetation on either side of the channel as well as a great deal of aquatic vegetation. A large amount of emergent vegetation encroaches into the channel. Further upstream, the channel narrows slightly and heavy riparian vegetation is replaced by a variety of meadow grasses. The presence of a previous beaver dam just below the meadow is evident from an old pond scour line and logjams consisting of drowned cottonwoods. According to J. Menke (personal communication) this dam was washed out in a 1997 flood. The dam created a pond that forced the deposition of organic matter and fine sediments ultimately creating the large open grass meadow that is now present. In this meadow portion of the reach there is a small amount of LWD in the channel and a great deal of rooted emergent and rooted submergent aquatic vegetation. Grasses and herbaceous vegetation surround the creek on either side and a cattle crossing traverses the creek in the meadow. Although grazing occurs periodically in the meadow on the left side of the creek, impacts were not evident.

Slightly upstream from the Emigrant Creek cattle crossing on the right bank is the seasonal outflow of the Baird drain and a bit further a left bank inflow of a cold spring. Another riparian forest begins further upstream from where those two inflows enter the channel. A mix of grasses, alder, hawthorn, and old growth cottonwood line the banks for several channel widths on either side. There are some piles of small woody debris gathered by landowners and piled on the right bank on a small flood plain. Continuing further upstream, channel bank slopes increase significantly and some incision can be seen. Huge cutbanks are present in multiple sites along the reach.

As described above, stream characteristics change drastically from the downstream to upstream ends of the sampling areas in both creeks. This provided the opportunity to survey seven almost completely different sample reaches. From these surveys we were able to observe and assess several factors limiting the relative abundance of juvenile salmonids.

Reach Characteristics

Seven sample reaches were chosen and surveyed along Mill and Emigrant Creeks. These reaches were chosen based on the diversity of channel morphology during stream reconnaissance. A layout of these reaches can be seen in Figure 6. Reach surveys included an assessment of general habitat condition, stream geomorphology, water quality, discharge, substrate condition, macroinvertebrate abundance, and relative fish abundance.

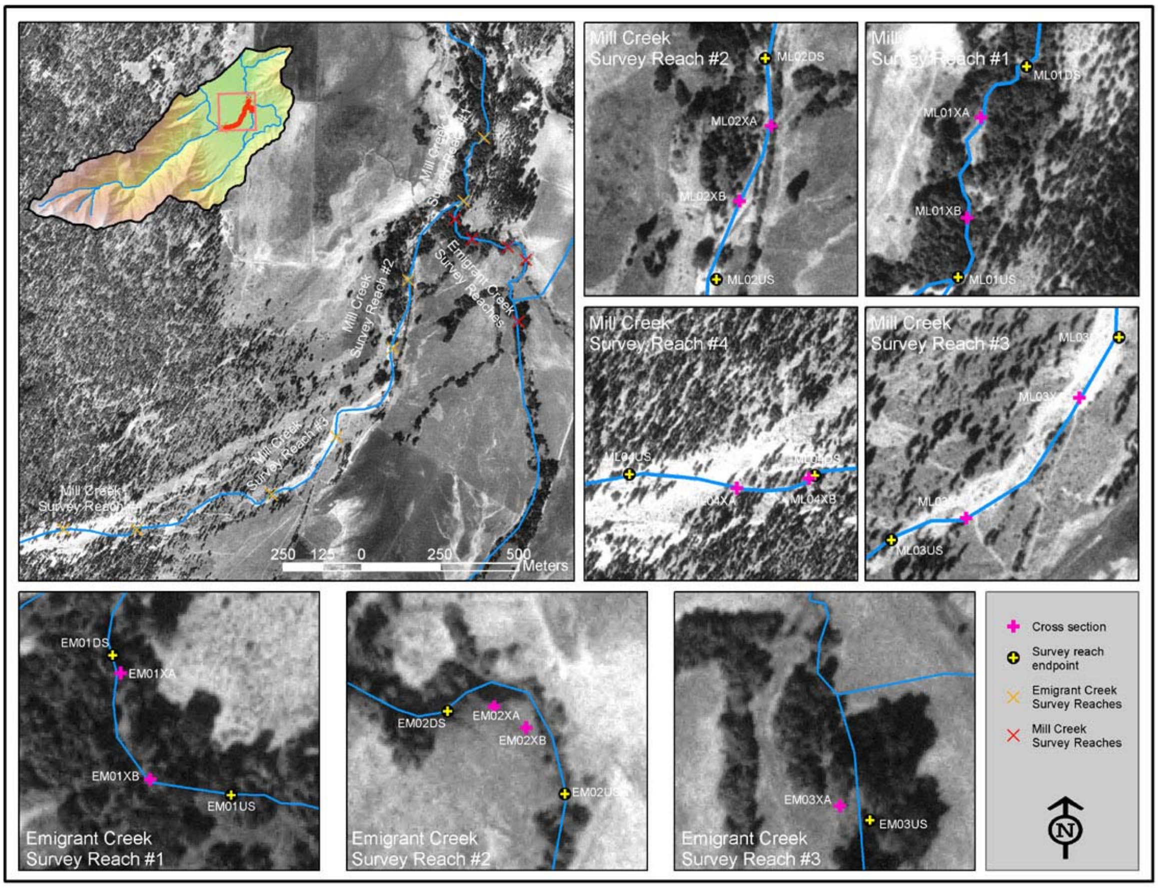


Figure 6. Surveyed reaches along Mill and Emigrant Creeks.

Geomorphology

Four sample reaches on Mill Creek and three reaches on Emigrant Creek were chosen as representative of the types of geomorphic features that may be seen within the Mill Creek watershed (Figure 6). Reach characterization surveys were performed to qualitatively and quantitatively describe the general conditions affecting the morphology of the reach, such as sediment input and vegetative growth. A summary of the geomorphic reach characteristics on Mill and Emigrant Creeks is given in Tables 2 and 3 respectively.

Reach ID	**ML01**	**ML02**	**ML03**	**ML04**
Reach Length (m)	210	230	315	246
Rosgen type	B3	B3	D3	C3
Channel Morphology	single channel	single and multiple	braided	anabranching
Geomorphic Units	riffle-pool	riffle-run	riffle-run	riffle-pool
Hydraulic Characteristics	ripple/waves	ripple/smooth	ripple/smooth	rippled
Surrounding land use	field/pasture	field/pasture	field/pasture	field/pasture
Hydrologic Alterations	Diversion	rip-rapped embankment	no evidence	no evidence
Degree of instream sedimentation	Low	low	low	none
Channel Stability	moderately stable	moderately stable	unstable	moderately unstable
Canopy Cover	partly shaded	partly shaded	open	open
Dominant riparian species	Alder	willows/alder	absent	herbaceous veg.
Vegetation age (yrs)	established (5-30 years)	full range of ages	n/a	immature
Slope (%)	1.17	1.37	0.35	1.89
Width/Depth ratio	60	44	55	11
Sediment Size XSA D16:D50:D84 (mm)	11.3 : 36.8 : 73.5	19.7 : 45.3 : 104.0	14.9 : 45.3 : 104.0	22.6 : 59.7 : 128.0
Sediment Size XSB D16:D50:D84 (mm)	8.0 : 39.4 : 97.0	21.1 : 55.7 : 104.0	9.8 : 52.0 : 78.8	5.3 : 42.2 : 104.0

Table 2. Mill Creek Reach Type Characteristics.

Reach ID	**EM01**	**EM02**	**EM03**
Reach Length (m)	102	107	49
Rosgen type	F4	E4	C4
Channel Morphology	single channel	single channel	single channel
Geomorphic Units	riffle-pool	riffle-pool	riffle-pool
Hydraulic Characteristics	ripple/smooth	ripple/upwelling	ripple/smooth
Surrounding land use	Field/pasture	field/pasture	field/pasture
Hydrologic Alterations	historical beaver pond site	tail water drain above reach	no evidence

Degree of instream sedimentation	Low	low	medium
Channel Stability	downcutting	stable	moderately unstable
Canopy Cover	partly shaded	open	partly shaded
Dominant riparian species	Grasses	grasses and herbaceous vege.	grasses and cottonwoods
Vegetation age (yrs)	established (5-30 years)	established (5-30 years)	mature
Slope (%)	0.44	0.45	0.38
Estimated width/ depth ratio	30	7	5
Sediment Size XSA D16:D50:D84 (mm)	2.0 : 10.6 : 21.1	1.0 : 5.3 : 13.0	2.8 : 8.0 : 21.1
Sediment Size XSB D16:D50:D84 (mm)	1.0 : 3.2 : 10.6	1.0 : 1.0 : 9.2	1.0 : 4.3 : 11.3

Table 3. Emigrant Creek Reach Type Characteristics.

Five of the seven reaches were dominated by alternating riffle-pool sequences interspersed with pools formed by plunge and scour processes due to root wads, emergent vegetation, large woody debris (LWD), or low hanging branches submerged during higher flows. In particular, the lowest segment of Emigrant Creek (EM01) had high quantities of vegetation in and around the channel creating an undulating riffle-pool sequence (Figure 7). There was also at least one case of pool formation due to human activities on Mill Creek (ML03). A small linear stack of larger cobbles and small boulders was placed perpendicular to the flow, crossing the entire width of the channel, and upstream of the stack a pool had been created. In addition, a small, shallow pool had formed immediately downstream of the jetty used to divert some of the water from Mill Creek into a culvert (in ML02).

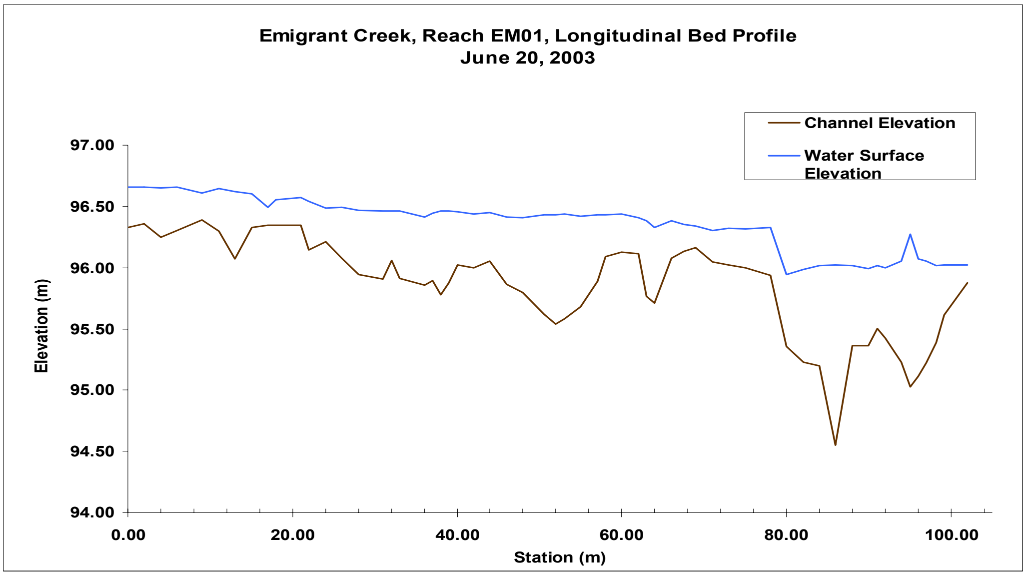


Figure 7. Emigrant Creek, EM01, Longitudinal Bed Profile.

The four reaches on Mill Creek showed a distributary and anabranching pattern in the upstream reach (ML04), with braided and subsurface flow through ML03, followed by converging tributaries in ML02, and finally a more confined single channel type system at the downstream reach, ML01. This pattern reflects the greater geomorphic conditions of the creek as it comes down out of the mountains, crosses an alluvial fan, and enters the Quartz Valley (Figure 8). In ML03, two channels were active during the start of the field surveys, both of which dried up during the course of the study reflecting the cessation of water flowing over at the headwaters of the creek from Mill Creek Ponds (Figure 9).

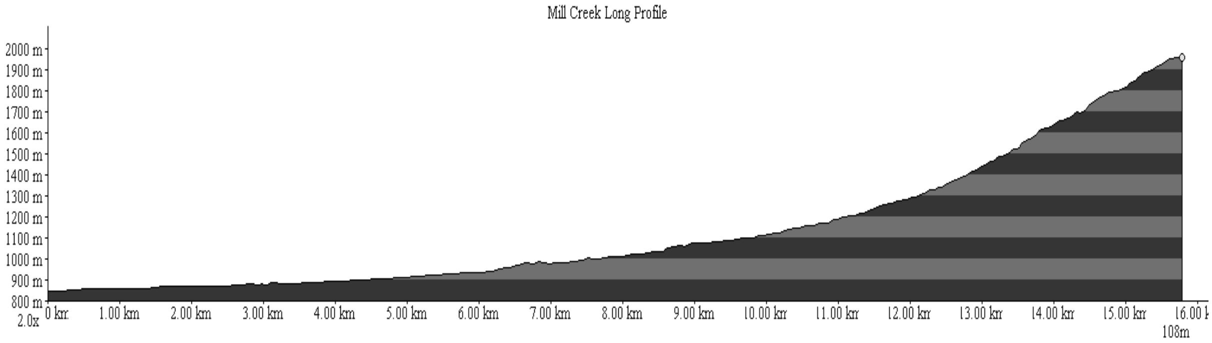


Figure 8. Longitudinal Profile of Mill Creek (confluence to headwaters).

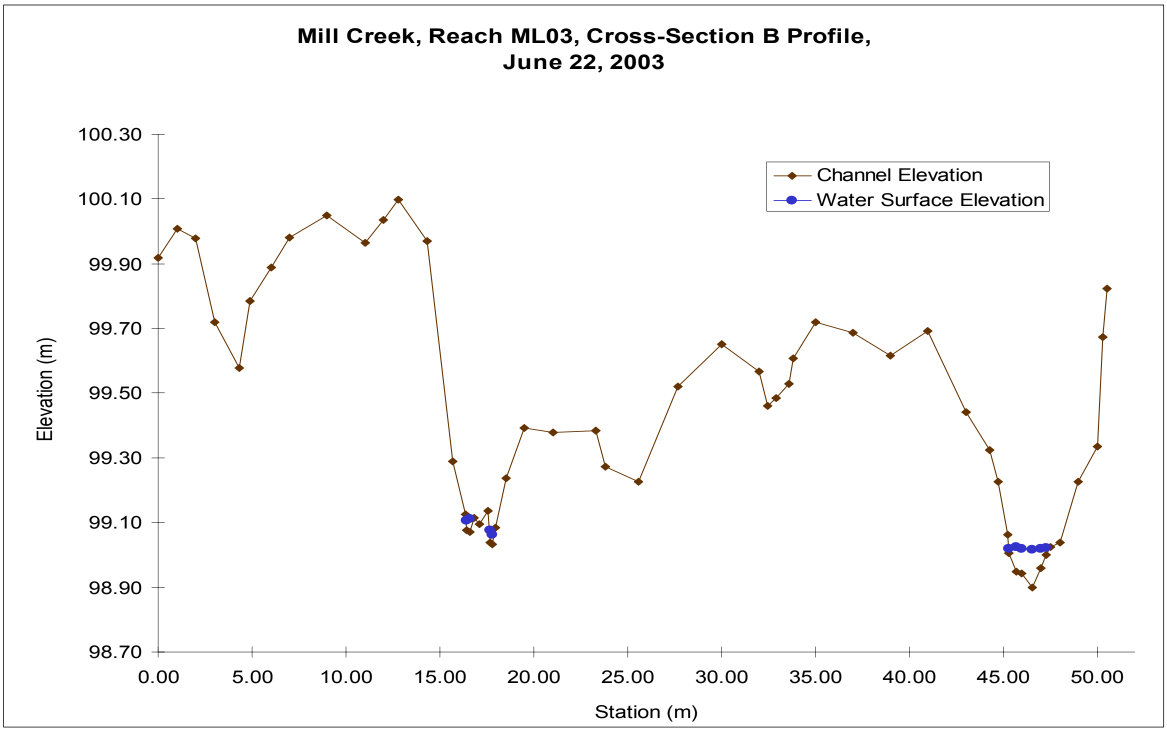


Figure 9. Mill Creek, ML03, Cross Section B.

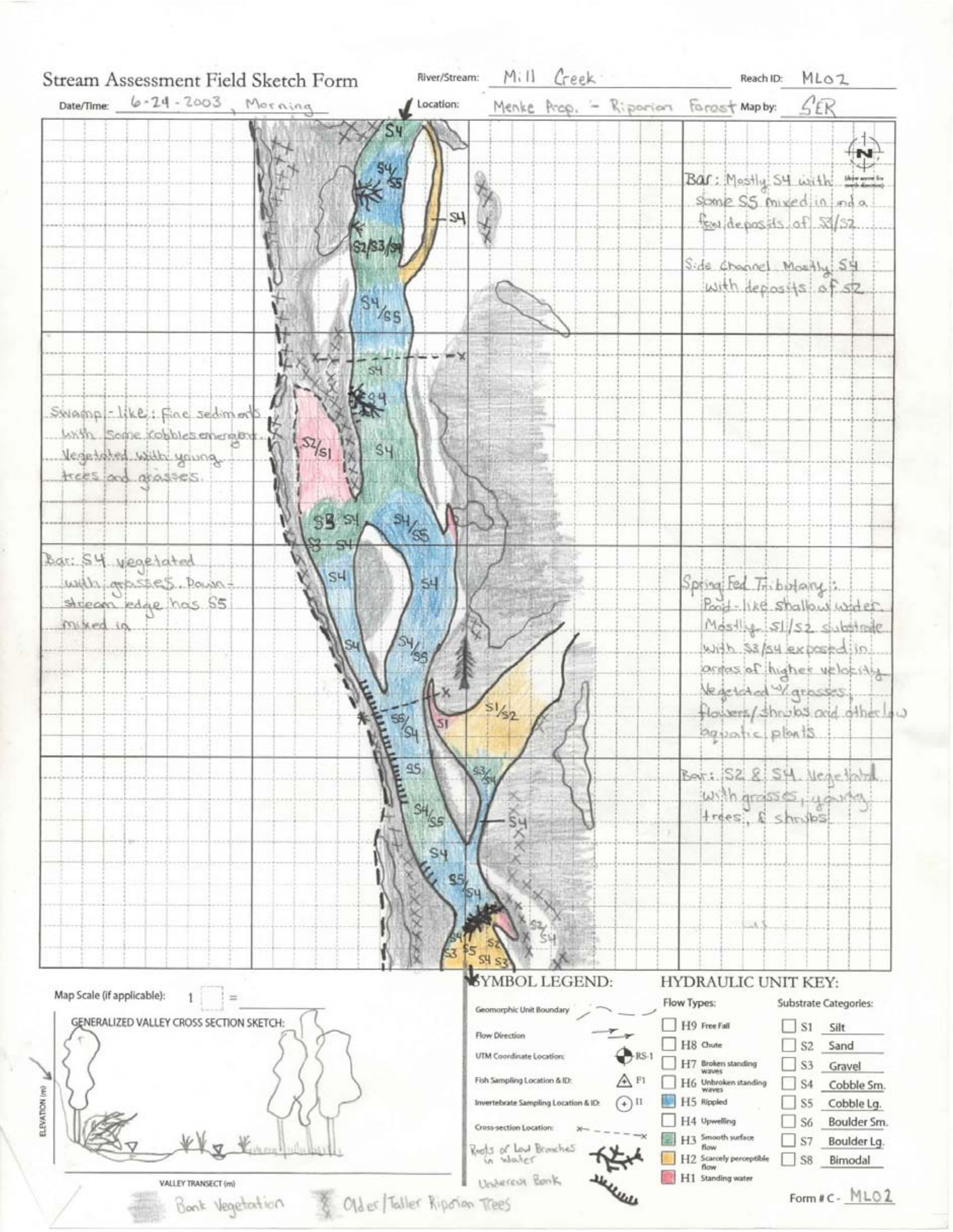
The upper portion of the Quartz Valley has numerous spring fed tributaries to the Mill Creek watershed. These tributaries provide an outlet for the subsurface flow coming off of the alluvial fans created at the base of the mountains. One of these tributaries can be seen in the reach sketch for ML02, where the tributary ponds up over the left bank before spilling down to join the main stem of Mill Creek (Figure 10). These spring-fed tributaries provide a valuable source of cold water to the creek long after flow from the Mill Creek ponds has ceased.

The major tributary to Mill Creek is the single channel Emigrant Creek whose confluence lies between the Mill Creek study reaches ML01 and ML02. Lower Emigrant Creek is spring fed and has continuous flow year round. All three reaches on Emigrant Creek were dominated by riffle-pool sequences, although ML01 had pools due to LWD and vegetation influences, ML02 had them in an undulating pattern, and ML03 had pools on the outside of meander bends in what is considered the "classic" meandering morphology. In addition, all three reaches had evidence of undercut banks, indicating a certain degree of instability likely due to a change in stream gradient which happened during the 1997 floods when a >2m beaver dam which used to be located in ML01 was blown out. Of these three reaches, only EM03 had a well developed, mature riparian forest and associated shade cover.

Emigrant Creek surface sediments, sampled during the Wolman pebble count were of a finer nature than those of Mill Creek. Mill Creek was dominated by a mixture of small and large cobbles throughout all morphology types (Figure 11a). Occasional sands and finer grained deposits were found, but mostly adjacent to unstable banks. Emigrant Creek contained a higher percentage of gravels and fines that filled the interstitial space between the cobbles (Figure 11b).

Hydrology

The discharge of each reach was measured using two methods: the velocity-area method, and the float method. Results of these measurements can be seen in Table 4. Due to the disparity between methods as seen from the data, it is hard to make solid conclusions about flows in these reaches. However, speculations and qualitative estimates can be made despite this, remembering that the velocity-area method tends to be more accurate in deeper water, whereas the float method is most accurate in shallow water.



Stream Assessment Field Sketch Form

River/Stream: Mill Creek
Reach ID: ML02
Date/Time: 6-24-2003, Morning
Location: Menke Prop. - Riparian Forest
Map by: SER

Bar: Mostly S4 with some S5 mixed in and a few deposits of S3/S2

Side channel Mostly S4 with deposits of S2

Swamp-like: Fine sediments with some cobbles emergent. Vegetated with young trees and grasses.

Bar: S4 vegetated with grasses. Downstream edge has S5 mixed in

Spring Fed Tributary: Pond-like shallow water. Mostly S1/S2 substrate with S3/S4 exposed in areas of higher velocity. Vegetated w/ grasses, flowers/shrubs and other low aquatic plants

Bar: S2 & S4. Vegetated with grasses, young trees, & shrubs

Map Scale (if applicable): 1 ☐ =

GENERALIZED VALLEY CROSS SECTION SKETCH:

SYMBOL LEGEND:
Geomorphic Unit Boundary
Flow Direction
UTM Coordinate Location: RS-1
Fish Sampling Location & ID: F1
Invertebrate Sampling Location & ID: I1
Cross-section Location:
Roots or Low Branches in Water
Undercut Bank

HYDRAULIC UNIT KEY:

Flow Types:
- ☐ H9 Free Fall
- ☐ H8 Chute
- ☐ H7 Broken standing waves
- ☐ H6 Unbroken standing waves
- 🟦 H5 Rippled
- ☐ H4 Upwelling
- 🟩 H3 Smooth surface flow
- 🟧 H2 Scarcely perceptible flow
- 🟥 H1 Standing water

Substrate Categories:
- ☐ S1 Silt
- ☐ S2 Sand
- ☐ S3 Gravel
- ☐ S4 Cobble Sm.
- ☐ S5 Cobble Lg.
- ☐ S6 Boulder Sm.
- ☐ S7 Boulder Lg.
- ☐ S8 Bimodal

Bank Vegetation
Older/Taller Riparian Trees

Form # C- ML02

Figure 10. Reach sketch for ML02.

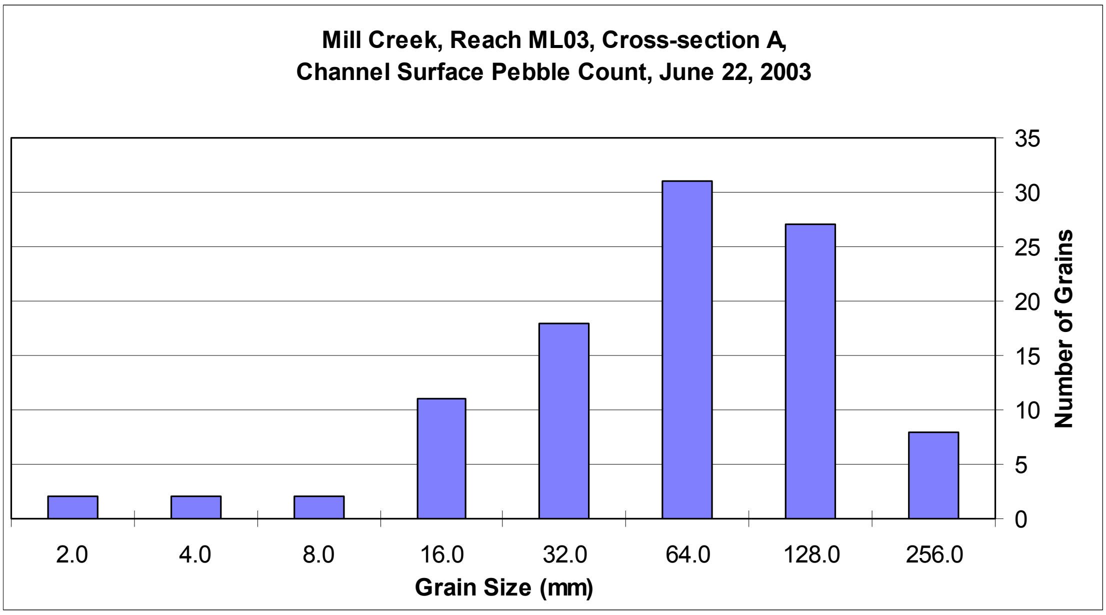


Figure 11a. Mill Creek (ML03) Cross Section A Wolman Pebble Count.

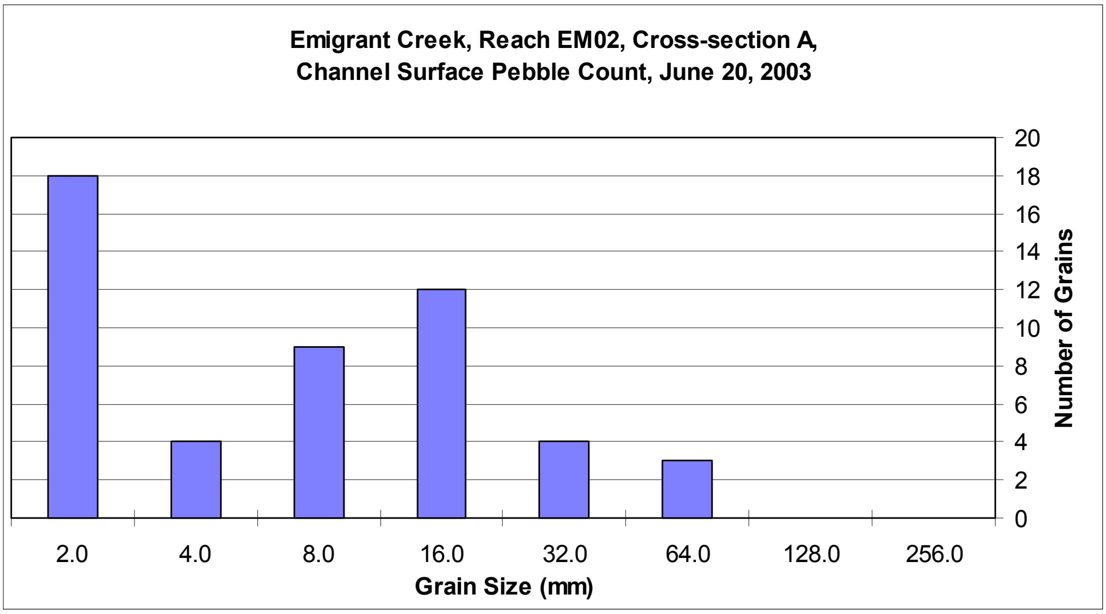


Figure 11b. Emigrant Creek (EM02) Cross Section A Wolman Pebble Count.

Unfortunately, velocities obtained using float-method data seem to contradict this conclusion. According to these values, flows increase between the uppermost and lowermost reaches on Mill Creek. This makes more sense intuitively and would account for the various influxes along the stream. This contradiction is probably the result of problems with the flow meter and extreme variability in the float method measurements related to date and time of measurement. Although some sections of the creek clearly had reduced flows, no conclusions can be made without further study.

Site ID	**Site Description**	**Date**	**Discharge (cms)- velocity-area method**	**Average Discharge (cms)- float method**
ML01	Mill Creek- below Emigrant confluence	6/18/03	0.303	0.875
ML02	Mill Creek- riparian corridor above Emigrant confluence	6/24/03	0.105	0.850
ML03	Mill Creek- alluvial fan flood plain	6/22/03	0.021	0.070
ML04	Mill Creek- just below uppermost Menke property line	6/22/03	0.326	0.197
EM01	Emigrant Creek- right above Mill confluence	6/19/03	n/a	0.450
EM02	Emigrant Creek- meadow	6/20/03	n/a	0.340
EM03	Emigrant Creek- riparian forest with old growth cottonwoods	6/24/03	0.031	0.093

Table 4. Summary of water discharges

Electrical conductivity, (EC), and pH were collected at each of the sample reaches with hand-held meters that were placed in the water to obtain quick and accurate readings. pH readings throughout the reaches were similar, close to pH 7, indicating that pH does not impact water quality and that all the reaches are influenced by the same geologic conditions. Collected EC values, however, demonstrate clear differences between Mill and Emigrant creeks. EC readings, which are a measure of salinity, on Emigrant creek were clearly higher than those recorded on Mill creek, (see Table 5). Mill creek EC readings also increased downstream after the Emigrant confluence. This suggests an influence of agriculture runoff or an ag-return drain somewhere on the creek providing an influx of salts to the system.

Water temperature data for the multiple reaches were collected in two different ways. Continuous sampling (15 minute intervals) was completed by thermisters placed in various key points along Mill and Emigrant creeks, and spot measurements were taken by hand with a thermometer at the same time pH and EC measurements were collected.

Point temperature data collected for the different reaches, shown in Table 5, were quite variable due to the fact that readings were taken at different times on different days throughout the survey period. However, the thermister data clearly shows diurnal fluctuations and relationships between temperatures on the upstream and downstream portions of the reach.

Site ID	**Site Description**	**Time**	**Date**	**Temp (˚C)**	**pH**	**EC (µs)**
ML01	Mill Creek- below Emigrant confluence	12:15pm	6/18/03	15	7.2	70
ML02	Mill Creek- riparian corridor above Emigrant confluence	9:20am	6/24/03	13.4	6.8	67
ML03	Mill Creek- alluvial fan flood plain	9:30am	6/22/03	12.5	7.4	57
ML04	Mill Creek- just below uppermost Menke property line	n/a	6/22/03	15.4	7.2	57
EM01	Emigrant Creek- right above Mill confluence	8:45am	6/19/03	12.8	6.8	117
EM02	Emigrant Creek- meadow	10:00am	6/20/03	13.8	6.7	114
EM03	Emigrant Creek- riparian forest with old growth cottonwoods	12:55pm	6/24/03	14.7	6.7	111

Table 5. Summary of water quality

Figure 12 shows the thermister data collected from the furthest upstream and downstream segments of Mill creek, as well as ambient air temperatures from June 17 to June 26. Upstream water temperatures showed larger daily fluctuations with greater maximum and minimum values, while downstream, the range of temperatures was smaller. This difference in temperature ranges is likely due to greater riparian cover in the downstream reaches. In the upstream reaches, with little to no riparian shade, water temperatures were more susceptible to ambient air temperatures. This suggests that during a sustained period of higher ambient air temperatures, such as in mid-summer, the portions of the stream with little canopy cover will likely exhibit higher water temperatures for a sustained period as well. Increased water temperatures can have negative impacts on native salmonids, specifically juvenile coho salmon which typically require that daily maximum temperatures generally remain below 18 ˚C (Moyle 2003).

Three additional thermisters were placed around the confluence the Baird drain in Emigrant Creek. One thermister was placed in the Baird drain about 7m upstream from the confluence with Emigrant. The other two were placed on Emigrant Creek, 15m upstream and

15m downstream from the confluence. The data can be seen in Figure 13. The inflow from Baird's drain is warmer than Emigrant creek and daily maxima at the downstream site seem to be greater than the upstream site. This suggests that the Baird drain plays a role in slightly warming downstream creek temperatures.

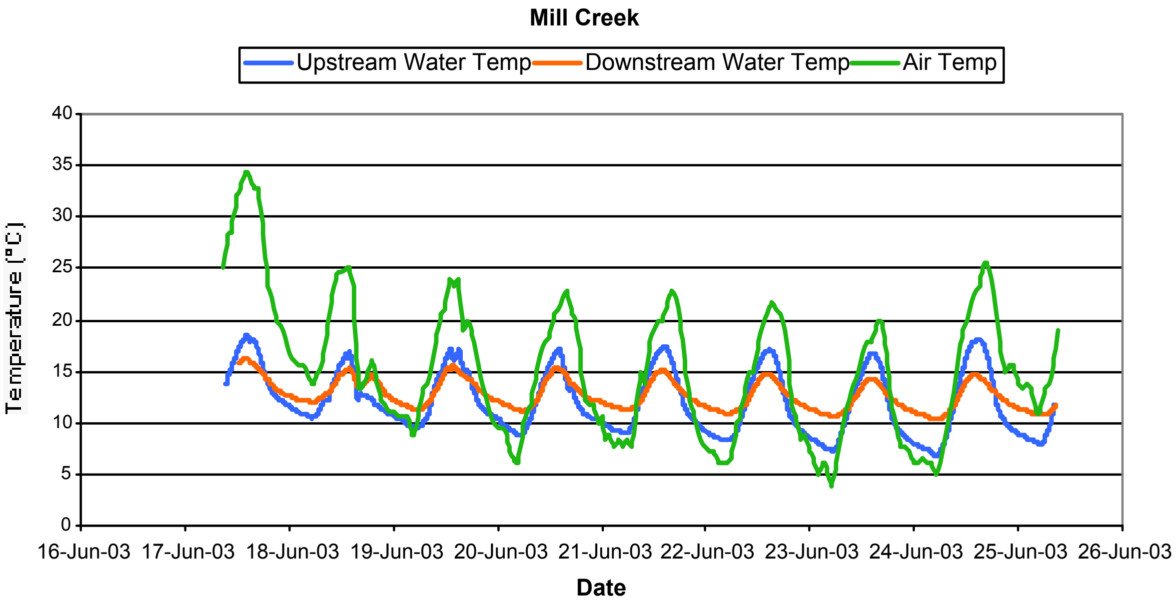


Figure 12. Thermister data from upstream and downstream locations on Mill creek from June 17 to June 26, 2003

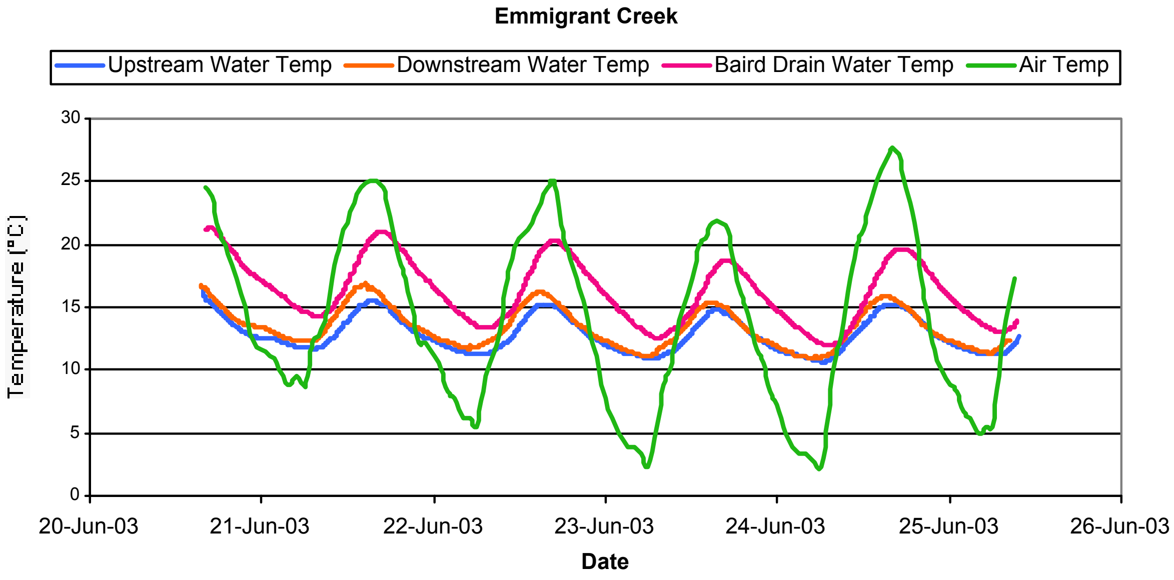


Figure 13. Thermister data from upstream and downstream locations on Emigrant Creek and Baird Drain from June 17 to June 26, 2003

Macroinvertebrates

Macroinvertebrates were sampled in each reach in three locations using a kick net. Velocity and temperature was recorded at each sampling site as well as a description of the reach type. Samples were generally taken in fast flowing riffles except for the first sample in ML01, and the second in EM01, which were taken in runs. The third sample in EM03 was taken in a pool. Sampling areas tended to be dominated by cobble along Mill creek, and by gravel on Emigrant creek. One sample on Emigrant creek was taken in sand. Depths for sampling averaged 0.17m, but ranged from 0.05 to 0.4m. The average sampling velocity was 0.3m/s and average temperature was 14.4 °C. Characteristic sampling locations can be seen in the reach sketches shown in Appendix A.

Total numbers of macroinvertebrates per reach on Mill creek decreased in an upstream direction, but increased upstream on Emigrant creek (Figure 14). These opposite trends could be due to the lack of riparian cover in upper Mill creek as well as receding flows during summer. On Emigrant creek this trend was most likely an effect of increased canopy cover and good habitat in the upper reaches.

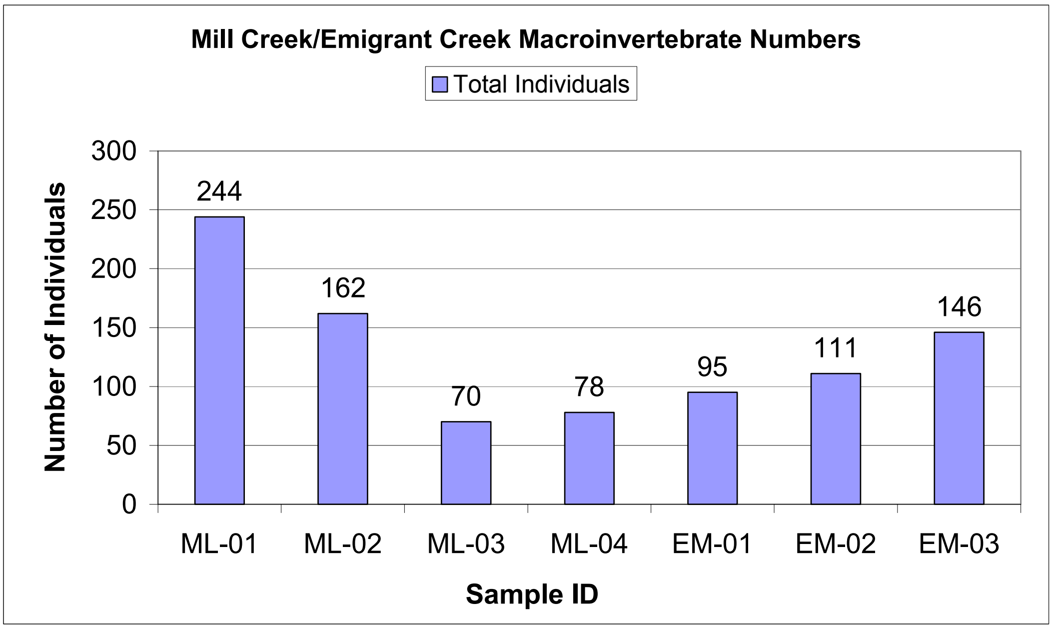


Figure 14. Total number of individuals sampled on each reach

A total of nine different orders were found throughout the two creeks. While there was little variation in the taxa richness of Mill creek, the taxa richness increased in an upstream direction on Emigrant creek (Figure 15). Low variation in substrate content on Mill creek could account for the lack of variation in taxa richness, whereas on Emigrant creek, perhaps the presence of more submerged macrophytes heightened richness by providing more habitat.

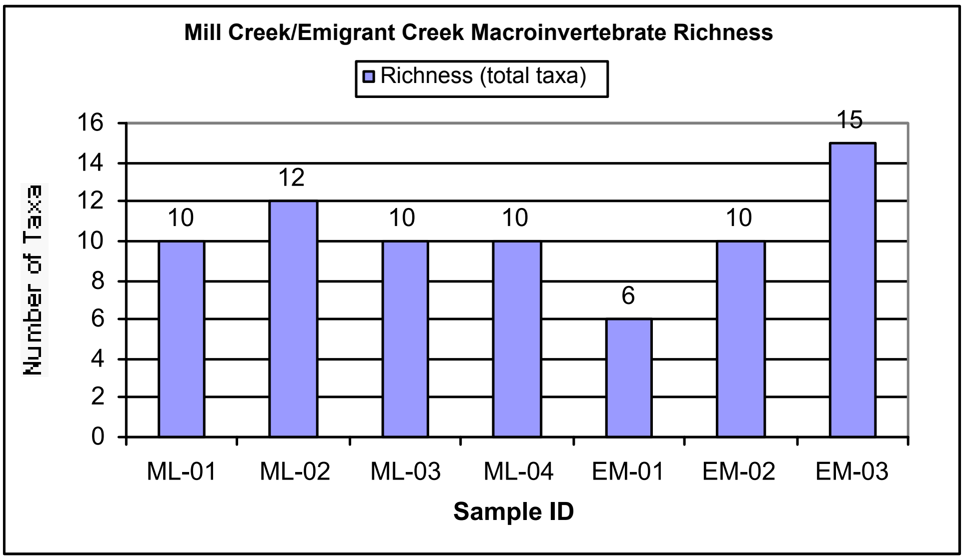


Figure 15. Macroinvertebrate richness on each sampled reach

Some important trends to note regarding the EPTD numbers (Figure 16) included a decrease in the number of Ephemeropera and Diptera in the upstream direction on Mill creek but little change in Plecoptera totals. On Emigrant creek there was an increasing trend in Plecoptera numbers upstream as well as large numbers of Diptera throughout the reach. Plecoptera are less tolerant of degraded stream conditions and the greater number of Plecoptera on Emigrant creek suggests a healthier stream. The increase in total individuals in the upstream direction on Emigrant creek can be accounted for by the increase in aquatic vegetation, which provides food. The higher total Ephemeroptera and Diptera levels on Mill creek can be explained by the presence of cobble-dominated substrate which provides better habitat and colonization potential.

EPT ratios, which can be a good indicator of stream health and total number of species richness, were calculated for each reach and can be seen in Figure 17. A lower EPT ratio generally means a healthier stream. It was found that the EPT ratio for Mill creek decreased moving upstream and increased upstream for Emigrant. From visual observation of the environment together with comparing total individual and taxa numbers, the EPT ratio for both creeks does not reflect actual stream conditions. The EPT ratio on Emigrant creek increased because total numbers of insects on Emigrant increased as well as total number of taxa. Due to this increase in numbers and taxa, upper Emigrant creek was healthier than what is shown with the EPT ratio. With this same reasoning, the lower reaches on Mill creek were healthier than upper Mill creek.

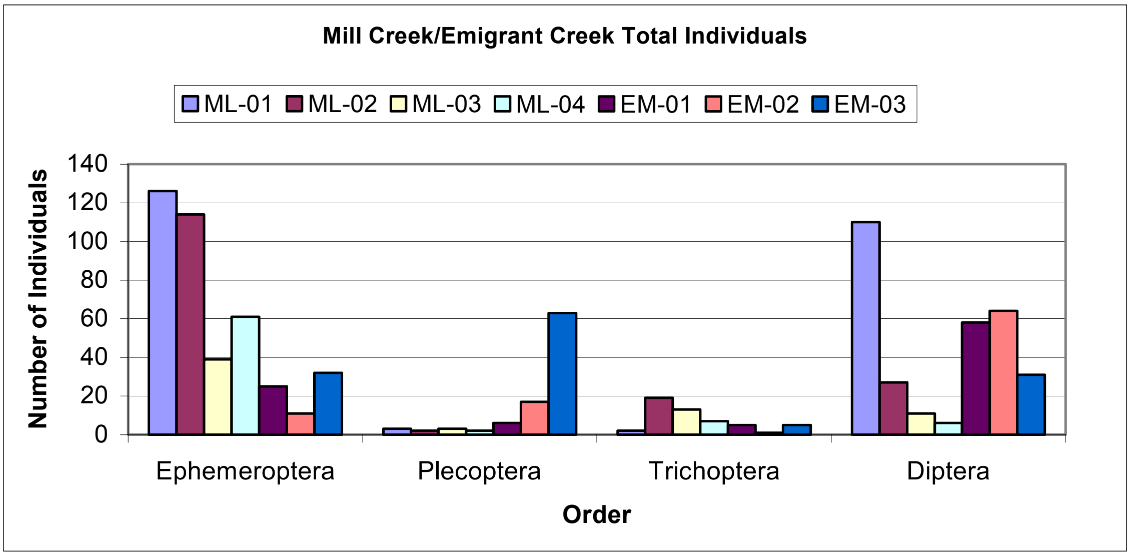


Figure 16. EPDT totals on each reach

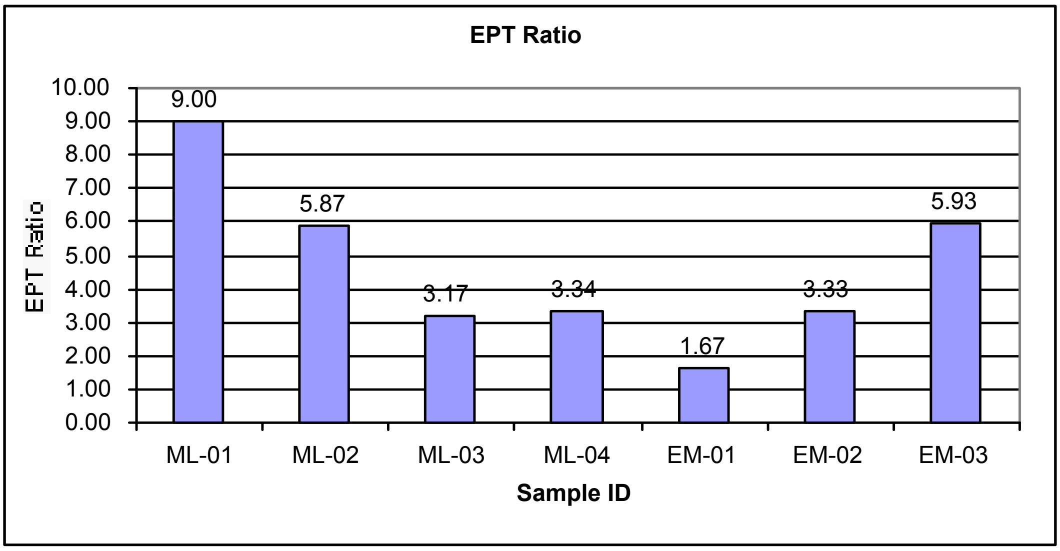


Figure 17. EPT ratios at each reach

In order to obtain a more complete view of macroinvertebrate diversity, a greater number of sampling methods should be used. Sampling habitat types other than riffles, and employing a greater variety of techniques, such as rock baskets on Emigrant creek, would provide a better assessment of stream conditions.

Fish

Overall, 5 native species were observed in Mill and Emigrant Creeks (Figure 18). The most common anadromous fish observed were juvenile rainbow trout (steelhead, *Oncorhynchus mykiss*), and they were found in all five reaches surveyed in these watersheds. Juvenile coho salmon were found in both streams, including above the receding diurnal hyporeic flows in Mill Creek in the most upper segment (ML04). In Emigrant Creek, juvenile coho were common and continued to be present far above the upper segment (EM03). The only segment where juvenile coho were not present was in the Mill Creek segment that was drying up (ML03). A lamprey (*Tridentata sp.*) was also observed in EM02 and speckled dace (*Rhincythus osculus*) were frequently observed snorkeling in all sampled reaches of Emigrant Creek. A small number of Marbled sculpin (*Cottus klamathensis*) were observed in the lower segments of Mill Creek (ML01) and Emigrant Creek (EM01 and EM02).

Reach	Area (m2)	Coho salmon	Steelhead	Speckled dace	sculpin	unknown salmonid	Sum
ML01	1155	53 (14)	323 (84)	0	1 (0.3)	6 (2)	383 (100)
ML02	520	28 (7)	351 (93)	0	0	0	379 (100)
ML03	862.5	0 (0)	24 (100)	0	0	0	24 (100)
ML04	1107	10 (24)	32(76)	0	0	0	42 (100)
EM01	459	36 (32.1)	62 (55.4)	6 (5.4)	0	8 (7.1)	112(100)
EM02	214	50 (26)	127 (65)	16 (8)	0	1 (1)	194
EM03	73.5	12(8)	143 (92)	0	0	0	155
Sum		189 (14.7)	1062 (82.4)	22 (1.7)	1	15 (1.2)	1289

Figure 18. Number of fish observed in each reach. Number in parathenesis is percent composition within each reach.

A single surveyor completed all snorkeling in Emigrant and Mill Creeks. Juvenile rainbow trout were the most common fish observed and their numbers decreased in the upper reaches of Mill and Emigrant Creeks. They constituted between 54-100% (Average= 73%) of the fish observed in sample reaches. Juvenile coho were the second most frequently observed fish, and ranged from 0.0-30.0% (Average=16.0%) of the fish sampled within each site. Juvenile coho were not present in ML03, which was drying up during the survey period, although 24 young-of-the-year trout were found in this section. In EM01, juvenile coho were 30.0% of the fish visually observed and this high frequency could be representative of progeny of spawning Mill Creek coho migrating up Emigrant Creek to utilize the cold and productive water in this stream. Although juvenile coho were observed to be a variety of sizes, none were determined to be 1+ size. Other native fish (speckled dace, lamprey, and Marbled sculpin) were uncommon in all sampled reaches. Lamprey were only observed using electrofishing. In EM01 and EM02, speckled dace accounted for 5% and 8%, respectively, of the fish visually surveyed. The reaches with perennial water (EM01-03, ML01, and ML02 contained the highest densities of fish. (Figure 19).

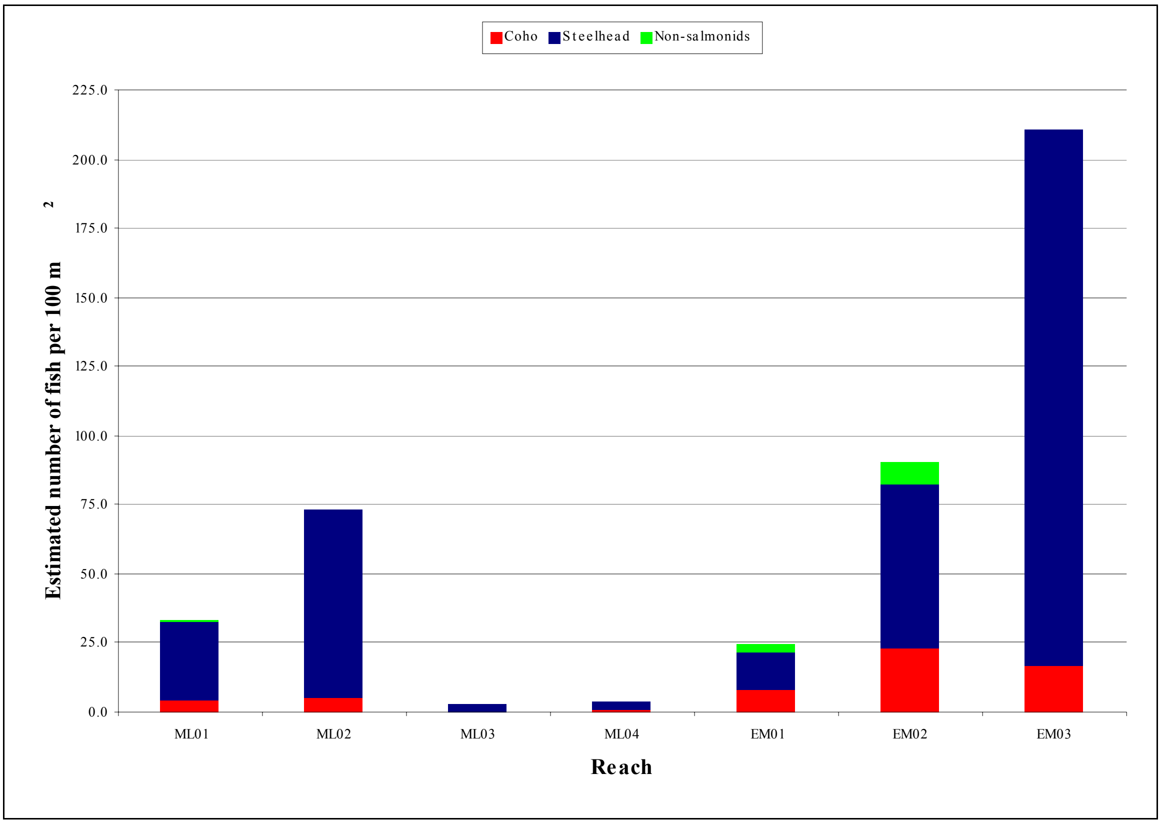


Figure 19. Estimated number of fish per 100 meters in each reach.

The perennial flows on portions of Mill and Emigrant Creek have allowed the native resident fishes to form multi-age class assemblages. Three size classes of Marbled sculpin and speckled dace were found in Mill and Emigrant Creeks (Figures 20a and 20b).

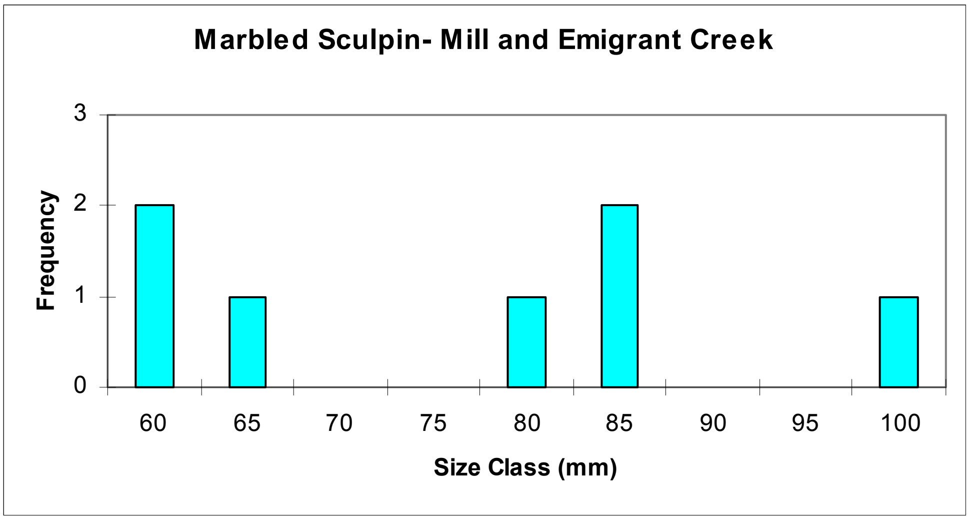


Figure 20a. Marbled sculpin size classes.

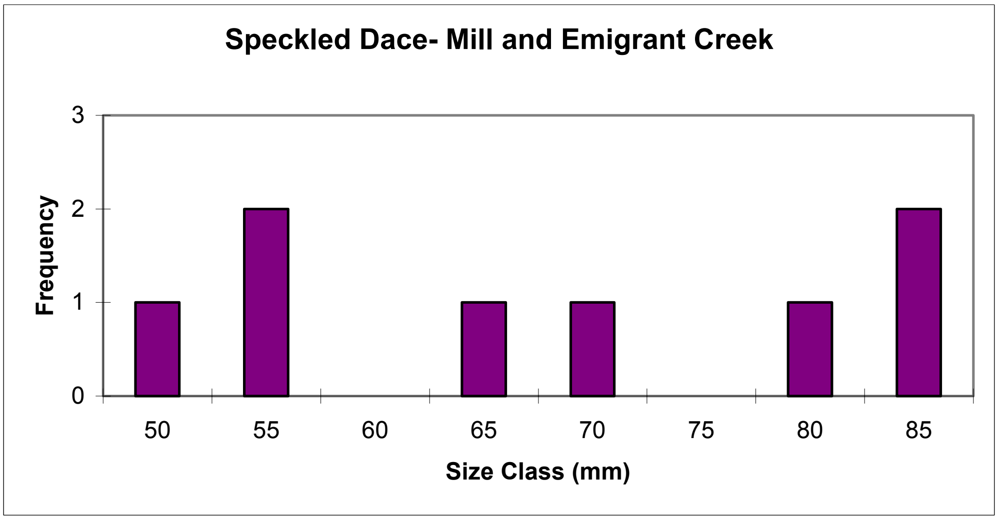


Figure 20b. Speckle dace size classes.

In Mill Creek at least two age classes were observed based on the electrofishing effort, while at least 3 age classes of trout with considerable habitat preferences were observed while snorkeling. Although temperatures were warmer in Mill Creek, a large proportion of juvenile trout electrofished were smaller than those found in Emigrant Creek (Figure 20c and 20d). This may be because smaller fish do not have the swimming ability to make it up into Emigrant Creek, suggesting that the trout found upstream were progeny of Mill Creek spawning steelhead. It is also possible that spawning occurred later in Mill Creek than Emigrant Creek or that habitat conditions in Emigrant Creek are more favorable such that growing rates are simply higher than in Mill Creek. Juvenile coho salmon show a similar relationship in young-of-year size when compared between Emigrant and Mill Creeks (Figure 20e and 20f).

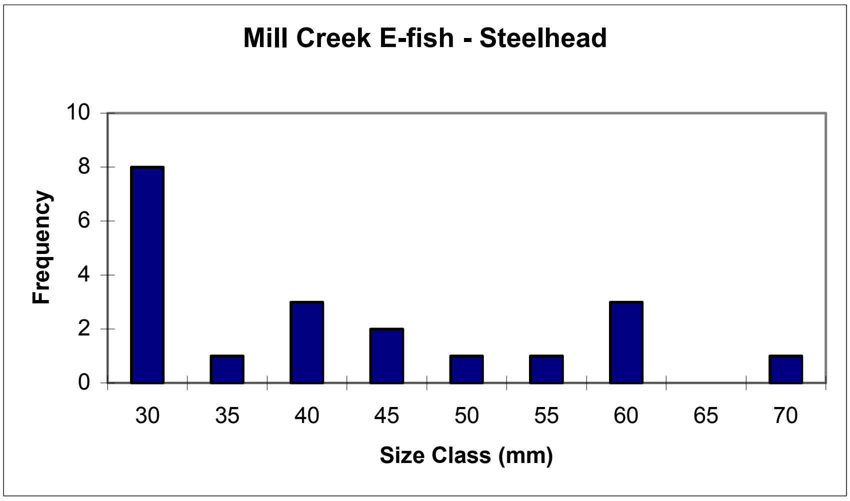


Figure 20c. Juvenile rainbow trout sizes in Mill Creek

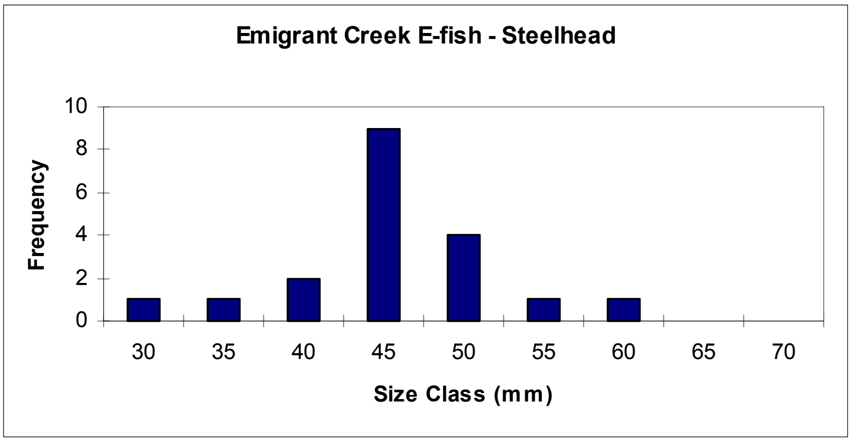


Figure 20d. Juvenile rainbow trout sizes in Emigrant Creek.

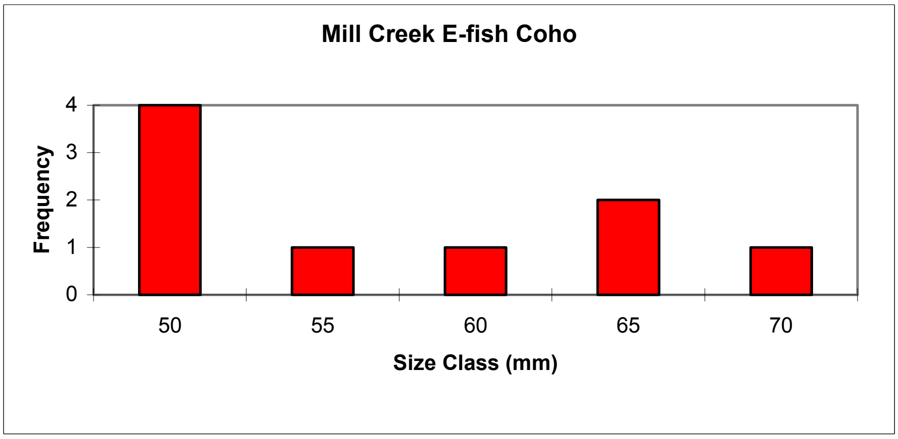


Figure 20e. Juvenile coho size on Mill Creek.

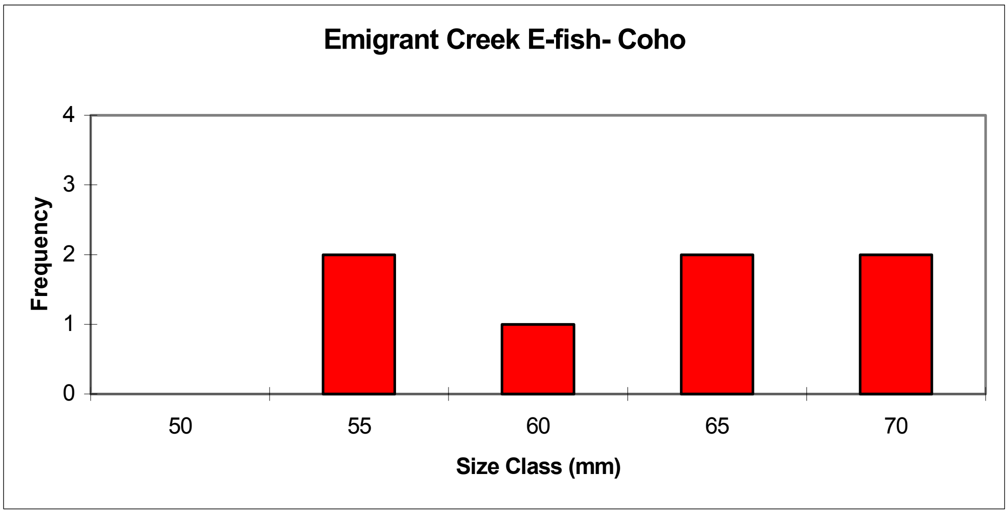


Figure 20f. Juvenile coho size on Emigrant Creek.

The juvenile rainbow trout were observed in a diversity of habitats. The smallest young-of-year trout were observed in riffle, pool, run, and side channel habitats. In riffles and runs, they were found close to the bottom among the cobbles and along heavily vegetated edges. These microhabitats were likely preferred because they occurred out of the high-velocity flows, allowing for holding and foraging on constant flotsam. In pools, larger young-of-year trout were often found mid-depth just outside the thalweg foraging on drift. Also, smaller trout often occupied the tails of pools against the bottom. Larger 2+ trout were often found in the head of pools. In Mill Creek (ML01 and ML04), it was observed that 2+ fish would take cover among exposed roots, undercut banks, or boulders when the surveyor approached. This behavior was not exhibited juvenile trout in Mill Creek, which did not retreat upon observation. Side channels were used by juvenile trout with preference for those allowing foraging and favorable conditions like those preferred in riffles and runs.

Juvenile coho salmon were not as ubiquitous as rainbow trout and displayed distinct habitat associations. The presence of juvenile coho salmon was dependent on the presence of some form of cover. In reaches that featured pools, juvenile coho primarily occupied slow-moving lateral scour pools, with the depth variable depending on the quantity and quality of cover. Emigrant Creek juvenile coho were found among woody debris in the form of mature willow root wads or undercut banks with exposed roots. Juvenile coho salmon in Emigrant Creek took advantage of deep and shallow slow-velocity pools when cover (large woody debris and root wads) was present. However, in Emigrant Creek juvenile coho were also found in deep-fast pools when cover was not present. In these cases, they preferred swimming along the bottom and foraged up into the thalweg for food. In stream reach segments lacking pools, juvenile coho were found in runs and riffles with higher velocities. In these cases, they were always associated with emerging vegetation or undercut banks along the edges. In Mill Creek, no coho salmon were observed in riffles or runs.

Marbled Sculpin in Mill Creek were observed in small cobbles or gravel on the bottom in fast-flowing riffles and runs. The lamprey in Emigrant Creek was observed in a sand-dominated pool tail. Speckled dace were most abundant in sample reaches containing a large portion of emergent vegetative bank cover, on the bottom of shallow portions of the stream, and out of high-velocity flows. A large number of dace were observed in similar microhabitats as juvenile coho salmon in Emigrant Creek.

FRENCH CREEK

Introduction

The French Creek watershed is bounded on the west by mountains of the Russian Wilderness, where it borders the Marble Mountain Wilderness (Figure 2). The tributaries of French Creek originate within the Russian Wilderness, and wind their way down from the southwestern slopes of the Middle Basin, where they meet and form the main stem of French Creek. French Creek continues in a northeasterly direction through the Scott Valley before it flows into the Scott River a few miles upstream of Etna, California. The headwaters and main stem of French Creek flow through areas of diverse land uses, which include timber harvest, agricultural fields, grazing range, and wild lands. Each land use category affects the stream and its fisheries differently. Land use, combined with the unique geomorphic, hydrologic, and ecological characteristics of French Creek, make the French Creek watershed an important and interesting place to study.

Watershed Characteristics

French Creek is a 3rd order tributary to the Scott River located on the southwest side of the Scott Valley. It flows in a northeast direction, has a total length of 14.8 river km and drains a watershed of 86 km^2. The upper watershed exceeds altitudes of 2100 meters, and is located within a wilderness area. The watershed's lowest point is at an altitude of 850 meters, which is located at the confluence of French Creek with the Scott River. Numerous tributaries in the watershed, when combined with the main stem, total 73.1 stream km with the headwaters of the tributaries located at an altitude of 6000' to 7000'. The main features of the French Creek Watershed are summarized in Table 6.

Watershed Area (m^2)	86323400
Watershed Perimeter (m)	43548
Watershed Aspect	north-northeast
Watershed Elevational Range (ft)	2815 to 7980
Stream Elevational Range (ft)	2815 to 6605
Emigrant/Miner (ft)	2925 to 3955
River Distance on Scott (m)	77296
Stream Order	3
Emigrant/Miner	2
Stream Length (m)	14782
Emigrant/Miner (m)	7462
Length of all Streams in Watershed	73102
Drainage Density (m per m^2)	0.00085

Table 6. French Creek Watershed Characteristics.

The upper portions of the watershed extend from an approximate elevation of 1200 meters to over 2100 meters, well into a region of decomposing granite and widespread timber operations (Figures 21-22). Abundant erosion within the upper watershed, primarily from logging roads throughout the granitic landscape, is reflected in the relative high levels of in-stream sedimentation of sand sized particles observed throughout the reaches surveyed on French Creek.

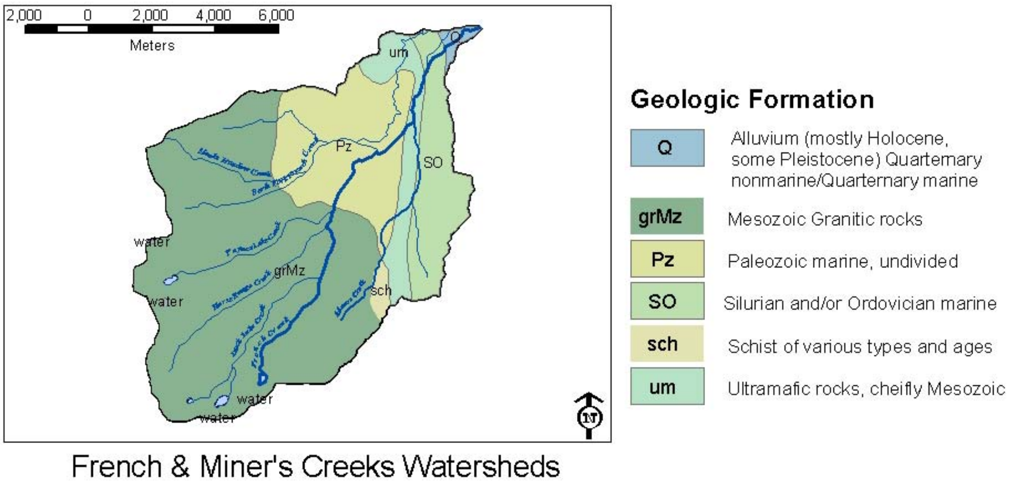


Figure 21. Geology of French Creek.

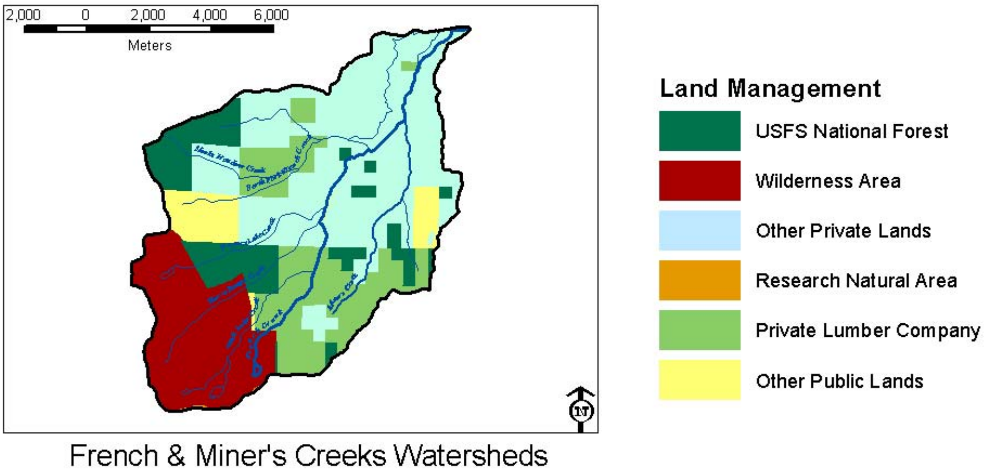


Figure 22. Land use in French Creek.

Land use

Prior to the 19th century, Native American tribes inhabited the French Creek watershed. Native Americans fished for coho and chinook salmon, lamprey, and other fish for food and trade. In addition, they burned meadows and wetlands for agricultural purposes, and dug intensively for roots in riparian areas.

Early settlers of French Creek focused on farming and ranching, particularly on raising sheep and cattle. As a consequence, large areas were burned and the riparian corridors were deforested in order to convert land to pastures for cattle grazing and cultivation of alfalfa for livestock feed. In addition to draining and damming of riverine wetlands, floodplains and meadows in order to clear the way for crops, diversions were created to redirect water from the creeks to the newly created agricultural fields. Large-scale irrigation and drainage became feasible around 1882 and was accompanied by the construction of numerous flood control projects. By the end of the 19th century, farms and ranches occupied the majority of the land near the lower reaches of French Creek.

In the 1850s, much like surrounding creeks, placer mining became a significant land use along French Creek. Mining continued for many years along French Creek and its tributaries, as piles of tailings along portions of the main stem and Miners Creek attest to today. Mining infrastructure and settlement needs prompted the beginning of commercial logging in the upper watershed in 1869. Logging volume and clearcutting increased dramatically with time, peaking in intensity in 1941. In order to support the logging operations, extensive road networks were cut into the upper watershed hillslopes, which are still in existence today.

Current land use practices are similar to the historic land uses along French Creek. Ranching, farming and timber harvest continue to be the dominant land uses in the French Creek watershed today. The lower reaches of the watershed are almost entirely private property, whereas the upper reaches of the watershed include public wilderness areas as well as private timber production land (Figure 22). Alfalfa fields encompass the majority of the valley section of the watershed, though cattle are free to roam and graze a portion of the creek as well. In addition to crop production and rangeland, current land uses along French Creek include horse ranches, open wild areas, a recreational ranch and private residential property. Although land uses continue to be similar to those in the early 20th Century, land use practices have significantly changed within the watershed. Riparian edges of French Creek have been fenced in order to minimize disturbance from cattle grazing. In addition to fencing, numerous sections of the creek have been restored or allowed to recover on their own. The main channel of French Creek is for the most part, allowed to freely flow and meander. Diversions are generally small and include fish screens and return flows. Active mining is no longer a factor along the creek, with the exception of recreational gold panning along the banks of the streams. However, private and public logging is the dominant land use in the upper watershed of French Creek, where numerous logging roads are present and continue to be used.

Reach Characteristics

A total of nine reaches within French Creek were characterized and described (Figure 23). These reaches were divided into upper watershed and lower watershed reaches. Four 100 to 200 meter reaches (FR01, FR02a, FR02b, FR03) were surveyed throughout a 4km section of the creek extending upstream from its confluence with the Scott River. In approximate distance from the confluence of French Creek with the Scott River, FR01 is located at 0.7 km, FR02 at 3 km, FR03 at 3.8, and FR04 km. An additional reach survey (FR04) was conducted at an upstream location in a higher gradient section of the creek, approximately 7 km from the confluence. A reconnaissance survey of four upper watershed tributaries (FR05, FR06, FR07, FR08) to French Creek was conducted approximately 10 km to 14 km upstream from the Scott River. These locations were chosen because of their biological and geomorphic relevance.

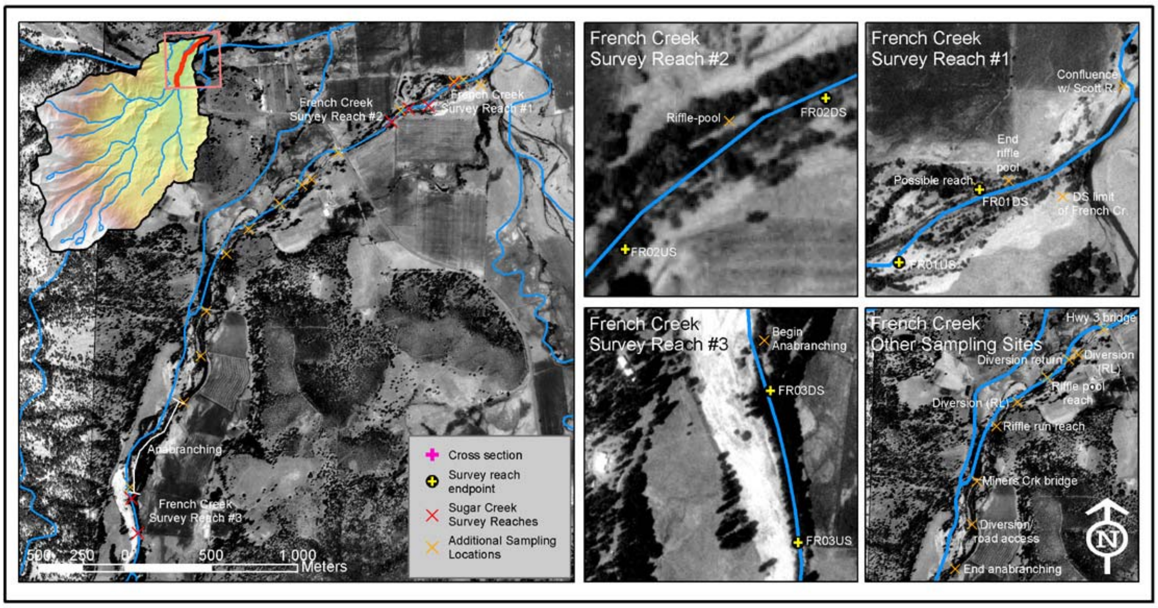


Figure 23. Surveyed reaches along French Creek.

Geomorphology

The lower surveyed reaches were dominated by repeating riffle-run sequences, with occasional stretches of alternating riffle-pool habitats. Throughout this lower section, the creek was primarily single channel, slightly sinuous, low gradient and dominated by cobble-sized substrate. Approximately 3 km upstream however, the creek changed character and spread out into a multi-channel system for approximately 0.8km. This anabranched section was fairly steep in gradient, dominated by cobble and boulder substrate and contained a variety of step-pool, plunge-pool, riffle and run habitats. The vegetation lining the multiple channels was mature and well-established, providing a significant amount of shade as well as stabilizing the channels into semi-permanent features. Further upstream, the creek returned to a single channel system, but with a higher gradient and coarser substrate than the lowermost reaches near the confluence with the Scott River.

The general habitat associated with each of the various study reaches was very different in nature (Table 7). FR01 was a single channel 200m section of a repeating riffle-pool sequence (Figure 24). Relative to other study reaches, FR01 was characterized by low gradient (0.5%), high amounts of deposited sand (40% of grains), limited spawning gravels (32% of grains) and an extensive floodplain. The pools in this reach were deeper than average and were often associated with scour around large woody debris or root wads. These pools in particular provided good cover for both steelhead and coho salmon.

French Creek: Reach Type Characteristics

Reach ID	FR-01	FR-02a	FR-02b	FR-03	FR-04
Reach Length (m)	200	100	100	190	89.9
Rosgen type	c3	b3	d3	b3	a2
Channel Morphology	single channel	multiple channel	anabranching	single channel	single channel
Geomorphic Units	rifle-pool	rifle-run, step pool	rifle-run	rifle-run	cascade, step-pool
Hydraulic Characteristics	H5, H7, H8	H1, H5, H7	H5,H6,H7	H5,H6,H7	H5,H7,H9
Surrounding land use	grazing	grazing	grazing	grazing	timber, residential
Hydrologic Alterations	none	none	none	none	none
Degree of instream sedimentation	high	low	medium	medium	medium
Channel Stability	moderate	moderate	moderate	stable	moderate
Canopy Cover	open	open	shaded	partly shaded	shaded
Dominant riparian species	willow shrubs	willow/alder	alder	alders	conifers
Vegetation age (yrs)	immature	immature/established	established	established	mature
Slope	0.5	3.2	0.08	0.5	5.5
Estimated width/ depth ratio	20	25	50	25	23.3
Sediment Size D16:D50:D84(A)	2.0:36.8:104.0	8.6:73.5:152.2	2.0:45.3:115.4	2.0:8.0:97.0	2.0:52.0:194.0
Sediment Size D16:D50:D84(B)	2.0:2.0:36.8	n/a	n/a	2.0:22.6:104.0	2.0:78.8:181.0

Table 7. Summary of geomorphologic characteristics of surveyed reaches.

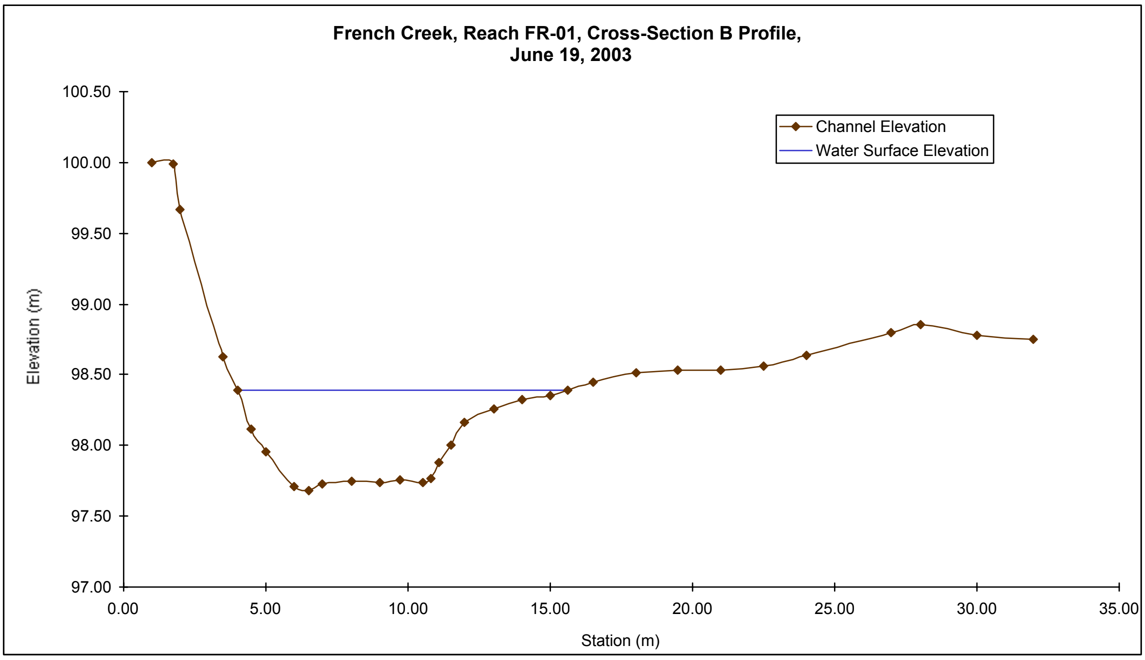


Figure 25. Cross-section of FR01, showing example of single channel system.

The remaining reaches were higher gradient with coarser cobble and boulder-sized substrates. FR02a was 100 meters in length and characterized by the confluence of a side channel with the main channel at the end of the 0.8 km anabranching portion of the creek (refer to reach sketches in Appendix B). The main channel was a repeating sequence of riffles and runs, while the side channel contained only a fraction of the discharge and was predominately alternating steps and pools. When compared to the other reaches, FR02a had a relatively high slope (3.2%), contained the highest relative amounts of desirable spawning gravels (56% of all grains) and the lowest observed amounts of sand (14% of all grains).

FR02b was located in the upper portion of the anabranched section of the creek and contained multiple channels (Figure 26). In this reach, debris jams and mid-channel islands, stabilized in many cases by large established trees, led to the bifurcation of channels of varying size (refer to reach sketches in Appendix B). The slope was 0.8 % for the entire reach. Similar to FR02a, sand-sized sediment accounted for 19 % of grains and spawning gravels accounted for 49% of grains.

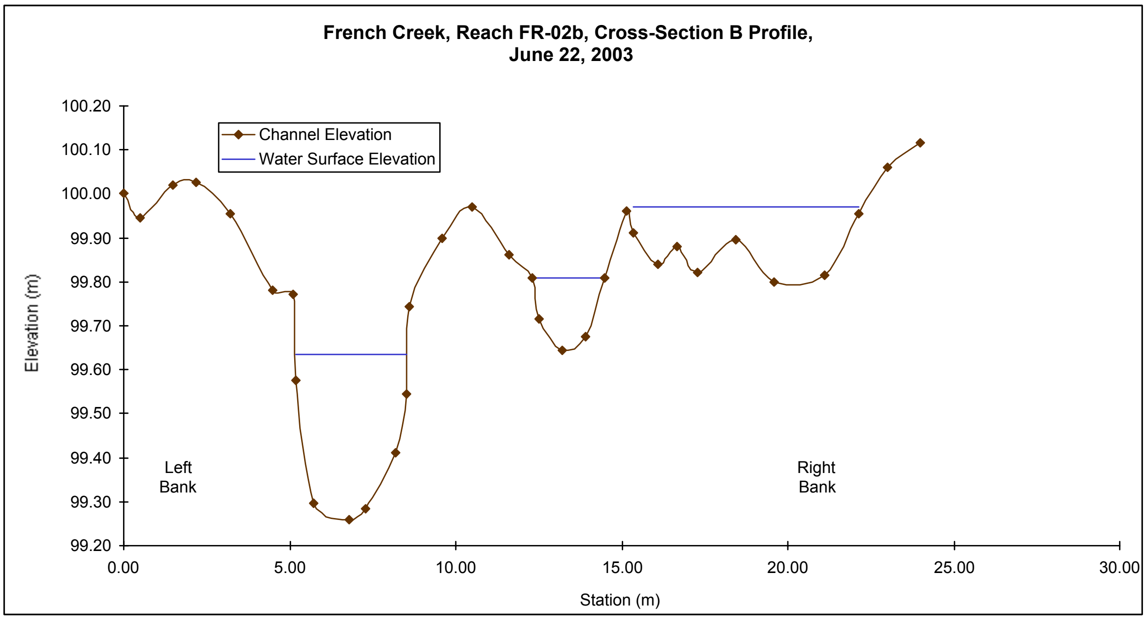


Figure 26. Cross section FR02b showing example of multi-channel system.

FR03 was a 190-meter section of repeating sequences of riffle-run located just upstream of the anabranched section. Although the slope was similar to FR02b (0.5 %), the flow was confined to a single channel with mixed sand and cobble-sized material (sand accounted for 34% of grains and spawning gravels accounted for 30% of all grains). Also similar to FR02b, but unlike the lower surveyed reaches, FR03 had a well-established riparian zone that, while not extensive beyond the immediate creek banks, provided a significant amount of shade.

FR04 was the most upstream reach that was fully surveyed in detail. Unlike any of the lower reaches, this reach was characterized by a steep gradient (5.5%), very coarse substrate dominated by boulders, cascades and step-pool habitats and an extensive mature riparian zone interspersed with conifers (refer to reach sketch in Appendix B). A fair amount of large woody debris was present in the channel that created scour pools and provided cover for juvenile fish.

Throughout the five lower surveyed reaches on French Creek, a variety of habitats existed that might possibly be conducive to juvenile salmonid rearing; however, the large degree of instream sedimentation, primarily from exposed logging roads in the upper watershed, has degraded the channel substrate in the most of the lower reaches. Sand filled most of the interstitial spaces between cobbles and gravels, and only in the highest gradient reaches where average velocities were greater was there substantial flow through the substrate. The potential effect of these geomorphic characteristics on juvenile salmonids is discussed further in the 'fish' section below.

Hydrology

During a normal precipitation year, discharge along French Creek is low during June and continues to decrease into the late summer, when French Creek completely dries out at the confluence of the Scott River (personal communication with landowners). However, the 2003 season was characterized by a particularly unusual hydrologic regime, where significant precipitation occurred in the late spring, causing snow to accumulate in the mountains. These late spring storms caused the Scott Valley and associated tributaries to be wetter and have higher discharges later in the season. The unusual discharge regime significantly impacted the ecological aspects of French Creek.

During the time of study, discharge was estimated at 4 separate stream reaches: FR01, FR02a, FR02b and FR03 (Table 8). Overall, the main channel of French Creek showed downstream increases in discharge as expected. Discharge at FR01 was measured the day after a storm event, which may have increased snowmelt runoff, which in turn would increase the discharge within the main channel on a short-term basis. In addition, increases in discharge in a downstream direction may be accompanied by increases in agricultural return of water into the stream. The upstream riparian vegetation tended to be larger and mature, which could potentially remove water from the main channel via seepage flows and plant uptake. However, a small discrepancy in this increasing downstream trend was observed from FR02b to FR02a. This may have been due to diurnal fluctuations in snowmelt or riparian water uptake, or might simply have been due to surveyor error. Surveyor error might also have been increased due to the numerous boulders and cascades found in these reaches, which disrupt flow velocities further reducing the accuracy of discharge measurements.

Site ID	Site Description	Date & Time	Discharge (cms)- velocity-area method	Average Discharge (cms)- float method
FR01	French Creek- no coverage, open to direct sunlight	6/18/03 1:00pm	3.27	n/a
FR02a	French Creek- no riparian coverage, confluence of Anabranch	6/23/03 9:30am	1.24	2.0
FR02b	French Creek- covered anabranch section	6/23/03 11:00am	1.38	1.6
FR03	French Creek- well covered with established riparian vegetation	6/20/03 11:00am	1.05	n/a
FR04	French Creek- dense established forest coverage	6/19/03 11:00am	0.192	0.34
FR05	North Fork French Creek- established riparian area	6/25/03 10:00am	n/a	1.23
FR06	Duck Lake Creek- established riparian area	6/25/03 12:45pm	n/a	0.61
FR07	Paynes Lake Creek – established riparian area	6/25/03 11:20pm	n/a	0.638
FR08	Horse Range Creek- established riparian area	6/25/03 11:40am	n/a	0.01

Table 8. Discharge at French Creek.

Two temperature loggers were deployed at French Creek, the first at FR01 (31), and the second at FR03 (13). Temperature readings were recorded every 5 minutes from June 17, 2003 to June 25, 2003 (Figure 27). These data demonstrated that FR-03 was colder than FR-01 by 2ºC - 4ºC. This cooling effect may have been due to the established riparian vegetation, which shades the reach for most of the day. FR01 was dominated by young riparian species, and had an open main channel that received significant sunlight and provided little shade.

Air and water temperature were strongly and positively correlated (Figure 28). The data show that the downstream reach had a stronger response to air temperature. This may be because it was less shaded by riparian vegetation. As a result, the potential for stream water temperature to increase with increasing air temperatures is high, which can negatively impact coho and steelhead habitat. The upstream reach (FR03) was not as sensitive to changes in temperature, most likely due to the high degree of riparian shading. It is possible that as air temperature increases, this reach may provide thermal refugia for fish during the late summer.

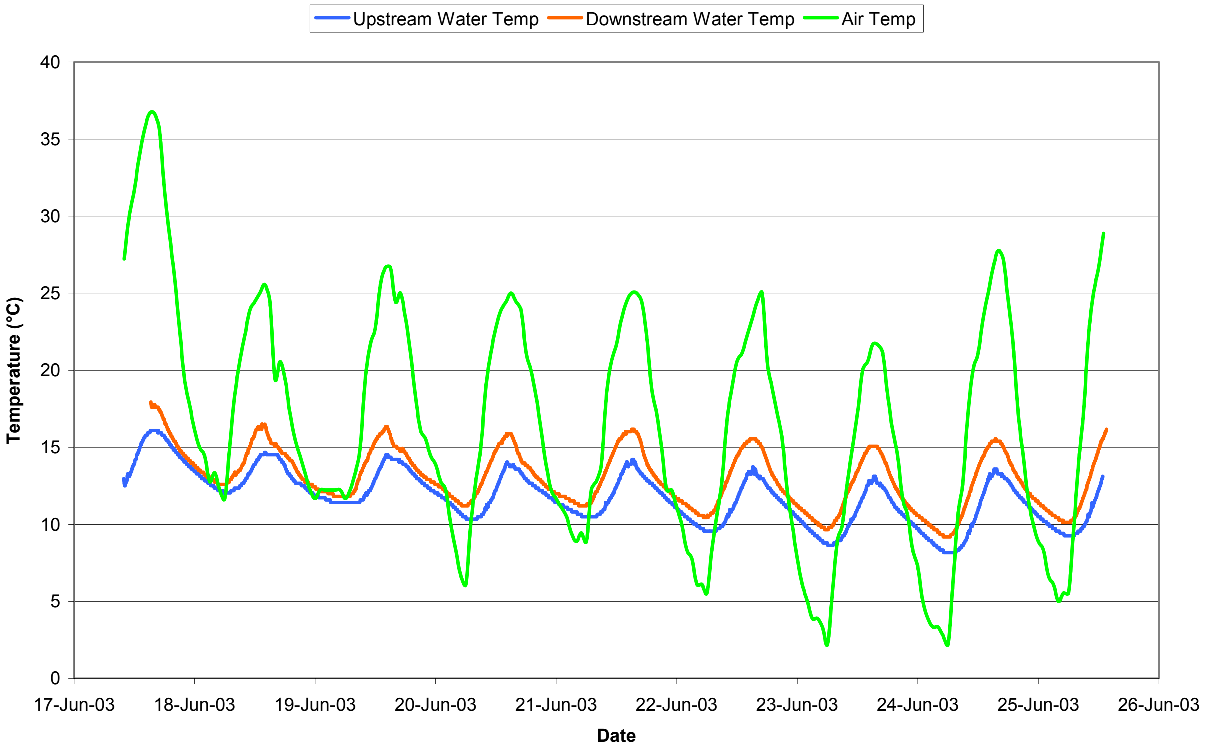


Figure 27. Temperature trends for French Creek over the study period.

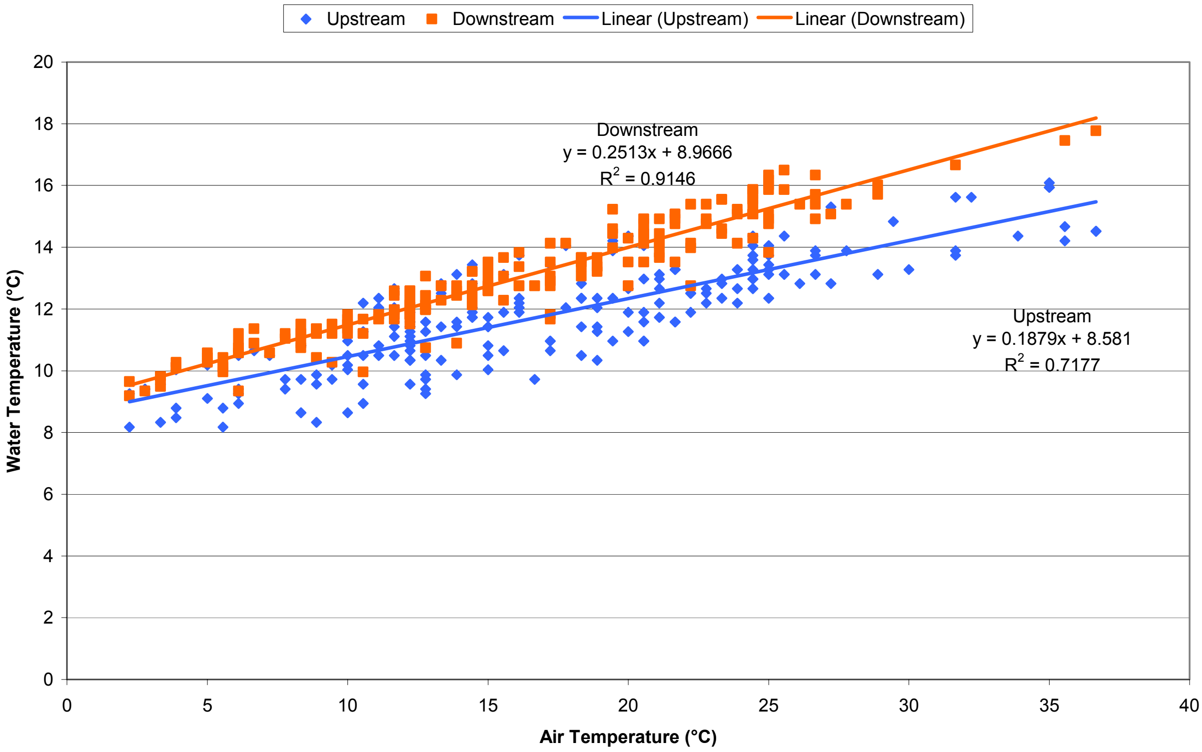


Figure 28. Correlation between air and water temperatures on French Creek.

Water quality data collected at each reach is summarized in Table 9. Total dissolved solids (TDS) and electrical conductivity (EC): TDS and EC increased in a downstream direction. TDS may include organic particles, such as leaves and planktonic algae as well as inorganic particles, like sand and silt. Agricultural returns, as well as Miners Creek, may contribute to the overall downstream increase in EC and TDS. However, overall EC reading and TDS readings were indicative of high water quality. pH was constant throughout the system, and did not seem to impact the ecology of French Creek. In addition, numerous epiphytes were observed in the upper reaches of French Creek. Bryophytes (mosses and liverworts) were abundant at FR04, FR05, FR06, FR07 and FR08, indicating high water quality within the upper watershed of French Creek. Overall, French Creek had high water quality, suitable for fish.

Site ID	Site Description	Time	Date	Temp ©	PH	TDS (ppm)	EC (µs)
FR01	French Creek- no coverage, open to direct sunlight	2:00pm	6/18/03	16.3	6.26	35	68
FR02a	French Creek- some riparian coverage, confluence of Anabranch	1:37pm	6/22/03	12.8	6.31	28	56
FR02b	French Creek- covered anabranch section	3:50pm	6/20/03	14.0	6.28	24	49
FR03	French Creek- well covered with established riparian vegetation	4:00pm	6/19/03	14.4	6.27	25	45
FR04	French Creek- dense established forest coverage	2:00pm	6/24/03	10.5	6.31	15	31
FR05	North Fork French Creek- established riparian area	10:00am	6/25/03	9.0	6.31	24	11
FR06	Duck Lake Creek- established riparian area	12:45pm	6/25/03	10.2	6.31	9	18
FR07	Paynes Lake Creek - established riparian area	11:20am	6/25/03	11.1	6.31	8	16
FR08	Horse Range Creek- established riparian area	11:40am	6/25/03	9.8	6.31	6	13

Table 9. Summary of Water Quality at French Creek.

Macroinvertebrates

Macroinvertebrate samples were collected from four lower sample reaches, as well as Miners Creek and three upper watershed reaches. In general, the lower watershed reaches tended to be dominated by riffle-run and riffle-pool geomorphology, whereas the upper reaches tended to be dominated by cascade geomorphology. Invertebrates were collected at 3 sample locations within each reach, with the exception of FR02a and FR02b, where only 2 samples were collected at each anabranch. At these sites, samples were collected from different branches of the channel in order to capture the macroivertebrate distribution variability. Water velocities at the various lower watershed sampling locations ranged from 0.1m/s to 1.4 m/s. The microhabitats sampled at the lower reaches included eight riffles, four runs and one pool, which was sampled at Miners Creek. The substrate sampled was mainly made up of cobbles, gravels, and aquatic macrophytes. Generally, sand was present at high levels in the substrate.

In contrast, the upper watershed sampling locations consisted of four riffles and five cascades, all of which were highly embedded with sand, had higher densities of periphyton and bryophytes, and were characterized by particularly high flow velocities that were difficult to measure due to the complexity of the cascades. Overall, the highest diversity of macroinvertebrates corresponded to reaches with high habitat heterogeneity and reaches where aquatic periphyton and bryophytes were present. Refer to reach sketches in Appendix B for macroinvertebrate sampling sites.

Macroinvertebrate abundance was highly variable throughout French Creek, but certain patterns can be noted. Invertebrate abundance was highest at the lowest and warmest stream reaches (FR01 and FR02) with 121 and 99 individuals per sample respectively (Figure 29). These reaches were also the least shaded reaches and had the most exposure to the sun. An increase in sunlight exposure can translate into higher rates of primary production, which increases the amount of edible algae available to grazing invertebrates. This could benefit fish by increasing prey numbers.

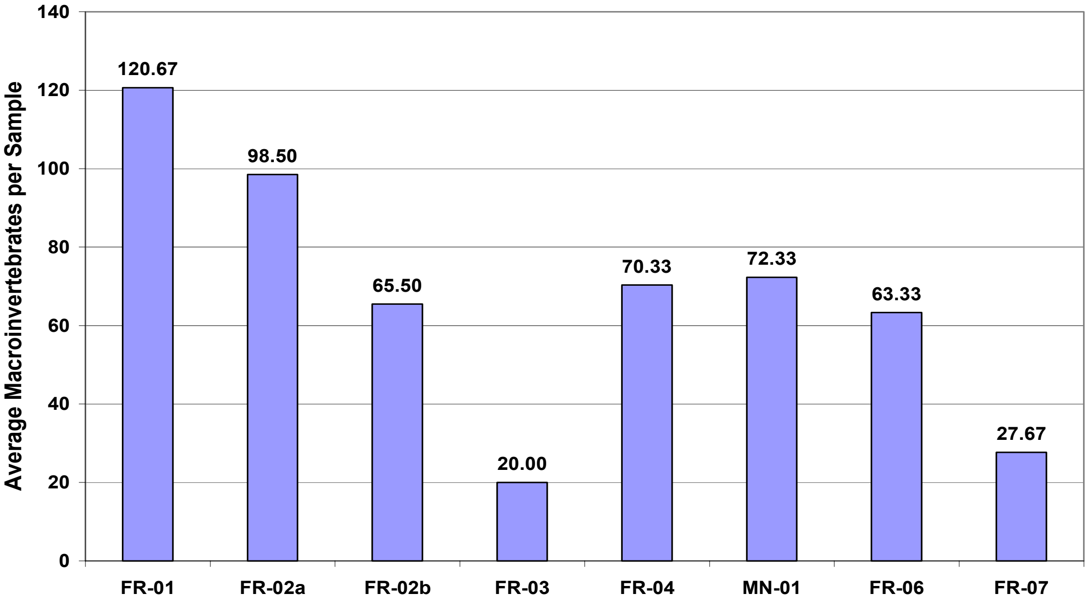


Figure 29. Macroinvertebrate abundance in each sample reach.

In addition, invertebrate abundance tended to be higher at sites where aquatic autotrophs were abundant; FR01, FR04, and FR06 averaged 121, 70, and 63 individuals per sample respectively (Figure 29). Periphyton and bryophytes were most abundant at the upper watershed reaches, where the dominant geomorphology was cascade (FR04, FR06). Aquatic macrophytes were most abundant in FR01, particularly in the sandy substrate. FR03 was the reach with the lowest macroinvertebrate abundance, only 20 invertebrates per sample. This reach was quite swift, straight and relatively deep with low habitat heterogeneity. FR07 had low macroinvertebrate abundance as well (28 macroinvertebrates per sample). The low abundance of macroinvertebrates in this reach may have been a direct consequence of the habitat characteristics, which was made up of large boulders and the lack of aquatic autotrophs.

Macroinvertebrate richness did not significantly vary between reaches regardless of location within the watershed (Figure 30). Between 15 and 18 macroinvertebrate taxa were observed at most reaches in French Creek. However, taxa richness did tend to be slightly higher in reach locations that have higher macroinvertebrate abundance. In contrast, two reaches with low richness and abundance stand out; FR07 had the lowest overall taxa richness with only 9 taxa present and FR03 only had 11 taxa. Both of these reaches also had the lowest macroinvertebrate abundance.

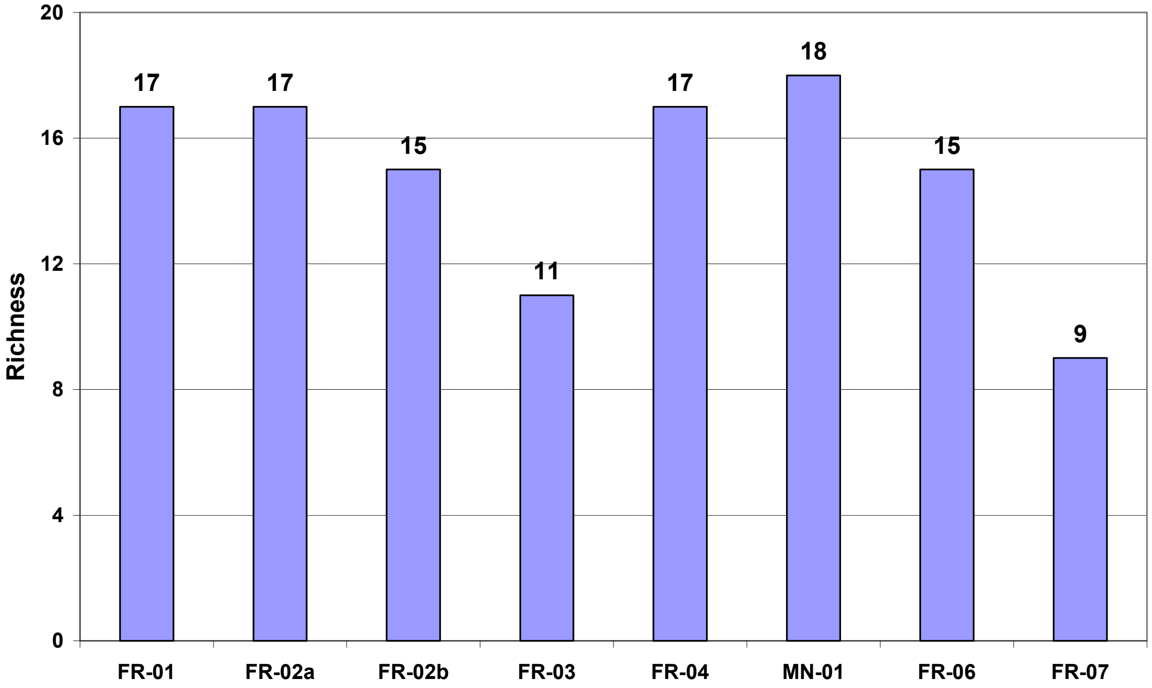


Figure 30. Macroinvertebrate richness in each sample reach on French Creek

While richness did vary significantly within French Creek, the species composition of the various reaches tended to shift dramatically (Figure 31). Ephemeroptera and Trichoptera were the dominant taxa at the lower reaches. Overall, Plecoptera were not very abundant within French Creek. However, at FR04, Plecoptera (which tends to be highly sensitive to changes in its environment) were the dominant taxa. At the time of sampling, all of the Plecoptera individuals were observed to be within the bryophytes on the downstream side of the rocks. In addition, Diptera larvae, which are high quality food for small fish, were abundant in a cascade reach (FR06) where fish were absent due to the cascade barriers that blocked upstream migration. The Diptera at this site were observed in high numbers within the algal mats growing on the surface and upstream side of the rocks. These two examples demonstrate the importance of periphyton and bryophyte as food sources and refuge for invertebrates. Total numbers of Trichoptera tended to increase in a downstream direction. The number of case-making Trichoptera peaked at the lowest reach, where sand loads are highest. This suggests that sand case making Trichoptera larvae will be most abundant in the sandier reaches.

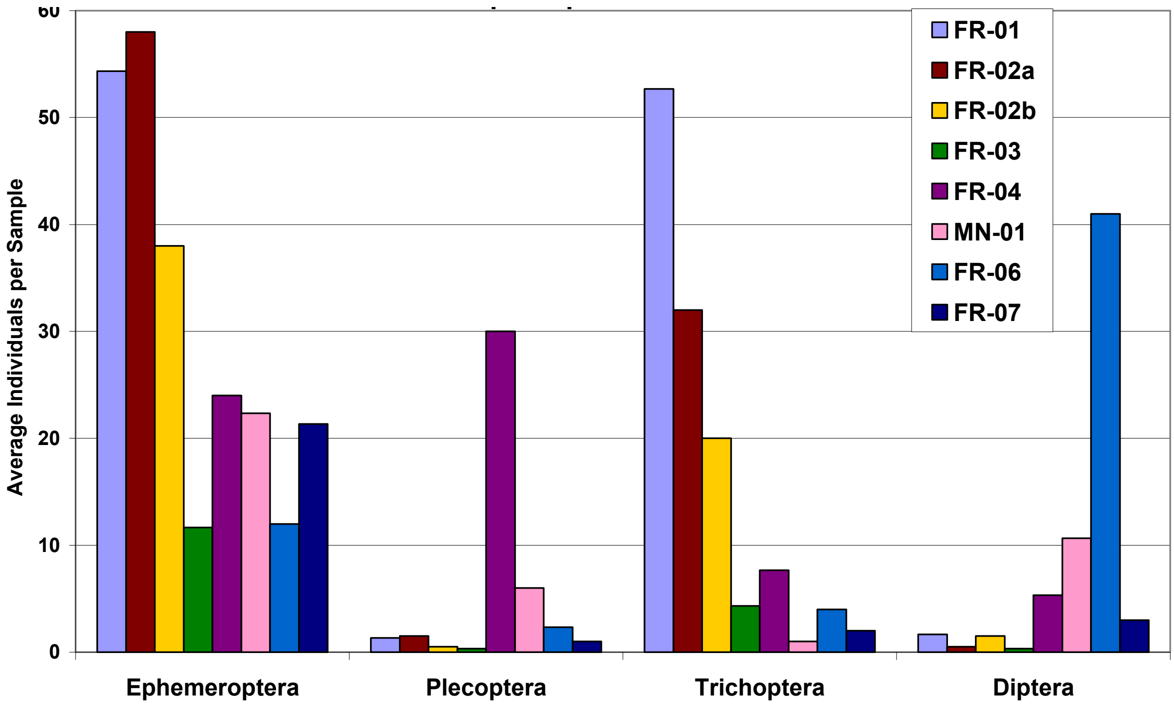


Figure 31. Average number of Ephemeroptera, Plecoptera, Trichoptera and Diptera (EPTD) per sample reach.

Miners Creek was dominated by Coleoptera, Ephemeroptera and Diptera. It was interesting to note that at Miners Creek, Odonata were present in all 3 types of microhabitats sampled (refer to data in Appendix B for details). Odonata may compete with the small fish for food resources and may be predators of very small fish, particularly in slower flow areas such as pools.

The Ephemeroptera: Plecoptera: Trichoptera (EPT) Index is often used as an indicator of water quality and stream habitat integrity. The lower the ratio, the healthier a stream is. However, the EPT Index patterns on French creek were not consistent and may not be a good indicator of stream health. The lowest EPT Index numbers were at FR03, FR06, FR07 and MN01 (Figure 32). These sites were highly variable in their geomorphology, flow regime, riparian vegetation and discharge; therefore it is difficult to draw conclusions about the health of these reaches based solely on the EPT index. However, the EPT Index did tend to increase in the lower reaches in a downstream direction, along with substrate sand loads, stream temperature and decreases in riparian vegetation. This suggests that the more sensitive invertebrates may be responding to temperature, substrate and habitat quality rather than water quality.

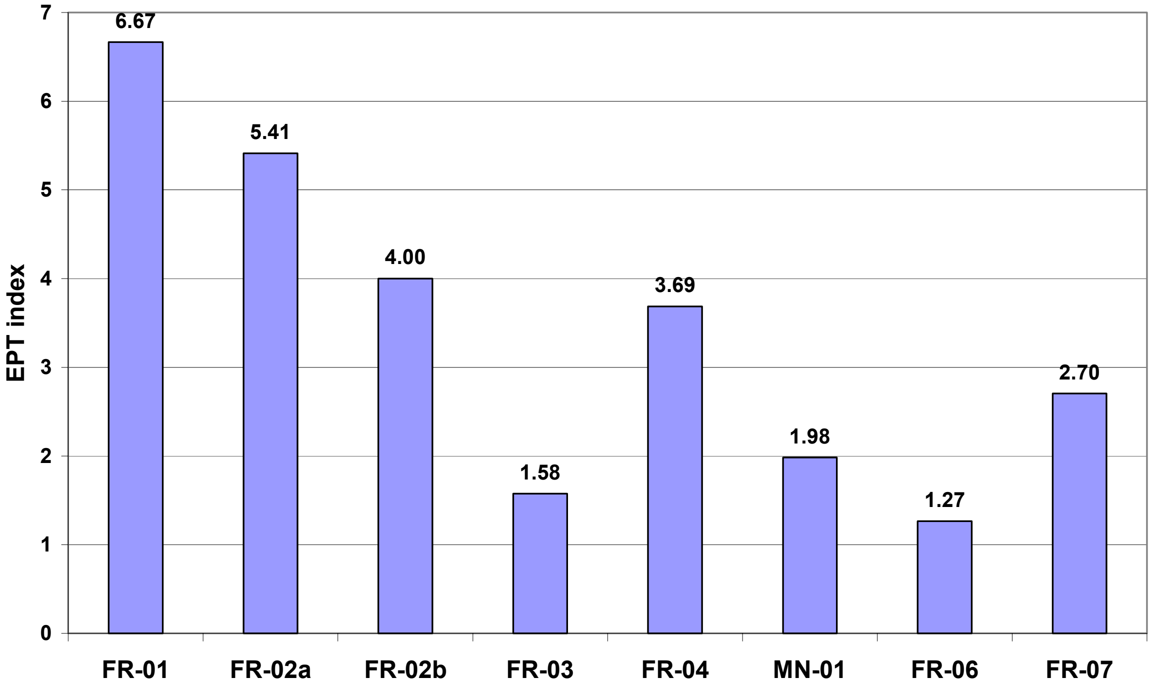


Figure 32. EPT Index for each sample reach on French Creek.

It important to keep in mind that aquatic macroinvertebrates can be highly variable within a stream reach, and respond quickly to changes in their environment. Therefore, we cannot extrapolate the conclusions drawn from a snapshot in time without gathering additional scientific information and gaining further understanding about the relationship of macroinvertebrates to their environment and other biota.

Fish

Between the reach on Miners Creek and the four reaches studied on French Creek, juveniles of six native fish species were observed along with one non-native species. Coho salmon were relatively uncommon in French Creek, being observed in small numbers in only two sections. On the other hand, rainbow trout were abundant, and significantly outnumbered all other species in areas fish were present. Other native species observed less frequently include speckled dace, sculpin, and lamprey, along with brook stickleback, which was the single introduced fish found in the system. Relative abundance of fish per sample reach is shown in figure 33.

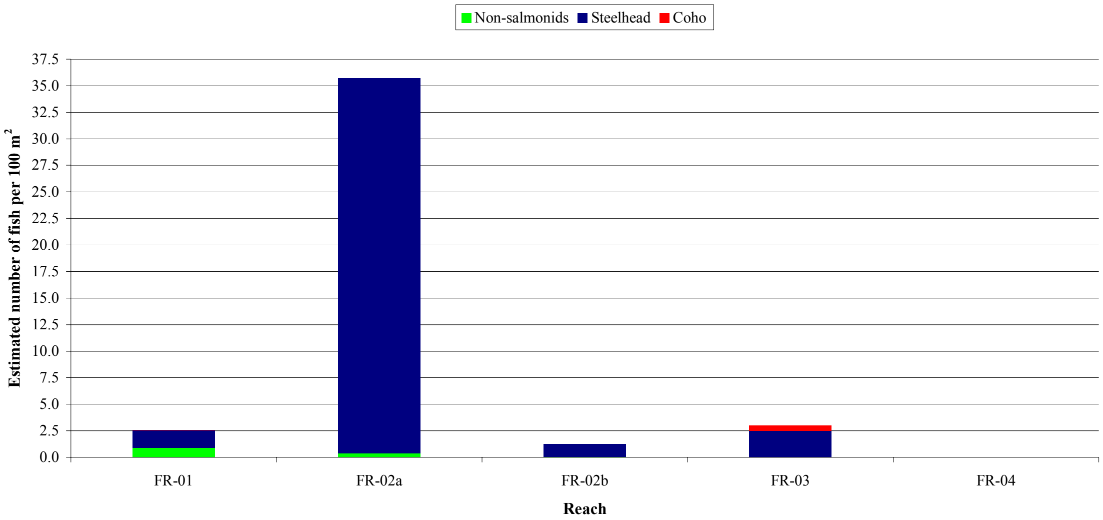


Figure 33. Relative abundance of fish in each sample reach on French Creek.

With the exception of FR04, which was the uppermost reach on main stem French Creek, fish were found throughout the drainage. FR04 was likely too far upstream, with distance and downstream obstacles preventing fish from spawning. Juvenile steelhead were observed in all other lower watershed reaches, but were most abundant in FR02a, which included the downstream confluence of the anabranching section of the creek. Steelhead outnumbered other fish by at least 6 to 1 within the reaches in which they were observed. The majority of juveniles observed were 0+ fish, with only a few 1+ individuals observed in the two anabranching sections (FR02a, FR02b) and in Miners Creek.

Coho salmon were present in two reaches of French Creek (FR01, FR03) as well as in Miners Creek (MN01). Most of the coho observed were located in the pools at Miners Creek, though a small number of the juveniles were found intermixed with a large number of steelhead in one French creek reach (FR03). Nearly all of the coho in both creeks were of the 0+ age class, with the exception of one 1+ fish electrofished slightly upstream of the upper anabranching section on French Creek (FR02b).

FR01, the lowermost reach on French Creek, was the only location in the entire study area in which speckled dace were observed. A group of 0+ juveniles was observed within one single species pool. No other age classes were represented. The other native families were far less prevalent in the French Creek system. Two sculpin were found in a run and undercut respectively on FR02a and a single lamprey was located by electrofishing on Miners Creek.

A brook stickleback was electrofished in the upper portions of the anabranching section of French Creek, representing the lone non-native fish species uncovered during the study period. This fish is common in the Midwest and has been recently introduced into the Scott Valley. It was found in an area of the creek that also contained both coho and steelhead. See Appendix B for raw fish survey data.

Juvenile steelhead were by far the most abundant species in the French Creek drainage, outnumbering other species by many orders of magnitude in all reaches where they were found. Speckled dace were observed more frequently than coho during snorkeling surveys, and both were more prominent than lamprey, sculpin, and brook stickleback combined. Except for the fishless FR04, each representative reach studied in the French creek drainage had its own distinct combination of species and abundances. FR-02a alone contained over 73% of the total fish observed in French Creek, with fish distributed evenly between the two channels comprising the reach.

Coho were observed in various areas of the creek, which included habitats that shared several characteristics. The bulk of the juvenile coho were observed near the banks of the stream, behind rocks or logs, or holding among exposed roots beneath undercut banks. These locations help the fish avoid high water velocities that could wash them downstream and allow them to be in proximity to the faster currents that transport suspended food particles that coho consume. Availability of these flow refugia appear to be essential for juvenile coho. In addition, coho were only observed in the French Creek drainage in shaded areas, below significant cover. The cover not only kept water temperatures moderated, but it also hid the fish from avian predators. When cover is not readily available, as in areas of Miners creek, the coho were observed holding near the bottom of deep, slow pools, which acted as a form of cover and flow refugia. The water temperatures in all reaches along French Creek were adequate for coho residence at the time of the study; however, temperatures in reaches with little vegetative cover such as FR01 and FR02a are already nearing the physiological limit for coho.

Juvenile steelhead appeared to prefer habitats similar to those preferred by coho, with some significant differences. Like coho, steelhead were mostly observed in slow areas behind rocks and large woody debris, or near undercut banks on the edge of the stream. However, steelhead were observed venturing out further from the protected banks than coho, actually holding in slow bankside current. A handful of larger steelhead were spotted swimming in the flows; conversely, coho were never seen anywhere near the full current. Steelhead were also observed more frequently in areas without cover, where sunlight shone through the water. In FR02a, a large number of steelhead were found in a shallow side channel, with very low flows and nearly no cover. It is hypothesized that this channel is the major reason for the significantly higher number of steelhead in FR02a than in any other reach since it provides refuge from flow as well as slightly warmer water which maintains larger insect populations and stimulates the fish to grow faster.

Speckled dace, although seen infrequently, were located in similar habitats to those of coho, within very slow waters protected from fast flows, with a lot of stream cover overhead. The dace were seen often in slow cobbled side channels or in deep bankside pools. The sculpin were observed mixed in with juvenile steelhead in a deep undercut bank beneath a large tree, while the lamprey on Miners Creek was electrofished off of a sand-dominated substrate midchannel.

During electrofishing, coho and steelhead of varying size ranges were observed. The majority of both species were small, suggesting that they likely hatched only a few weeks earlier. With the exception of a single 75 mm individual, all of the coho sampled had lengths between 40 and 60 mm (Figure 34). Steelhead exhibited a more diverse range of size classes, with the majority of the fish sized between 25 and 45 mm, three in the 70 to 85 mm range, and three more that were 120 mm long (Figure 35). Of the observed fish, several steelhead individuals were far smaller than the coho sampled. Additionally, several steelhead observed were much larger than the coho sampled. It is interesting to point out that coho salmon had a larger average length of 52 mm versus the steelhead’s 42 mm average.

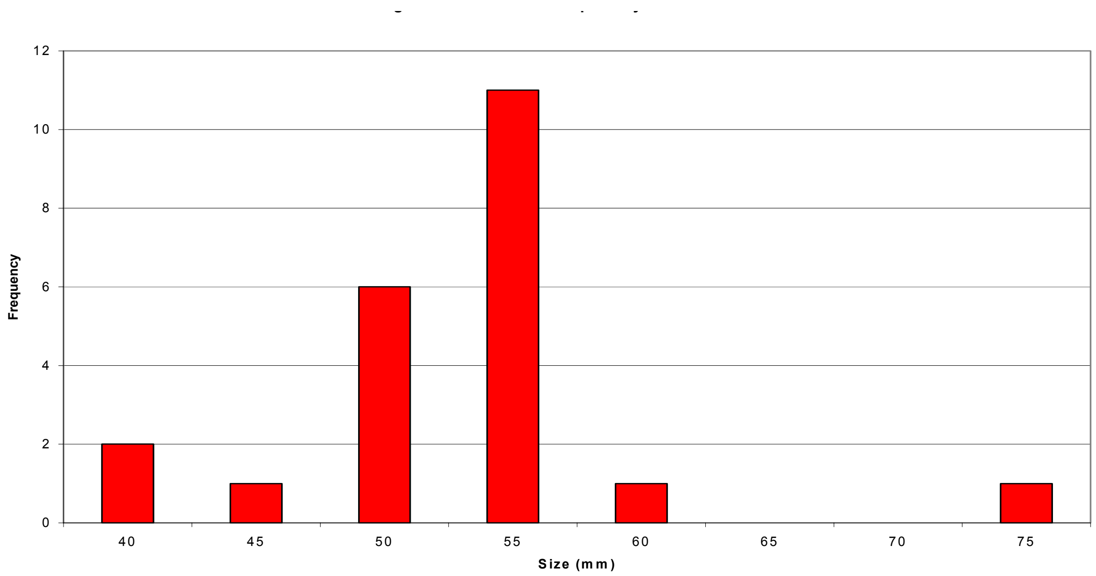


Figure 34. Fequency of coho versus size indicating 2 age classes.

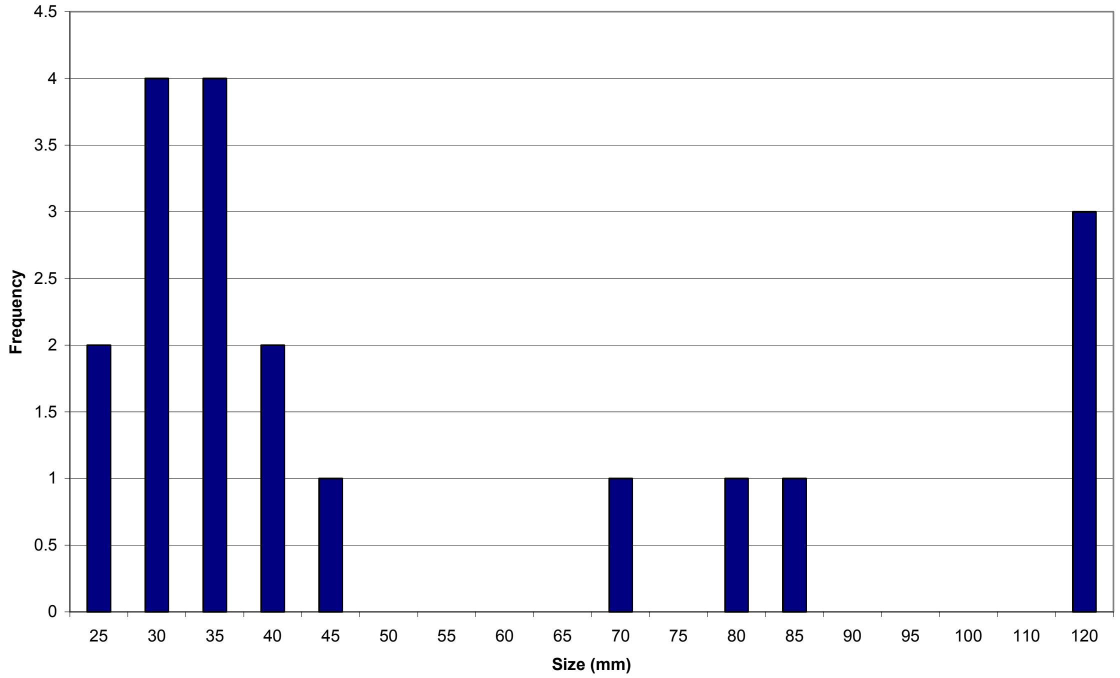


Figure 35. Frenquency of steelhead versus size indicating 3 age classes.

An analysis of several variables measured at the four downstream reaches revealed a potentially interesting relationship between the channel geomorphology and fish density (Table 10; Figure 36). Most significantly, reach FR02a alone accounted for over 73 % of all fish observed in the four reaches on French Creek. The high densities of fish observed, coupled with the relatively high slope, abundance of spawning gravels, and low percentage of sand suggests that a relationship may exist between these four variables. Higher channel slopes result in increased stream power and shear stress on the channel substrate. This, in turn, increases the creek's ability to transport sediment (both in size and amount), and results in less sand-sized sediment deposition on the bed. Larger, cobble-sized material (the most desirable sizes of gravels for spawning) are deposited, creating better opportunities for fish spawning. In the other reaches, higher levels of sand deposition in and around spawning gravels were observed; this can have a negative effect on the survival of eggs at those locations (Moyle, 2003). Because newly hatched steelhead and salmon fry do not move far from their spawning sites, FR02a may represent a location where ideal physical conditions led to a high level of spawning success for steelhead and salmon populations. No fish were observed in FR04, likely indicating that some steep cascade sections, with slopes in excess of 11%, acted as fish barriers to migration.

Reach ID	**slope (%)*10**	**sand (% grains)**	**spawning gravel (%grains)**	**fish per 100m2**
FR-01	5	40	32	1.7
FR-02a	32	14	56	35.3
FR-02b	9	19	49	1.2
FR-03	5	34	30	3

Table 10. Geomorphology vs. fish density.

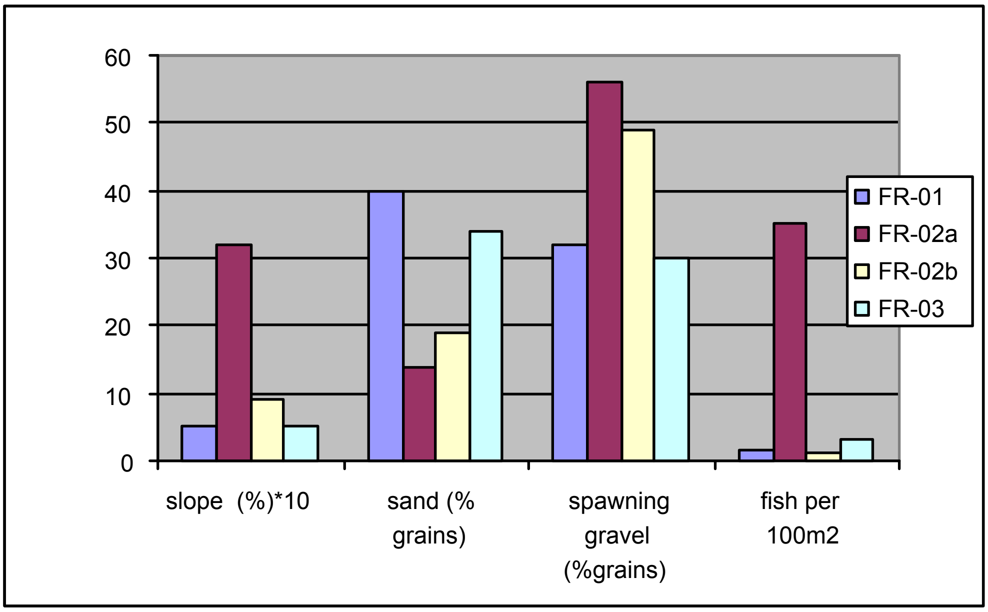


Figure 36. Geomorphology vs. fish density.

The apparent relationship between slope, sediment and fish density observed on FR02a is only one of many possible explanations for the large fish density observed in the reach. Many factors affect the distribution of juvenile fishes, in addition to the amount of sand and gravel present. Additional scientific investigations would need to be undertaken to determine if a true relationship between geomorphology and fish abundance exists. As a result, the analysis outlined here is only a possibility, and not necessarily of statistical significance.

SUGAR CREEK

Introduction

Sugar Creek is a cold-water tributary to the Scott River located in the southwestern region of the watershed (Figure 2). Sugar Creek flows from its source high in the Russian Wilderness down to its confluence with the Scott River near Callahan, CA. Due to its location on the western side of the Scott Valley, the Sugar Creek watershed receives more precipitation than the eastern side of the Scott Valley. The Sugar Creek watershed encompasses a unique distribution of vegetation, geology, and land use, which are described in greater detail in the following section.

Watershed Characteristics

The Sugar Creek watershed has an area of approximately 32.657 km^2. The elevation ranges from 2,490 m at the uppermost edge of the watershed to 916 m at the confluence with the Scott River. Aspect of the watershed is east-northeast facing. The mountainous and forested upper portion of the watershed has a much steeper slope than the lower portion of the watershed. The elevation profile along Sugar Creek is shown in Figure 37. The geology of the Sugar Creek basin is characterized by Mesozoic granitic rock in the upper half of the watershed and a combination of schist of various types and ages, chiefly Mesozoic ultramafic rocks, and Silurian and/or Ordovician marine formations in the lower half of the watershed. Much of this bedrock is overlain by alluvial material. Vegetation cover is predominantly mixed conifer in the upper watershed, ponderosa pine at lower elevations, and annual grassland in the lower most reaches of Sugar Creek. Refer to Table 11 and Figures 38-39 for a summary of Sugar Creek watershed characteristics.

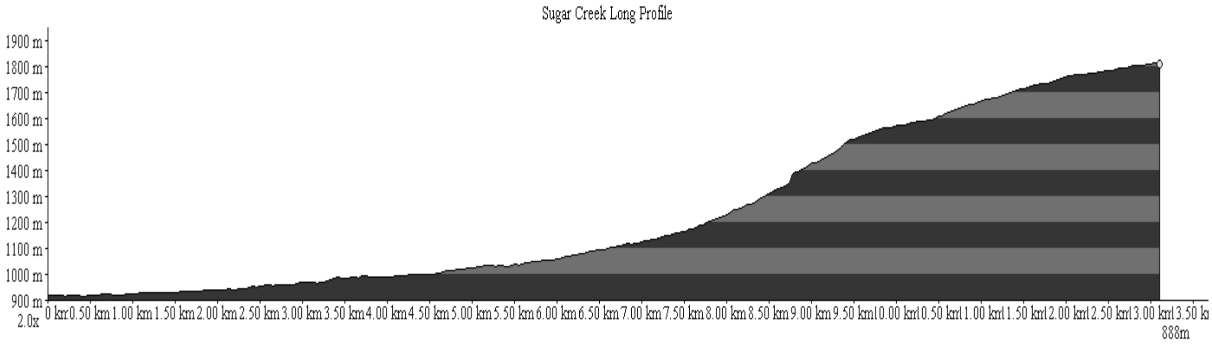


Figure 37. Longitudinal Profile of Sugar Creek.

Watershed Characteristics	Sugar Creek
Watershed Area (km ^{2})	32.657
Watershed Perimeter (km)	32.37
Watershed Aspect	east-northeast
Wtrshd Elevational Range (m)	916 to 2490
Stream Elevational Range (m)	916 to 2179
River Distance on Scott (km)	87
Stream Order	4
Stream Length (km)	14
Length of all Streams in Wtrshd (km)	24
Drainage Density (km per km ^{2})	0.42900

Table 11. Watershed Characteristics of Sugar Creek

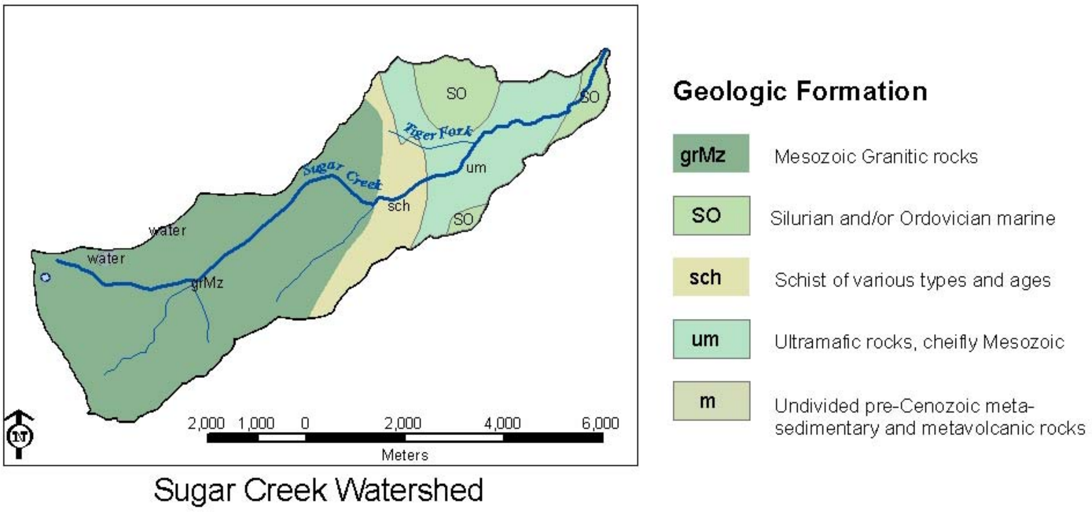


Figure 38. Map of geology of Sugar Creek watershed

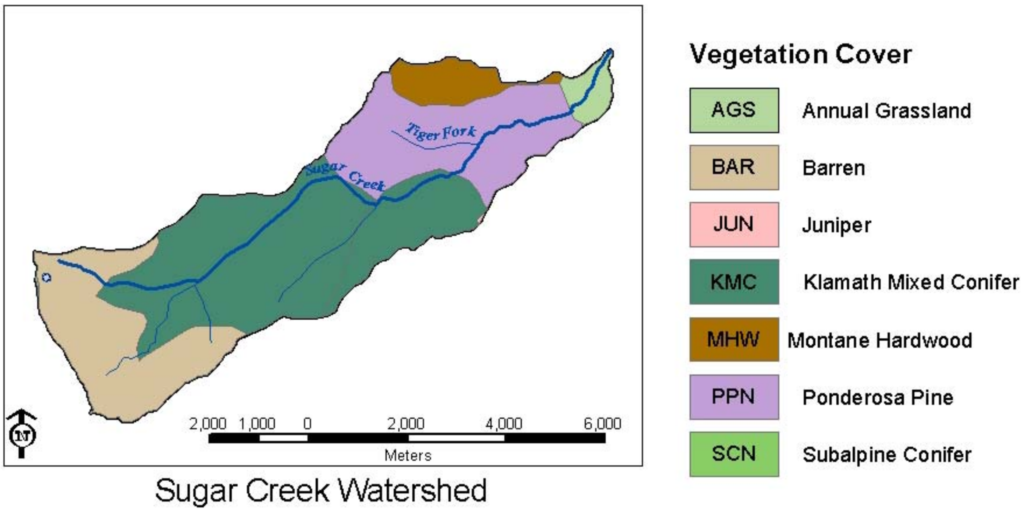


Figure 39. Map of vegetation cover in the Sugar Creek watershed.

The current land uses in the upper watershed (elevations above 1585 m) are the Sugar Creek Research Natural Area and the Russian Wilderness Area. The middle section of the watershed is predominantly Klamath National Forest. Current and historic land use in this middle section of National Forest is timber harvesting. Much of the lower portion of the watershed (elevation below 975 m) is under private ownership. The land uses in the lower watershed are shrub and brush rangeland and both irrigated and non-irrigated pastureland. The land adjacent to Sugar Creek in the vicinity of its confluence with the Scott River consists of large piles of mine tailings associated with historic gold mining. A map of land use and ownership is displayed in Figure 40.

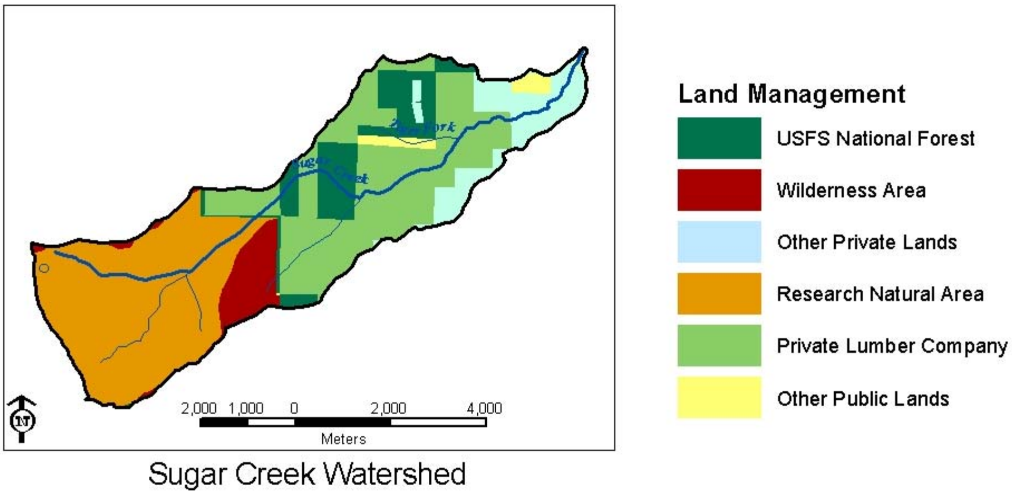


Figure 40. Map of the land uses near Sugar Creek.

Sugar Creek is a fourth order stream. The upper section of Sugar Creek consists of a northern third order branch and a southern second order branch that join together to form the main stem of Sugar Creek. The system of tributaries that collectively forms the northern-most branch of the upper section Sugar Creek originates near High Lake and converges just upstream of Sugar Lake. The tributaries that form the southern branch originate near South Sugar Lake, Grizzly Peak, and Wildcat Peak. A tributary originating near Eaton Peak also enters the main stem of Upper Sugar Creek. Several more first and second order streams enter the main stem of Sugar Creek between the border of the Russian Wilderness Area and the mouth of Sugar Creek at Scott River.

Sugar Creek is a generally stable system with a predominantly healthy riparian corridor; however, high levels of sand infill the channel substrate in various reaches. Although there are multiple, significant diversions on Sugar Creek, we observed no diversions on our study reaches. A more detailed description of upper stream characteristics and lower stream characteristics are discussed separately below.

The upper watershed was observed from just below Sugar Lake downstream to the boundary of the Russian Wilderness Area and a small reach located on public lands 1/3 of the way between the Wilderness boundary and the Tiger Fork confluence. The upper section of Sugar Creek is characterized by a high gradient step-pool system interspersed with occasional cascade sections. The channel substrate is dominated by large cobble to small and large sized boulders. In the reach below the Russian Wilderness boundary, large deposits of decomposed granite of size ranging from coarse-grained sand to small gravel were observed in pools and other areas of low velocity. Riparian vegetation in the upper portion of Sugar Creek consists of less than one channel width of various species of alder shrubs adjacent to stream banks with a continuous mixed conifer forest stretching outward from the stream channel on either side. The mixed conifer forest of the upper section below the Wilderness boundary is laced with unpaved access roads that were constructed for timber harvesting. It is believed that these unpaved timber access roads are at least partially responsible for increased sediment delivery to Sugar Creek. No diversions were directly observed along the upper portion of Sugar Creek.

Several reaches of the lower watershed were observed from just below the perimeter of private timber company property downstream to the confluence with Scott River. The lower section of Sugar Creek is characterized by a relatively low gradient riffle-run system. Stream channel substrate is predominantly small cobble, gravel, and sand. Deposition of sand in low velocity areas of the stream channel was observed in all lower reaches. The majority of the lower section has 1-5 channel widths of riparian vegetation dominated by established alder, cottonwood, and willow trees. The riparian zone along Sugar Creek near its mouth is notably narrower and even absent in a few places, likely due to extensive mounds of mine tailings that are less than one channel width distance from the stream channel in some areas. The land beyond the riparian zone is a mixture of irrigated and non-irrigated pastureland and private homes. One diversion canal was observed south of the lower section of Sugar Creek, but the point of diversion from the stream was not observed within any of the study reaches.

Reach Characteristics

Five reaches on Sugar Creek were surveyed in this study. Two of the reaches were located within the upper watershed, and the remaining three reaches studied were along the lower section of Sugar Creek (Figure 41). The uppermost reach, SGU1, was located just below Sugar Lake and had a length of 21.6 meters. Reach SGU2 was located near Road 40N23 in the Klamath National Forest and had a length of 30 meters. The furthest downstream of the lower reaches was SGO1, a 200-meter reach between the Highway 3 bridge and the confluence with Scott River. Reach SG02 had a length of 110 meters, and reach SG03 was 137 meters. Both were located on private property upstream of Highway 3.

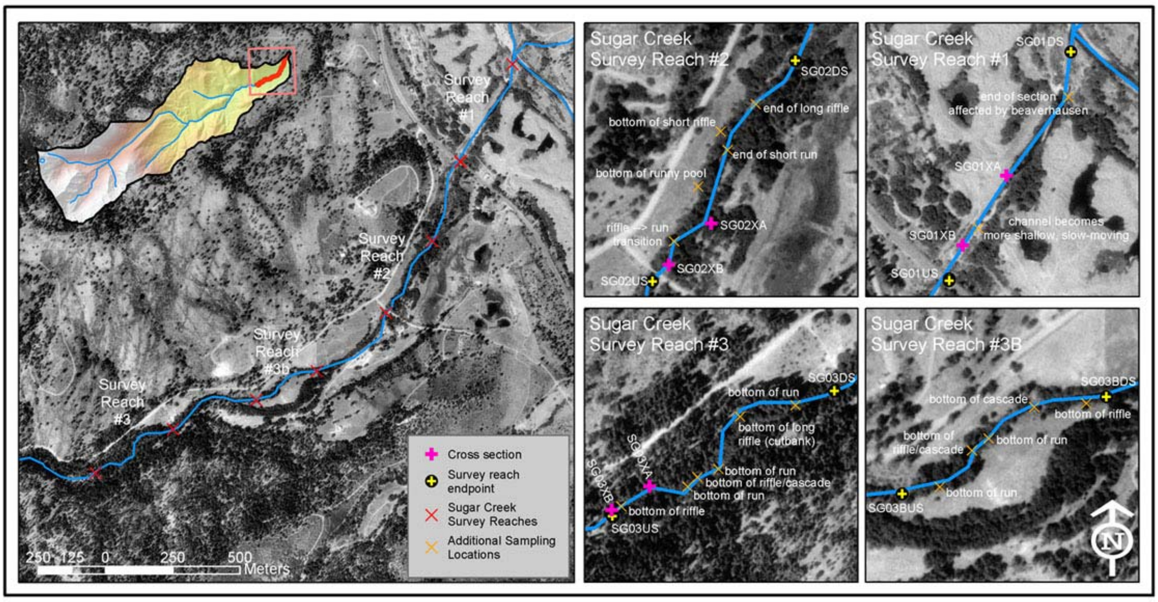


Figure 41. Map of reaches surveyed on Sugar Creek.

Geomorphology

Sugar Creek varied in geomorphology from the lower to the upper section. The lower section was characterized by low gradient riffle-run segments, while the upper section contained mostly steep cascading step-pools. Dominant size of stream bed material decreased from boulders in the upper reaches to gravel and sand in the lowest reach. Instream sedimentation was present in all reaches except for the uppermost, SGU1. It appeared that the lowermost reach, SG01, may have been actively aggrading sand-sized material. Infilling of sand was common in several reaches where flow was not rapid enough to transport sand. Sugar Creek ranged from fully to partly shaded along its entire length, with the exception of the non-shaded section in the reach below the Highway 3 bridge. Dominant riparian vegetation type ranged from small alder shrubs and mature mixed conifer forest in the upper reaches to a mixture of willow, alder, and cottonwood in the lower reaches. See Table 12 for a summary of geomorphological characteristics in Sugar Creek.

				SGU2	SGU1
Reach Length (m)	200	110	137	30	21.6
Rosgen type	C4	B3	B3	A2	A2
Channel Morphology	single channel	single chanel	single channel	single to multiple	single channel
Geomorphic Units	riffle run	riffle run	riffle run	step pool	step pool
Hydraulic Characteristics	ripple	ripple/ waves	rippled/ waves	chute/ rippled	chute/ rippled
Surrounding land use	mine tailings	pasture	pasture	forrest	forrest
Hydrologic Alterations	beaver dam	none	none	none	none
Degree of instream sedimentation	medium	high	medium	medium	none
Channel Stability	aggrading	stable	stable	stable	stable
Canopy Cover	partly shaded	shaded	shaded	partly shaded	shaded
Dominant riparian species	willow/ alder	alder/cotnwd	ald/wil/cotnwd	alder	alder
Vegetation age (yrs)	established 5-30	established 5-30	established 5-30	mature >30	mature >30
Slope	0.16%	0.56%	1.45%	8.30%	6.20%
Estimated width/ depth ratio	16	24	10.67	9.33	6
Sediment Size D16:D50:D84(A)	sand:sand:sand	sand:9.5:168.9	6.1:71.0:349.7	sand:5.7:294.1	
Sediment Size D16:D50:D84(B)	sand:12.6:59.7	3.5:84.4:215.3	sand:48.5:294.1		

Table 12. Summary of geomorphologic characteristics of Sugar Creek.

The lower portion of Sugar Creek was a stable system dominated by alternating segments of riffles and deeper runs. A reflection of the downstream trend mentioned previously, the dominant substrate grain size decreased from boulders in the upper section to cobble in the majority of lower sections. An excess of sand, with extremely similar size and mineral composition to the sand in the upper reaches within timber-harvesting land, infilled the reach such that the cobble bed material was partially embedded. It appeared that a portion Sugar Creek was entrenched, as two sets of terraces (former stream base levels) were visible on either side of the channel in reach SG03 (Figure 42). Floodplain terraces were also present lower in the stream profile, though not as prominent.


Stream Assessment Field Sketch Form

Date/Time: 6/22/03

River/Stream: Sugar Creek

Reach ID: SG03

Location: 03 - just below Tinber Co. land

Map by: EK Anderson

Map Scale (if applicable): 1 ☐ =

SYMBOL LEGEND:

Geomorphic Unit Boundary

Flow Direction

UTM Coordinate Location: RS-1

Fish Sampling Location & ID: F1

Invertebrate Sampling Location & ID: I1

Cross-section Location:

undercut bank

LWD

HYDRAULIC UNIT KEY:

Flow Types:

- ☐ H9 Free Fall
- 🟥 H8 Chute
- ☐ H7 Broken standing waves
- 🟨 H6 Unbroken standing waves
- 🟦 H5 Rippled
- ☐ H4 Upwelling
- 🟪 H3 Smooth surface flow
- 🟦 H2 Scarcely perceptible flow
- 🟧 H1 Standing water

Substrate Categories:

- ☐ S1 Silt
- ▩ S2 Sand
- ▨ S3 Gravel
- ▩ S4 Cobble Sm.
- ■ S5 Cobble Lg.
- ☐ S6 Boulder Sm.
- ☐ S7 Boulder Lg.
- ☐ S8 Bimodal

Form # C -

Figure 42. Reach sketch of SG03.

During major floods, such as in 1964, Sugar Creek likely migrated laterally within the floodplain (Don Swanson, personal communication). The relatively low gradient of Sugar Creek in the lower watershed may have contributed to the stream's ability for lateral migration during high flow events. A typical stream gradient in the lower section of Sugar Creek is shown in Figure 43. Riparian vegetation was continuous beyond the stream banks for 1-5 channel widths or up to the fences separating it from pastureland. The riparian zone was composed of a mixture of establish alders, cottonwood, and willows. Small mounds of mine tailings were spotted on the left bank just below the Klamath National Forest border, thus there was evidence of small-scale historical mining in the area.

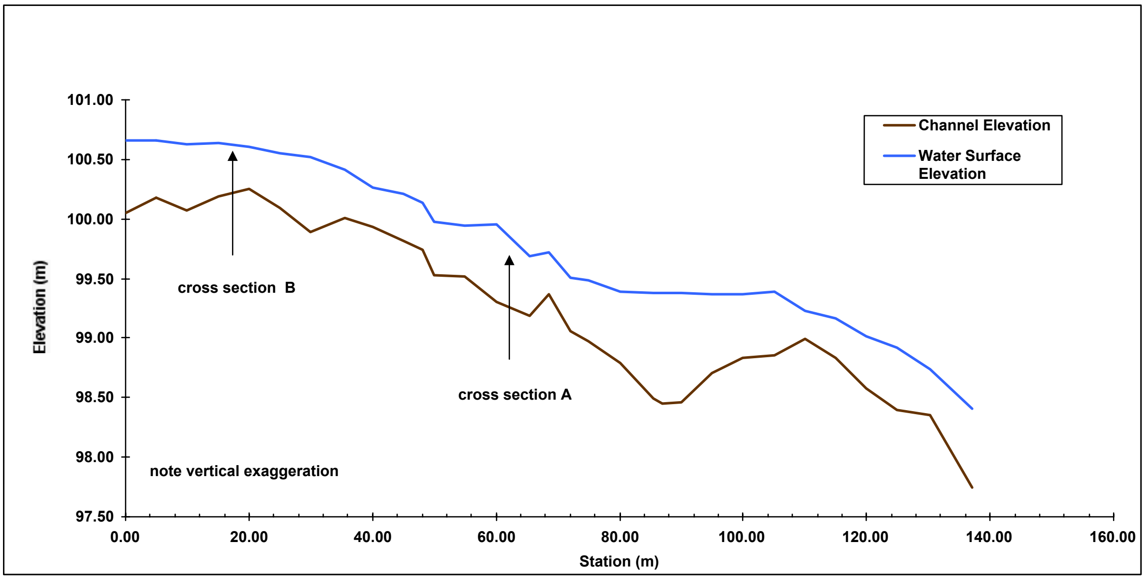


Figure 43. Longitudinal Profile of SG03

The lowermost reach surveyed, SG01, was a unique system whose characteristics were not generally representative of Sugar Creek as a whole. This reach was strongly affected by the presence of riparian mine tailings and beaver activity/damming about 50 meters upstream from the confluence with Scott River. The upstream segment of the run was a riffle within a cobble bed, but just short of midway down the reach, the velocity of flow decreased, and the stream formed a deep, slow-moving run with a sand bed. The results of a surface pebble count within the deep run revealed an uncharacteristically high percentage of fine bed material compared to typical pebble counts in the lower section of Sugar Creek (see Figure 44a and Figure 44b). The beaver dam disrupted the natural flow regime and caused the decreased velocity, channel widening, and sand infilling that a\were characteristic of the deep run segment.

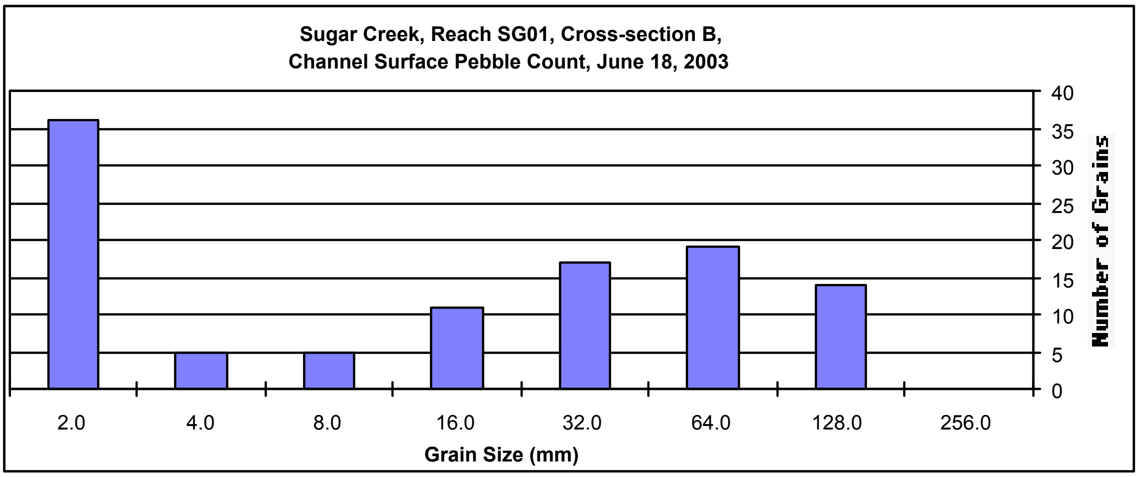


Figure 44a. Pebble count from SG01

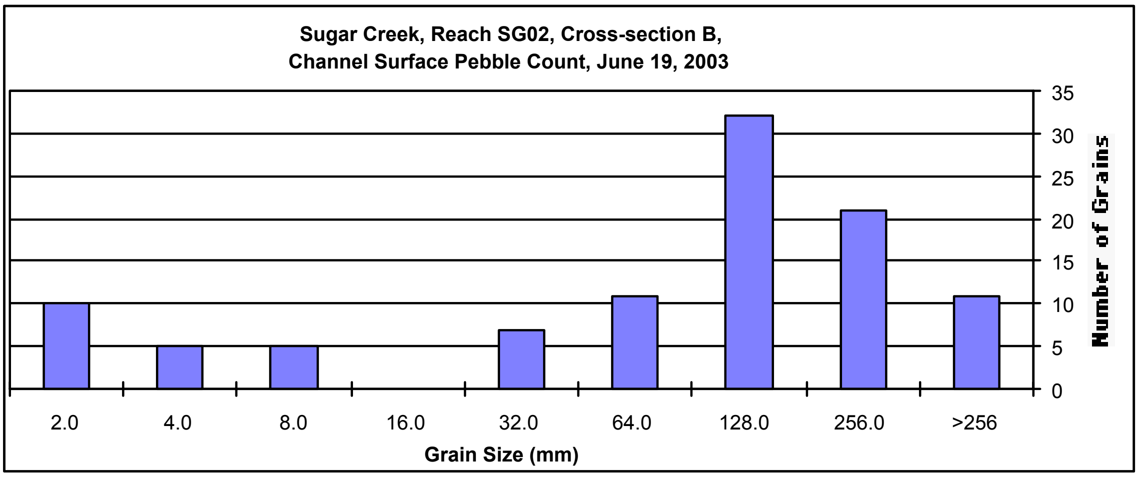
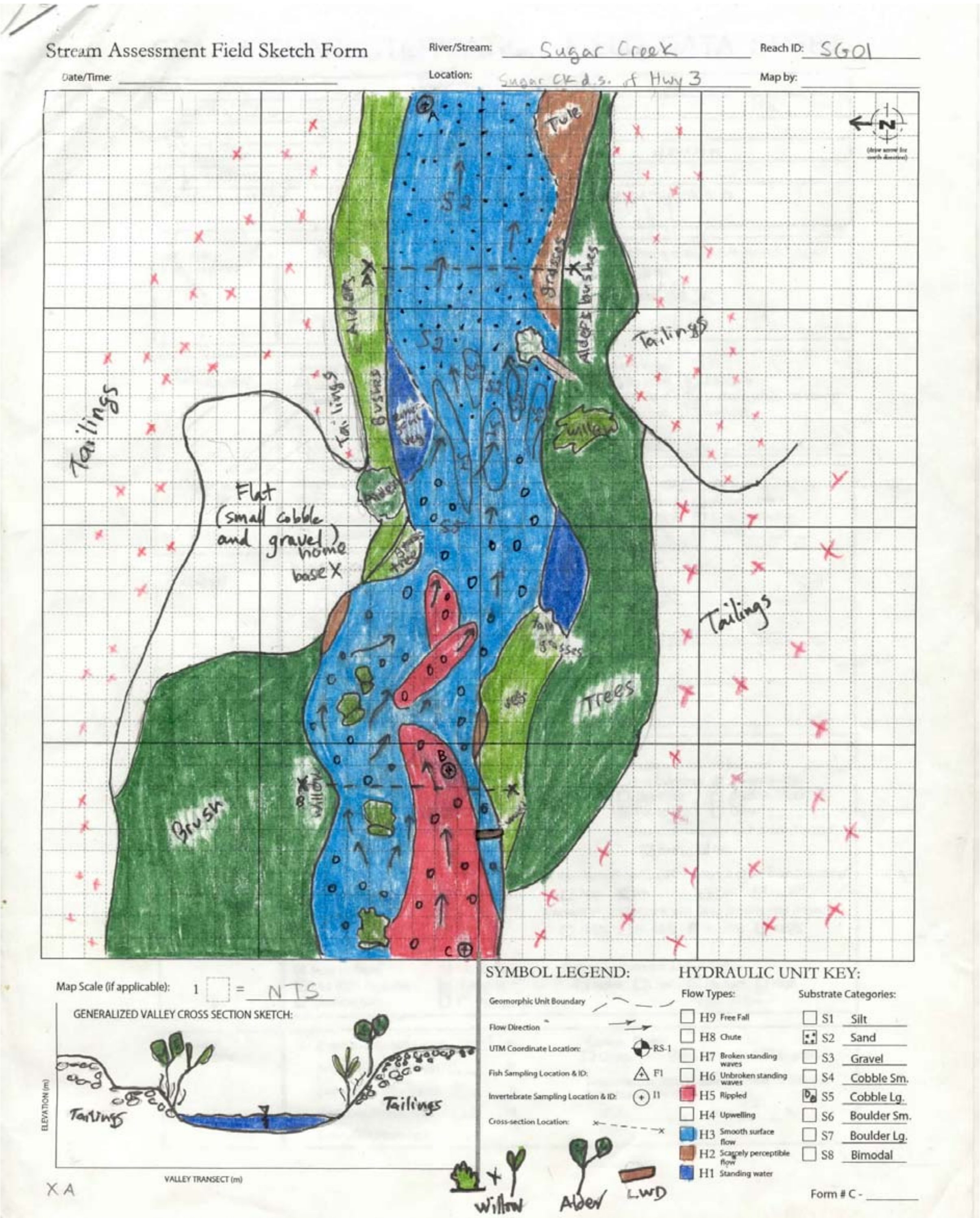


Figure 44b. Pebble count from SG02.

The mine tailings exert a strong control over the morphology of Sugar Creek near its mouth. The tailings, several meters high on either side of the stream channel, limit the ability of the creek to migrate laterally within its floodplain (refer to Figure 45 for spatial distribution of mine tailings). Based on the effects of the tailings and beaver dam and excessive sand found within the channel bed material, we infer that Sugar Creek may be actively aggrading in the lower portion of reach SG01. Riparian vegetation was not extensive in the lower reach, ranging from non-existent to dominantly willow shrubbery to established willow and alder trees.



Stream Assessment Field Sketch Form

River/Stream: Sugar Creek

Reach ID: SG01

Date/Time:

Location: Sugar Ck d.s. of Hwy 3

Map by:

Map Scale (if applicable): 1 ☐ = NTS

SYMBOL LEGEND:

Geomorphic Unit Boundary

Flow Direction

UTM Coordinate Location: RS-1

Fish Sampling Location & ID: F1

Invertebrate Sampling Location & ID: I1

Cross-section Location:

HYDRAULIC UNIT KEY:

Flow Types:

- ☐ H9 Free Fall
- ☐ H8 Chute
- ☐ H7 Broken standing waves
- ☐ H6 Unbroken standing waves
- 🟥 H5 Rippled
- ☐ H4 Upwelling
- 🟦 H3 Smooth surface flow
- 🟫 H2 Scarcely perceptible flow
- 🟦 H1 Standing water

Substrate Categories:

- ☐ S1 Silt
- ☐ S2 Sand
- ☐ S3 Gravel
- ☐ S4 Cobble Sm.
- ☐ S5 Cobble Lg.
- ☐ S6 Boulder Sm.
- ☐ S7 Boulder Lg.
- ☐ S8 Bimodal

Form # C -

Figure 45. Reach sketch of SG01.

The upper portion of Sugar Creek was made up of successive step-pool sequences that transitioned into cascading step-pools downstream as stream gradient decreased. Changes in slope altered stream morphology. In reach SGU2, for example, the gradient decreased, and the channel substrate prograded outward into a debris fan composed of varying sizes of

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boulders and large cobbles. As the stream widened across the debris fan, multiple channels developed beyond the main, step-pool channel (Figure 46). The longitudinal profile of reach SGU1 (Figure 47) shows the typical high gradient of the upper section of Sugar Creek.

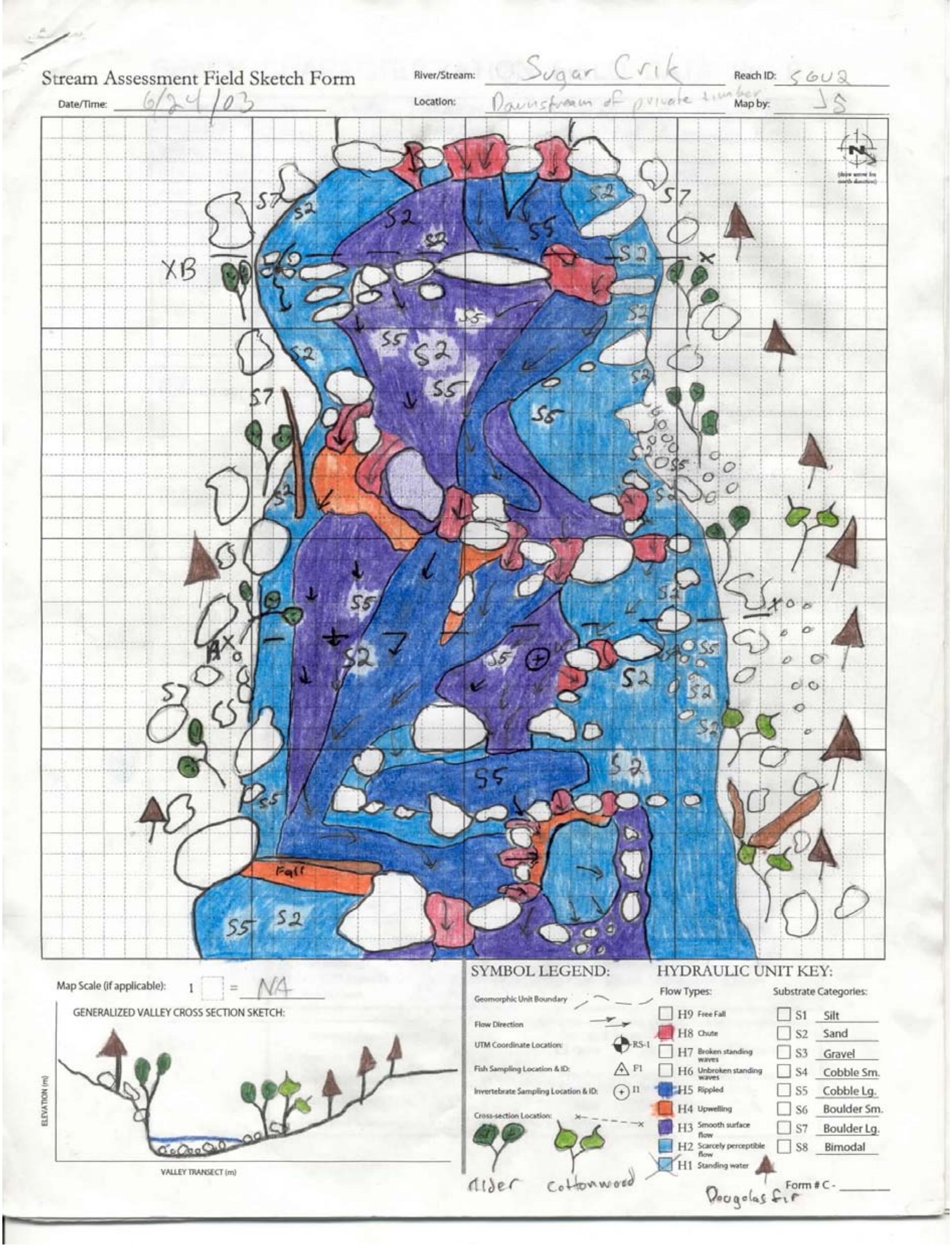

Stream Assessment Field Sketch Form
River/Stream: Sugar Crik
Reach ID: SGU2
Date/Time: 6/24/03
Location: Downstream of private timber
Map by: JS
Map Scale (if applicable): 1 ☐ = NA
Form # C - ______

Figure 46. Reach sketch of SGU2

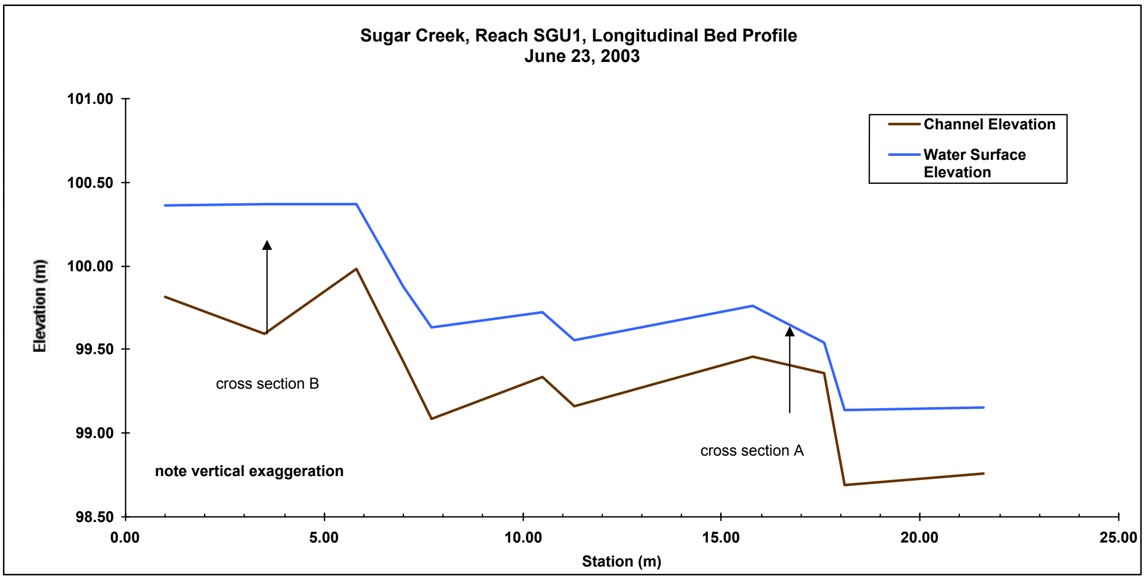


Figure 47. Longitudinal Profile of SGU1

Although the upper watershed had relatively high relief, the stream channel was very stable. Fine sediment infilling in pools was absent in the upper section where the gradient was high, but an excess of sand-sized, decomposed granitic sediment had accumulated within pools and in the areas of low flow velocity found within the multi-channel section in SGU2. This decomposed granite likely reached the stream directly from timber harvesting access roads. In reach SG02, we observed an access road intersecting the stream channel just upstream of the reach. Sediment did not reach the channel directly in the uppermost section of Sugar Creek above timber harvesting land, however, partly due to the generous distribution of young alders on the stream banks and the continuous, mature conifer forest and dense understory that stretched outward from the stream channel. The only human alteration that may have affected Sugar Creek above timber harvesting land was a small concrete dam at the outlet of Sugar Lake. Riparian vegetation was similar throughout the upper watershed, but the mature conifer forest was interspersed by a network of timber harvesting access roads below the non-logging region in the Russian Wilderness Area.

Hydrology

We measured and calculated discharge using two methods, the velocity area and the float method, for all lower reaches. Due to flow complexity, discharge measurements were not possible in the two upper reaches. The magnitude of discharge at each reach using both methods is shown in Table 13. Discharge calculated using the float method is on average about 40% higher than discharge calculated using the velocity-area method. In the lower section of Sugar Creek, discharge increased downstream with 0.627 cms at SG03 and 1.061 cms (velocity-area method) near the outlet at SG01. The downstream increase in flow volume is likely attributed to inputs from groundwater and the contribution of flow from tributaries that flow into Sugar Creek between the reaches. The effects of tributaries, groundwater, and diversion canals on flow volume were not considered in this study.

Site ID	Site Description	Date	Discharge (cms)- velocity-area method	Average Discharge (cms)- float method
SG01	Sugar Creek- Below Hwy 3 Bridge	6/18/03	1.061	1.989
SG02	Sugar Creek- Below private Bridge	6/19/03	0.854	1.22
SG03	Sugar Creek- Below Fruit Growers property	6/22/03	0.6271	0.854
SGU2	Upper Sugar Creek- Between Fruit Growers property	6/24/03	n/a	n/a
SGU1	Upper Sugar Creek- Below Sugar Lake	6/23/03	n/a	n/a

Table 13. Discharge data

The water quality parameters measured at each reach included water temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS). These water quality parameters for Sugar Creek are summarized in Table 14. Water temperatures in the upper reaches of Sugar Creek were only slightly lower (less than 1˚C) than temperatures recorded in lower reaches. The measurements for pH did not vary between reaches. Electrical conductivity and total dissolved solids were much lower for the upper reaches than for the lower reaches, although even the highest values for these parameters did not indicate adverse water quality.

Site ID	Site Description	Time	Date	Temp (C)	PH	TDS (ppm)	EC (µs)
SG01	Sugar Creek- Below Hwy 3 Bridge	10:00am	6/18/03	11.8	7.33	18	36
SG02	Sugar Creek- Below private Bridge	2:15pm	6/19/03	12.2	7.33	20	39
SG03	Sugar Creek- Below Fruit Growers property	9:00am	6/22/03	12.1	7.32	26	52
SGU2	Upper Sugar Creek- Between Fruit Growers property	11:00am	6/24/03	11.4	7.33	2	5
SGU1	Upper Sugar Creek- Below Sugar Lake	1:30am	6/23/03	11.4	7.33	3	7

Table 14. Water quality data

A continuous record of water temperature in Sugar Creek was recorded for the entire study period at two locations: the upstream end of reach SG03 and just downstream of the Highway 3 bridge. At each of the two sites, a thermister was submerged in a shaded area of the stream near the bank. Figure 48 shows the temperature fluctuations of the upstream and downstream thermisters plotted with air temperature fluctuations measured at Callahan, CA. According to Figure 48, there was a general trend of decreasing water temperature and air temperature during the study period. Daily air temperature fluctuation was much greater than daily water temperature fluctuation. Linear correlation between air temperature and water temperature (Figure 49) revealed an R^2 value of 0.596 for the upstream thermister and 0.6278 for the downstream thermister. The relatively weak correlation between air temperature and water temperature was likely due to the abundance of riparian vegetation that shaded much of the water flowing through Sugar Creek. Sugar Creek was unique among the four major tributaries in this study in that it was a consistently cold system not strongly affected by ambient air temperature.

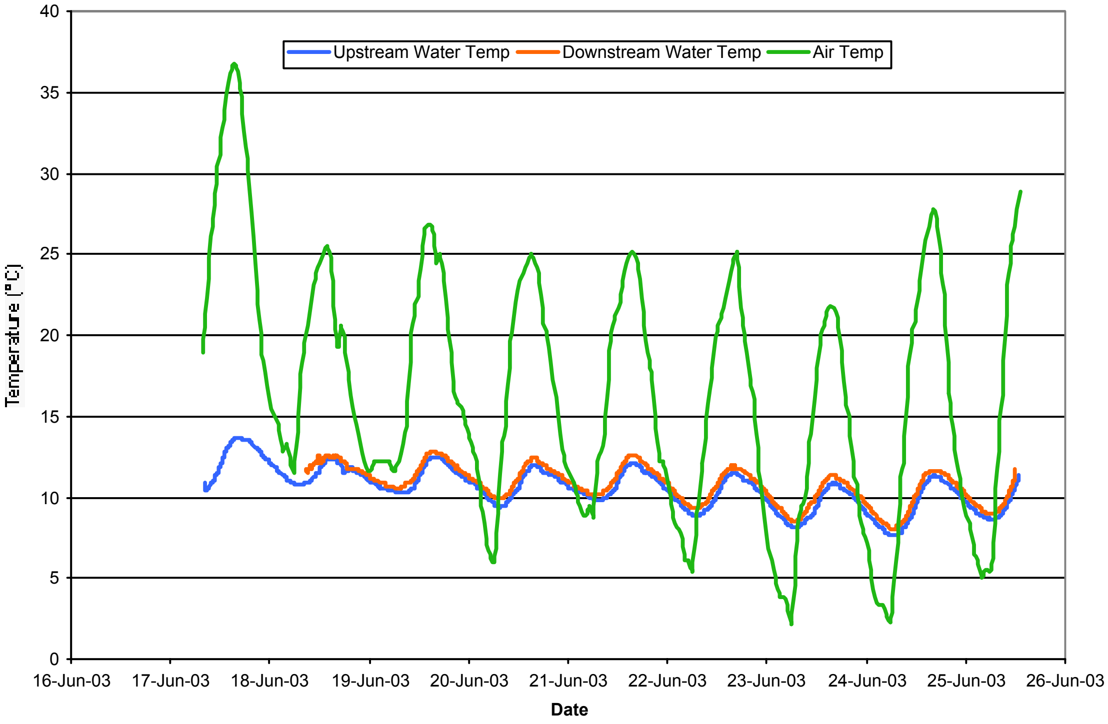


Figure 48. Air temperature at Callahan, CA and water temperature at Sugar Creek during the study

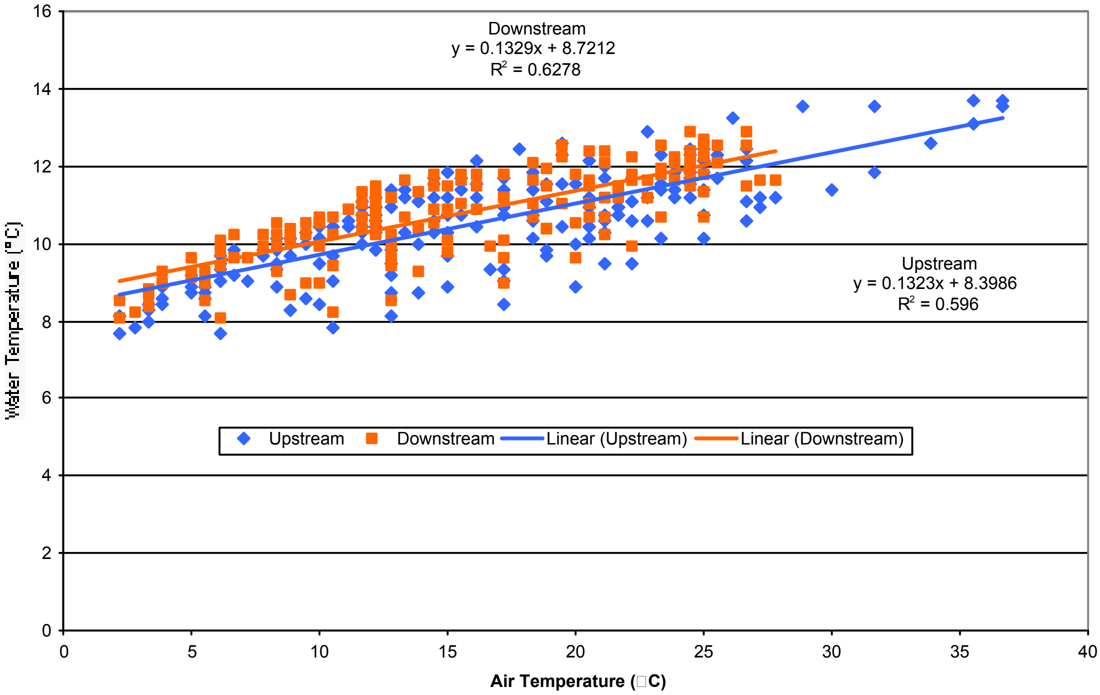


Figure 49. Linear correlation air temperature and water temperature

Macroinvertebrates

Aquatic macroinvertebrate samples were taken in areas that were representative of habitat types within each reach. Two kicks (macroinvertebrate samples) were performed within lower reaches SG03 and SG02, and three kicks were performed in reach SG01. One kick was done at each upper section reach. Kick locations are shown on each of the survey reach sketches (see figures 42, 45, 46 and Appendix B).

Deposition of sand in all reaches with the exception of SGU1 (the uppermost reach) show varying degrees of infilling by fine sand and gravel-sized sediment. Site SG01 contains the greatest amount of in-stream accumulation of fine sediment (refer to Geomorphology section for explanation of aggradation causes). Fine sediment infilling around gravel, cobble, and boulder streambed material is considered unfavorable habitat for aquatic macroinvertebrate colonization.

The total number of macroinvertebrates found on Sugar Creek decreased in an upstream direction with the exception of reach SGU1. Figure 50 illustrates this trend. The number of different taxa found in each sample is shown in Figure 51. In general, more taxa were found in the lower reaches than in the upper reaches. Site SGU1 was located just downstream of Sugar Lake. The abundance of taxa and individual macroinvertebrates in this reach was probably tied to its proximity to the lake. The large number of Diptera found in this reach versus lower reaches suggests that the lake may exhibit some control over macroinvertebrate populations directly downstream. Reach SGU2 was nearly devoid of macroinvertebrates, probably due to an excess of fine sediments within the channel.

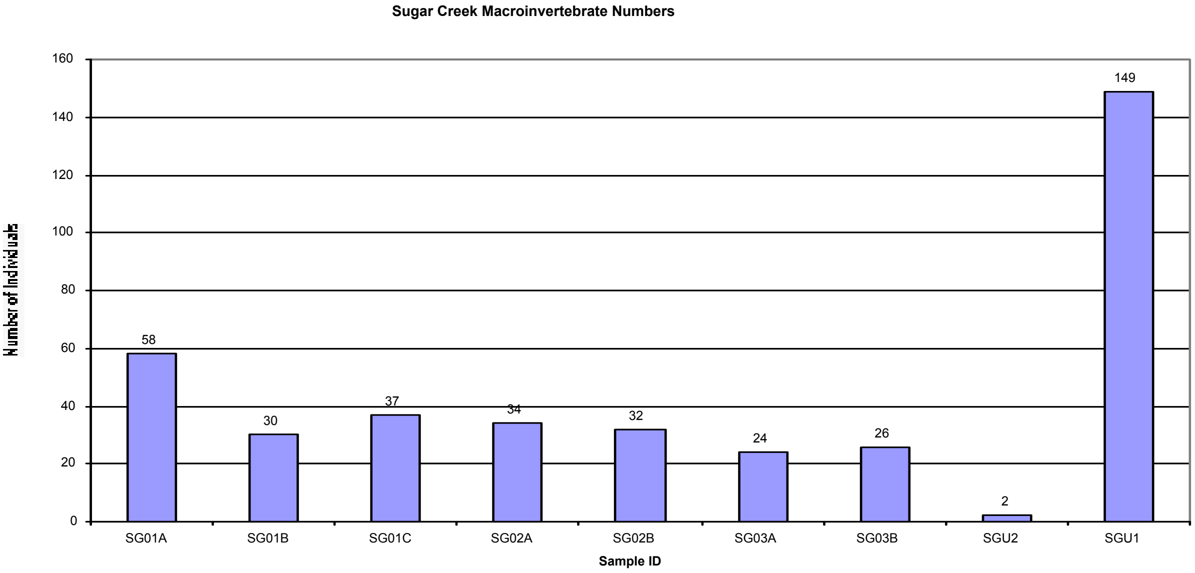


Figure 50. Number of macroinvertebrates found in Sugar Creek

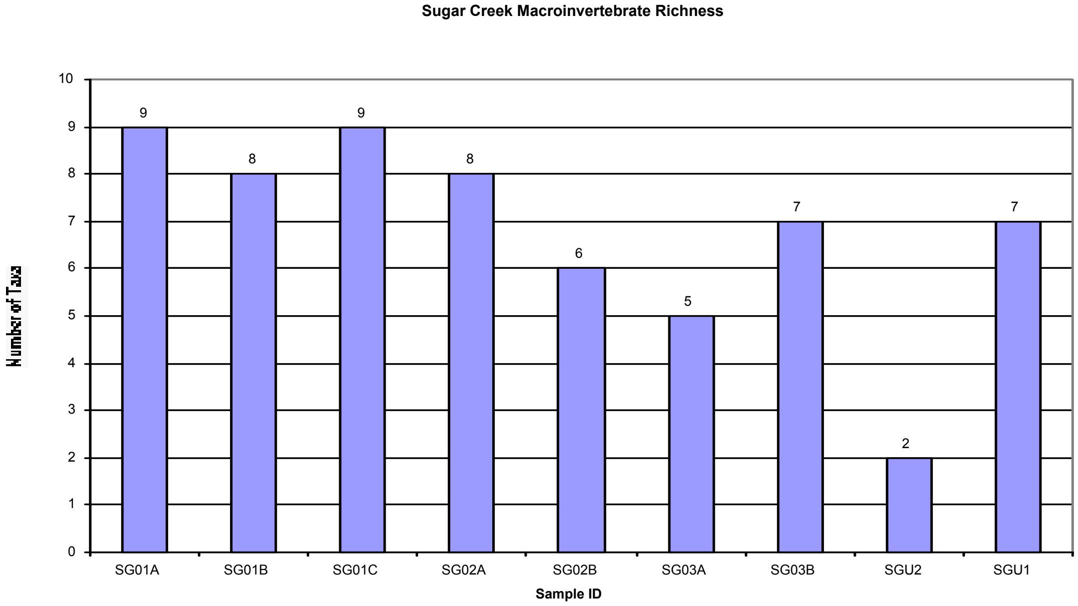


Figure 51. Number of taxa found in Sugar Creek

Lower Sugar Creek contained a greater diversity of taxa than the upper reaches. The most abundant taxa was Ephemeroptera (See raw data in Appendix B for more details). These individuals seemed to prefer riffles to both runs and pools. Plecoptera and Trichoptera appeared to be evenly distributed between riffles and runs. Substrate in the gravel and cobble size range was the most suitable substrate for most aquatic insects, while sand was much less hospitable. Temperature, water depth, and stream velocity did not seem to have a significant affect on the distribution of insects.

EPT ratios implied that reach SGU2 had the best habitat for aquatic insects (Figure 52); however, the low number of individuals found in this reach suggested this was untrue. Reach SGU1 had a higher EPT ratio than many of the other reaches, implying that it had a less diverse insect community. However, the large number of Diptera and Lepidoptera found at this site suggest that the habitat, although not diverse, was suitable to these orders of aquatic insects.

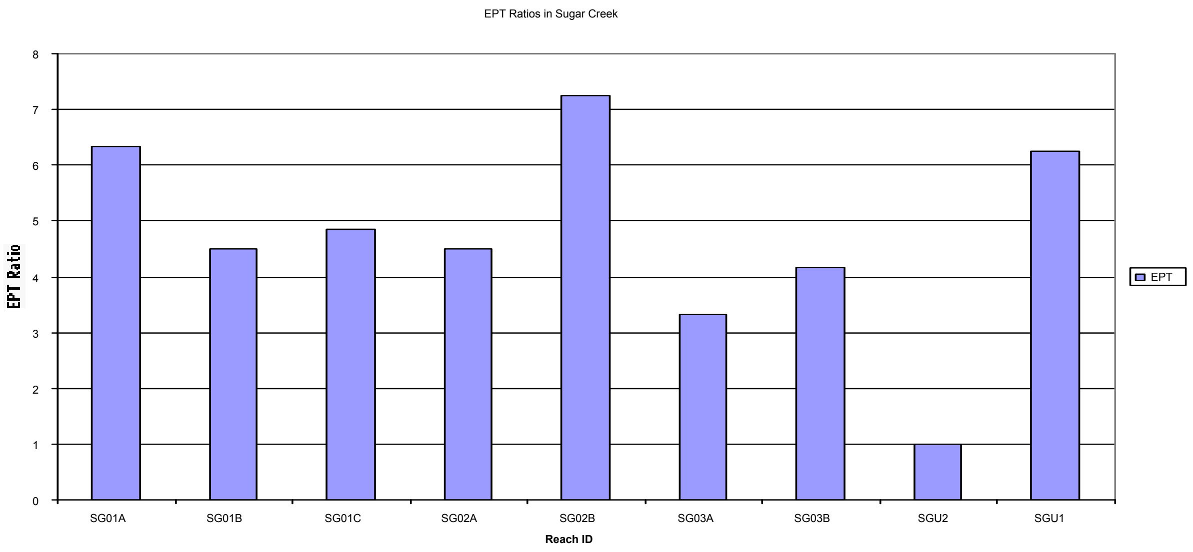


Figure 52. EPT ratios in Sugar Creek

Fish

The available microhabitats in Sugar Creek ultimately dictated what species of fish were likely to persist in a given location. The water temperature of all reaches studied ranged from 11.4° to 12.2°C and therefore appeared to meet minimum salmonid fish requirements of temperature and available oxygen (high levels of dissolved oxygen in water were inferred given temperature, aeration (riffles), and pH). Also, the water in all studied sections of the creek was very clear and showed no visible or olfactory evidence of pollutants. However, Sugar Creek had no optimal fish habitat due to the impact of past and continuing human activities in the watershed. For example, erosion from logging and forest access roads in the watershed contributed heavily to the deposition of sand in the Creek. This sand essentially blocked access to the cobble habitat that would otherwise be used by insects and for fish spawning. Another major factor limiting fish habitat in Sugar Creek was the lack of large woody debris necessary for providing velocity shelter for juveniles. Table 15 lists factors (both biotic and physical) required for optimal fish habitat and their status in each reach surveyed. Refer to the reach sketches of each survey reach in Appendix B and to Table 16 for the number of fish counted in each reach.

	Optimal Fish Habitat Characteristics						
Reach ID	Water Quality	Available food (insects and insect habitat)	Shade and overhanging Vegetation	Spawning habitat	Large woody Debris	Deep Pools Or varied flow areas	Water availability Threatened from diversions?
SGU2	High	Yes	Yes	No	Yes	Yes	No
SGU1	High	None	Yes	No	Yes	yes	No
SG03	High	Few	Yes	Possible	No	no	Yes
SG02	High	Few	Yes	Possible	No	Some	Yes
SG01	High	Yes	No	Some	Some	yes	Yes

Table 15. Optimal fish habitat characteristics in Sugar Creek

reach name	reach type	reach area (sq m)	Fish (number observed)					
			coho	steelhead	sculpin	dace	lamprey	**sum**
SGU1	step-pool	63		1				1
SGU2	step-pool	245						0
SG01	riffle-run	1600	287	253		5		545
SG02	riffle-run	720	13	62	1			76
SG03	riffle-run	1280		23			1	24
		sum	300	339	1	5	1	--

Table 16. Number of fish found in Sugar Creek

The uppermost section (SGU1) flowed directly out of Sugar Lake. It was a high gradient, step-pool portion of the stream. One rainbow trout was caught by rod and reel on the first attempted cast, thus it might be inferred that mainly rainbow trout were found in this reach. Fish most likely entered this section of the creek from Sugar Lake since the high gradient, large boulders, and high velocity flows of Sugar Creek in the sections below SGU1 presumably acted as barriers to upstream migration. Good water quality, diverse fish habitat, and abundant food (insects) were observed in this uppermost section.

Reach SGU2 also had a high gradient, step-pool morphology, but no fish were observed in this area. Despite good water quality and cover, a great deal of sand was found in the streambed, which may be responsible for the lack of macroinvertebrates found in this section. It is possible that the lack of insects as food for the fish was the limiting factor for fish in this reach.

The lower section of Sugar Creek had a low gradient and was within a couple miles of Sugar Creek's confluence with Scott River. Reaches SG02 and SG03 were riffle-run sections extensively shaded by riparian vegetation. Reach SG01 (nearest to the confluence) was best described as a swift and deep riffle that enters a long, slow-moving run with only partial shading. The differences in habitat among the lower reaches were reflected by the number and type of fish found.

In reach SG03, we observed only one juvenile steelhead out of 23 total fish counted. These fish were approximately 12 centimeters long and inhabited the thalweg in the area where a riffle entered a section of relatively slower water (pool-like, but containing fast moving water). We assume that the absence of shelter from fast moving water (i.e., lack of woody debris), was an important reason why no juvenile coho salmon or steelhead were found in this section.

SG02 was similar to SG03 in terms of shade and stream gradient, but it had areas of slower-moving water where juvenile coho and steelhead were observed. 13 coho and 62 steelhead juveniles were counted along the edges of the creek in areas sheltered from high velocities (e.g. root masses and woody debris).

The upper portion of reach SG01 was a strong, deep riffle with in-stream willows providing root mass for fish habitat. This riffle transitioned into a deep, slow run and then to a very slow-moving beaver pond. 287 coho and 253 steelhead juveniles were counted in reach SG01, mostly in the upper riffle area. These fish were observed exclusively along the edges of the stream channel and in areas of root mass, woody debris, grasses and other shelters from high flow velocity. The large number of fish counted in this reach may be attributed to areas of spawning habitat available to adults last season coupled with the availability of insects and shelter for this year's juveniles. In the slower and deeper sections of the reach (near the beaver pond), five speckled dace were observed swimming along the bottom, primarily among attached algae.

In summary, the presence or absence of fish in a given section of Sugar Creek was the function of many interacting biological and physical factors. Optimal coho salmon habitat was not observed in any section of Sugar Creek. When a section of the Creek contained one habitat requirement, it often lacked another. For example, reach SGU2 had available woody debris, great water quality, and varying flow regimes, but since it was embedded by sand from road erosion, there was no insect habitat and therefore no food for fish. As a result, the low numbers of fish observed were probably the result of other factors such as spawning and rearing habitat, available food (insect habitat), and physical obstacles (dams, diversions). It is important to note that this study took place in late spring-early summer and that stream conditions in late summer-early fall are less favorable for fish. This is due to decreased runoff from snowmelt, increased agricultural water demand, and increased ambient air temperatures.

EAST FORK SCOTT RIVER

Introduction

Few coho salmon were observed on the East Fork Scott River, despite many favorable habitat attributes. The East Fork of the Scott River is a tributary to the Scott River, and their confluence is at Callahan (Figure 2). The East Fork Scott River is located in the dry, southeastern side of the Scott River watershed. It is possible that disconnection of the East Fork Scott River from the mainstem Scott River near Callahan during dry years blocks coho salmon migration, inhibiting spawning of anadromous fish.

This section begins with a broad description of the East Fork Scott River, and notes historic and current land use practices. Reach survey locations are described with attention given to differences in the upper and lower portions of the East Fork Scott watershed. Reach characteristics and preliminary results are discussed, findings are divided by discipline into geomorphology, hydrology, macroinvertebrates and fisheries sections. The section ends with a discussion of the limiting factors to coho spawning and rearing.

Watershed Characteristics

The East Fork Scott River drains the Scott Mountains, which, due to a rainshadow effect, are generally drier than the mountains in the west side of the watershed. This is reflected in the vegetation of the valley, which is predominately Ponderosa Pine and sagebrush scrub in unirrigated and non-riparian sections of the valley (Figure 53). The geology of the East Fork Scott Valley is comprised of ultramafic rocks, such as serpentine, which limit plant growth, contributing to its arid appearance (Figure 54). The East Fork Scott

River is in a broad U-Shaped valley, and elevation changes are gradual along the watershed ranging from 951 m to 2600 m (Table 17; Figure 55). Diversions from the East Fork Scott River are common for irrigation. Typically diversion return flows are delivered back into the creek. Some of these diversions have fish screens, and there is increasing effort to screen all diversions. In the East Fork Scott River, sediment size is mixed, with gravel, cobble, and boulders. Backwaters and side channels often exist, providing habitat for juvenile fish.

Watershed Characteristics	East Fork Scott River
Watershed Area (km^2)	298.808
Watershed Perimeter (km)	84.65
Watershed Aspect	southwest
Wtrshd Elevational Range (m)	951 to 2600
Stream Elevational Range (m)	951 to 1483
River Distance on Scott (km)	91
Stream Order	5
Stream Length (km)	26
Length of all Streams in Wtrshd (km)	193
Drainage Density (m per m^2)	0.64590

Table 17. Physical watershed characteristics.

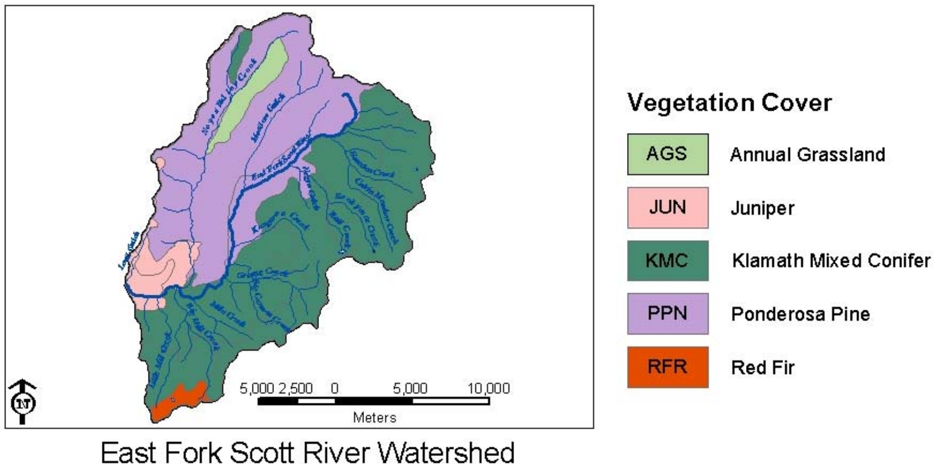


Figure 53. Vegetation map of East Fork Scott River watershed

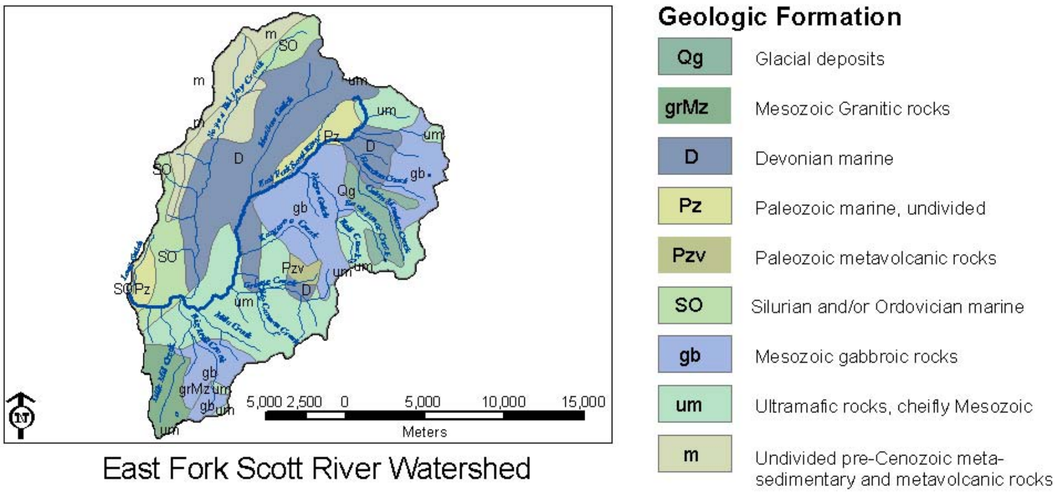


Figure 54. Geology map of East Fork Scott River watershed

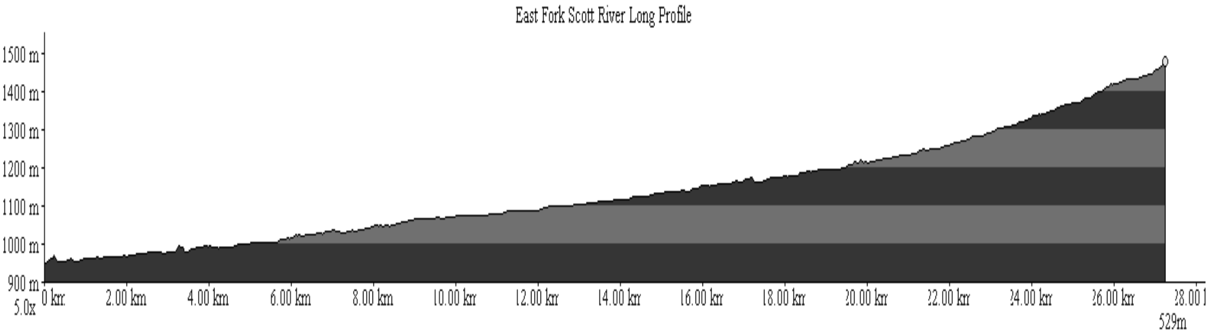


Figure 55. East Fork Scott River Elevation Profile

Tributaries to the East Fork Scott River differ in many aspects with the East Fork Scott River. The tributaries have colder water, and steeper gradient channels that create V-shaped valleys from incision. The geology is varied with glacial deposits, gabbros, and serpentines. Sediments are large, mostly comprised of cobble and boulder sized particles. Erosion is a concern on hillslopes and streambanks from extensive logging and road building. Anabranching, or the formation of multiple channels, is common due to large sized debris and logs falling in the streambeds and blocking channels. Despite this, some tributaries have large numbers of steelhead trout. Vegetation surrounding the tributaries, outside the riparian corridor is predominantly Douglas Fir, Incense Cedar, and Ponderosa Pine.

During the past century, there have been numerous land use practices to utilize the resources in the East Fork Scott Valley. Extensive mining occurred historically, including both hydraulic and placer mining. Although the extent of mining has decreased dramatically in the past century, there are still small working mines in the watershed. In addition, dredged rock piles and unstable slopes from mining practices are identifiable in some areas of the East Fork Scott basin. Logging has also been practiced historically and continues today, although the extent of logging varies (Figure 56). In some areas, forests have been thinned, or helicopter logged. However, on tributaries in the upper watershed of the East Fork Scott River, there are sections of the forest that have been clear-cut and replanted during the past decade. Along these tributaries, there are numerous logging roads and skid trails which result in slope instability and increased sedimentation in the stream channels.

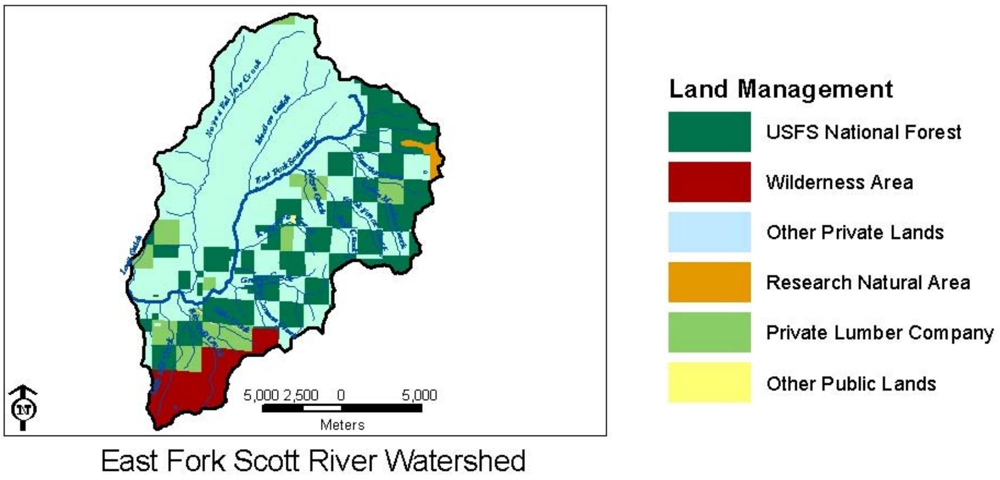


Figure 56. East Fork Scott River Land Management

In the East Fork Scott Valley, current private land use is comprised mainly of irrigated rangeland. The East Fork Scott River above the confluence of Kangaroo Creek is nearly entirely private land and irrigated pasture is the main land use (Figure 56). Pastures have been irrigated in this valley for nearly a century. There are small areas of agricultural production lower in the watershed.

Reach Characteristics

Detailed surveys were completed at three sites on the East Fork Scott River (EF01, EF02, and EF03), all located on Jay and Raelene Phelps' property. In addition, two reaches were surveyed on tributaries to the East Fork Scott River: a reach on Forest Service land near the Jolly Rogers Mine on Grouse Creek (GC01), and a reach on Cabin Meadows Creek

(CM01), downstream of road 41N10. A total of five complete reach surveys were completed (Figure 57).

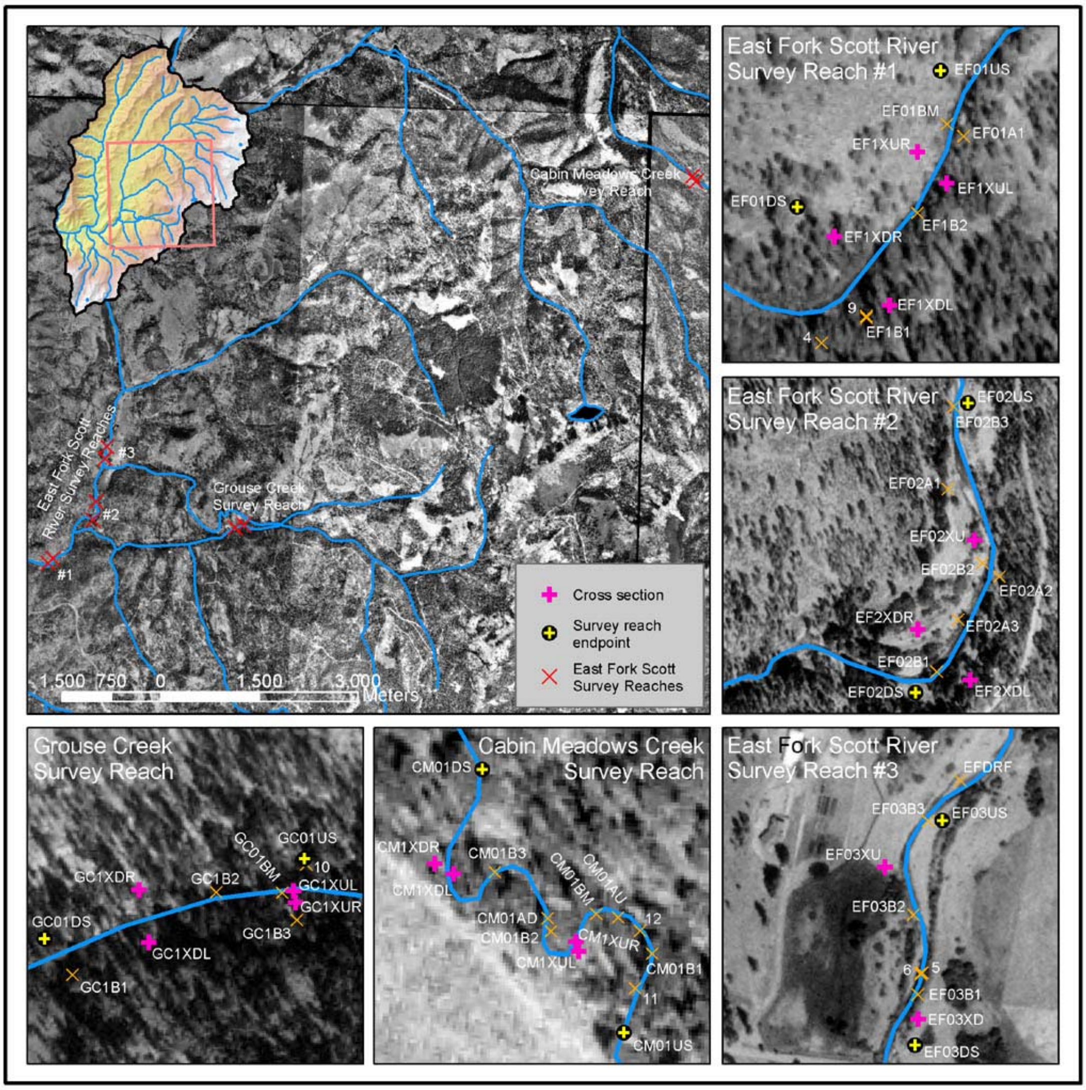


Figure 57. East Fork Scott Valley survey reach locations

Geomorphology

The upper reaches on the East Fork Scott River (EF02 and EF03) were mainly dominated by riffle and run habitats, and the farthest downstream reach (EF01) was primarily cascade and run habitats (Table 18). These reaches could be described as Rosgen type B3 (intermediate gradient, cobble) and Rosgen type B2 (intermediate gradient, boulder) channels respectively. EF01 was confined by bedrock outcrops, resulting in a single channel (Figure 58). Side channels and backwaters were observed in EF02, as were numerous dry channels and flood terraces (Figure 59). EF03 had a single channel due to riprap at all stream bends;

however, there were numerous dry channels indicating natural tendencies to anabranch (Figure 60). In all these reaches there were mixed sizes of sediment; however, the majority of grains were in the coarse gravel, cobble, and boulder size classes.

Reach ID	**EF01**	**EF02**	**EF03**	**GC01**	**CM01**
Reach Length (m)	156	300	215	150	106
Rosgen type	B2	B3	B3	A2	A2
Channel Morphology	Single channel	Side Channels and backwaters present, numerous dry channels	Single channel, dry channels Common	Single channel	Multi-channel anabranching/Braided along with riffle run sequences
Geomorphic Units	riffle/run & cascade	riffle/run	riffle/run	cascade & step-pool	Cascade & step-pool
Hydraulic Characteristics	unbroken standing waves, ripples and turbulent eddies	unbroken standing waves, ripples and minor edding	borken standing waves, ripples	broken standing waves	broken standing waves
Surrounding land use	Forest & Pasture	Forest & Pasture	Pasture	Forest	Logging
Hydraulic Alterations	none	none	riprap & waterwings	none	none
Degree of instream sedimentation	Low	Low	Low	Low	Medium
Channel Stability	stable	moderately stable	stable	stable	aggrading
Canopy Cover	partly shaded	partly shaded	open	partly shaded	partly shaded
Dominant riparian species	Alder & Pine	Alder, Willow & Conifers	Alder	Alder	Cedar & Pine
Vegetation age (yrs)	Established (5-30yrs)	Established (5-30yrs)	Immature (<5years)	Established (5-30yrs)	Immature (<5years)
Slope %	1.25	0.5	1	4.28	6
Estimated width/ depth ratio	23	25	2.14	10	25
Sediment Size D16:D50:D84 Cross Section A	06:08.8	5.6:7.5:3.3	5.5:6.9:3.5	3.2:8:1	3.5:5.7:1.1
Sediment Size D16:D50:D84 A Cross Section B	7:8.7:3.5	5.4:6.7:2.8	5.3:7.9:1.7	4:7.7:1.2	6:8.5:3.8

Table 18. Summary of the dominant geomorphology characteristics of each surveyed reach.

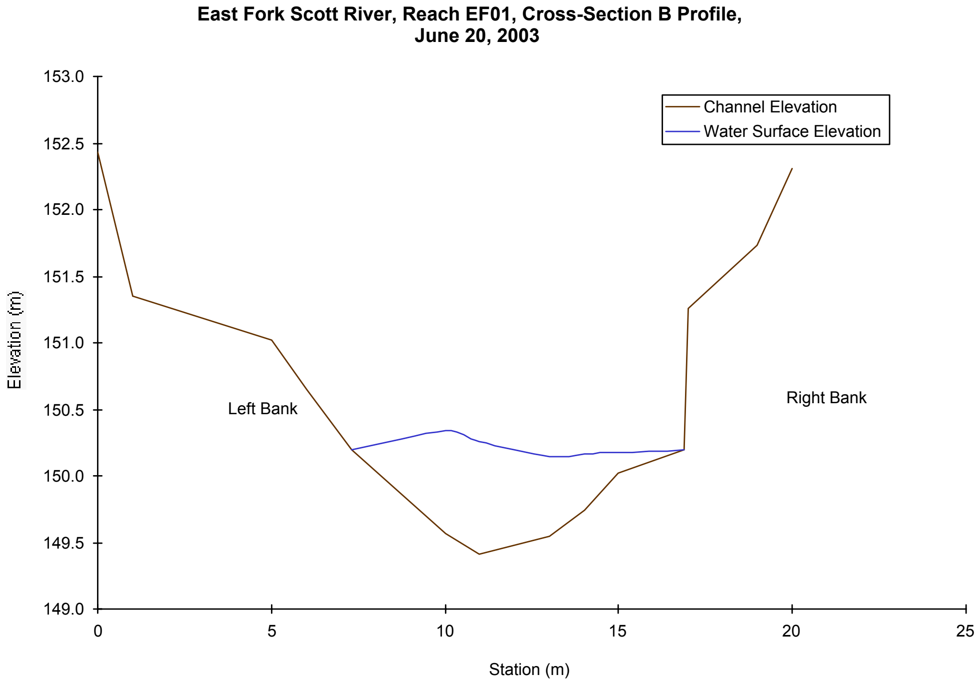
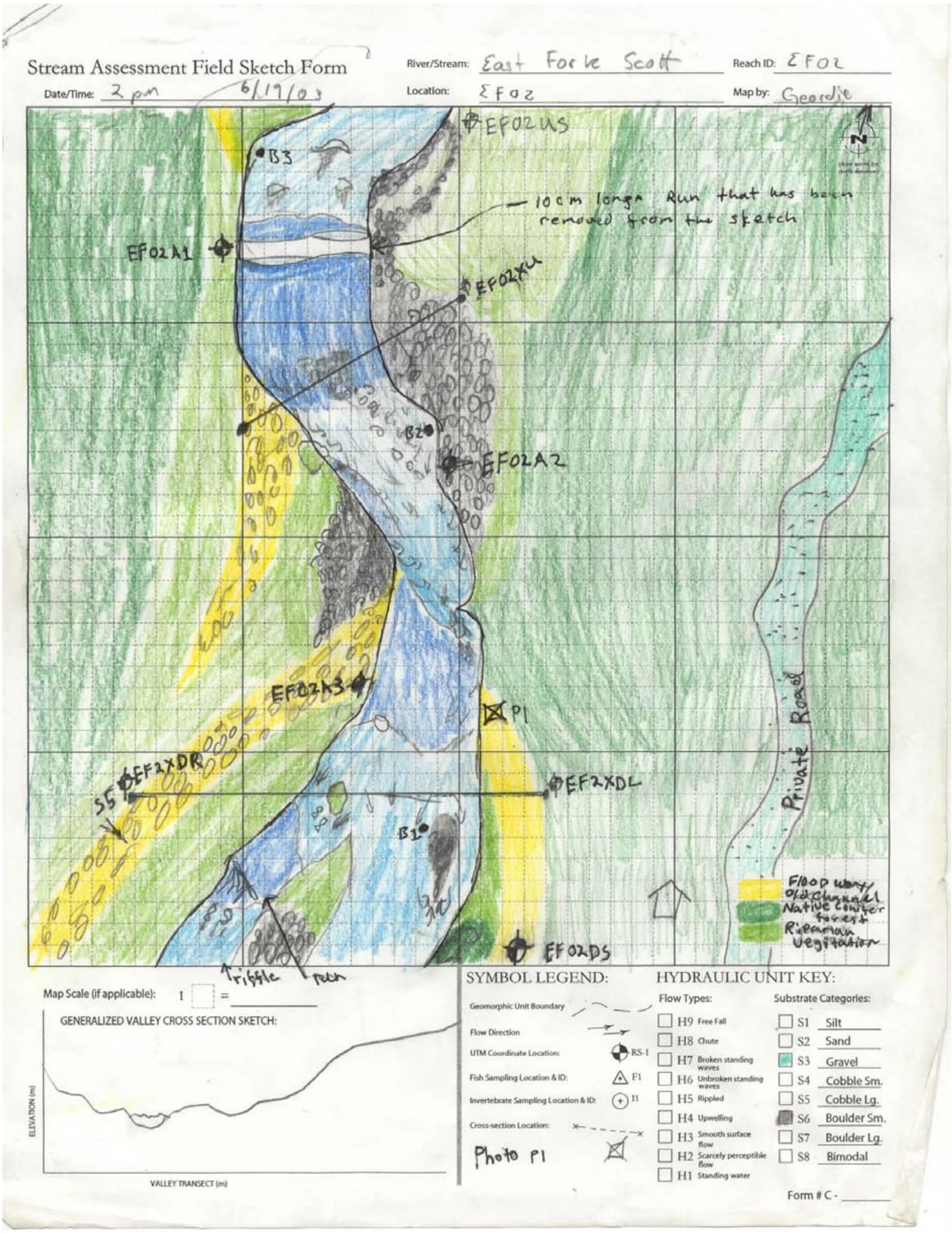


Figure 58. Cross-section transect of a single channel system (Reach EF01).



Stream Assessment Field Sketch Form

River/Stream: East Forke Scott

Reach ID: EF02

Date/Time: 2 pm 6/19/03

Location: EF02

Map by: Geordie

Map Scale (if applicable): 1 ☐ = ______

GENERALIZED VALLEY CROSS SECTION SKETCH:

SYMBOL LEGEND:

Geomorphic Unit Boundary
Flow Direction
UTM Coordinate Location: RS-1
Fish Sampling Location & ID: F1
Invertebrate Sampling Location & ID: I1
Cross-section Location:
Photo P1

HYDRAULIC UNIT KEY:

Flow Types:

- ☐ H9 Free Fall
- ☐ H8 Chute
- ☐ H7 Broken standing waves
- ☐ H6 Unbroken standing waves
- ☐ H5 Rippled
- ☐ H4 Upwelling
- ☐ H3 Smooth surface flow
- ☐ H2 Scarcely perceptible flow
- ☐ H1 Standing water

Substrate Categories:

- ☐ S1 Silt
- ☐ S2 Sand
- ☑ S3 Gravel
- ☐ S4 Cobble Sm.
- ☐ S5 Cobble Lg.
- ☑ S6 Boulder Sm.
- ☐ S7 Boulder Lg.
- ☐ S8 Bimodal

Form # C - ______

Figure 59. Reach sketch of EF02.

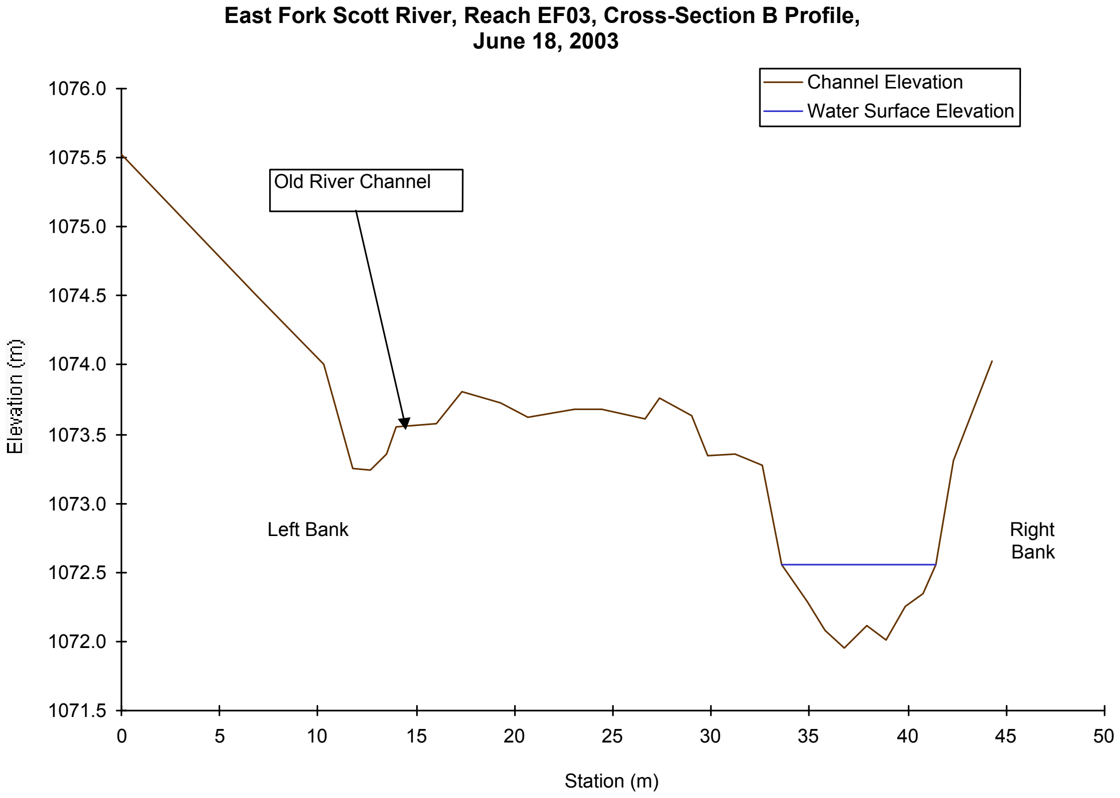
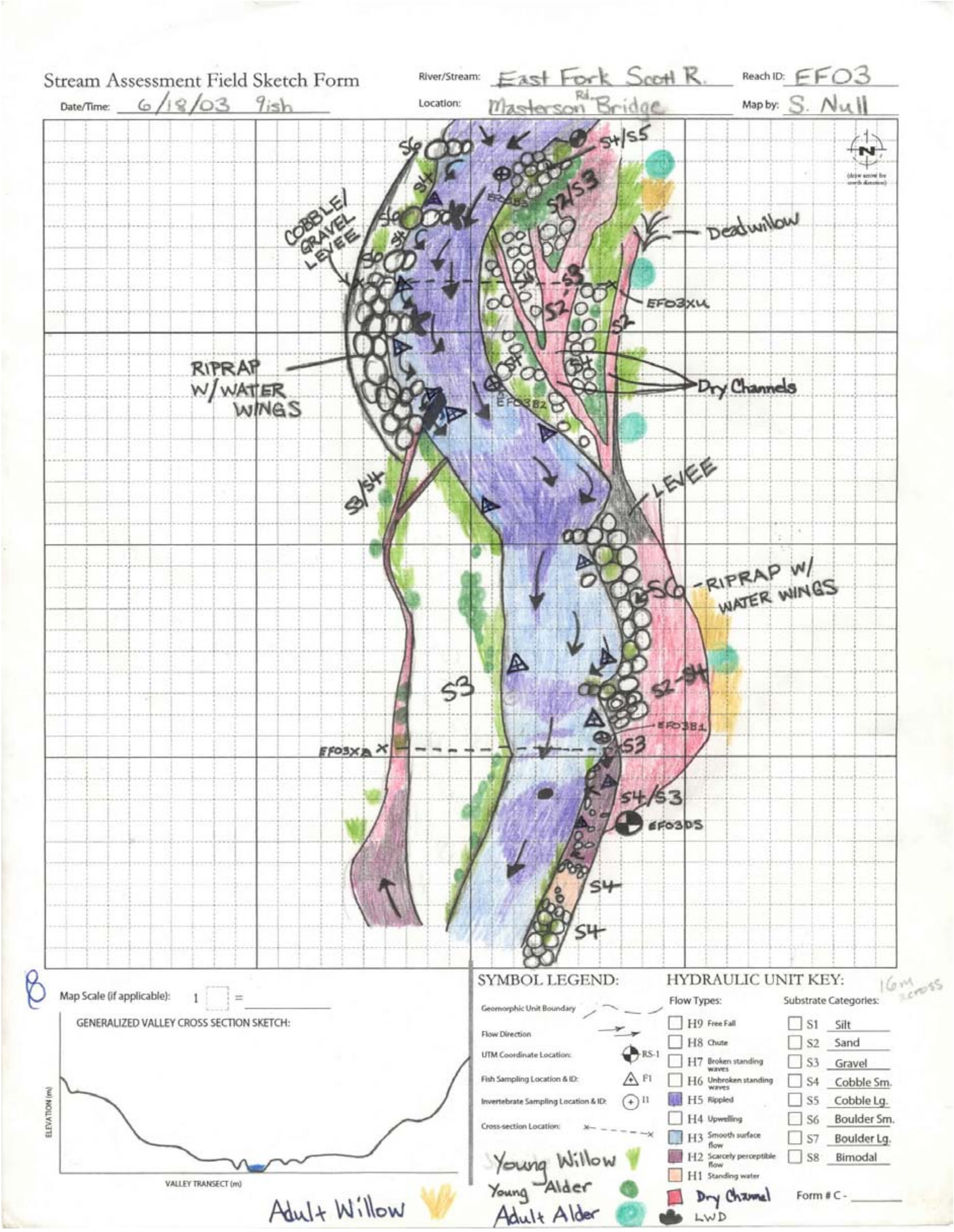


Figure 60. Cross-section transect at EF03 (riprapped reach) showing old channels. Elevation has been exaggerated.

Reach EF03 differed from other reaches on the East Fork Scott River because it had human alterations such as riprap for channel confinement, water wings and revegetation for habitat restoration. It is apparent from cross-sections that the river used to have multiple channels, rather than the single channel found there now. Indeed large, established riparian vegetation remains along now-dry channels. These shaded side channels could provide salmonids with over-winter habitat, and could help to provide refuges from high velocity flows. To make up for this loss of habitat, water wings (large boulders and LWD that juts into the channel perpendicularly) were added to riprapped bends to create eddies (Figure 61). In addition, the area was planted with young alder and willow trees to provide cover for fish, and presumably, to improve the stability of the channel banks. Here, the revegetation appears to be successful; although downstream from the reach, all saplings that were planted have not survived.



Stream Assessment Field Sketch Form

Date/Time: 6/18/03 9ish

River/Stream: East Fork Scott R.

Reach ID: EF03

Location: Masterson Rd. Bridge

Map by: S. Null

8

Map Scale (if applicable): 1 ☐ = ________

GENERALIZED VALLEY CROSS SECTION SKETCH:

SYMBOL LEGEND:

Geomorphic Unit Boundary

Flow Direction

UTM Coordinate Location: RS-1

Fish Sampling Location & ID: F1

Invertebrate Sampling Location & ID: I1

Cross-section Location:

Young Willow

Young Alder

Adult Alder

Adult Willow

HYDRAULIC UNIT KEY:

16m across

Flow Types:

- ☐ H9 Free Fall
- ☐ H8 Chute
- ☐ H7 Broken standing waves
- ☐ H6 Unbroken standing waves
- ▨ H5 Rippled
- ☐ H4 Upwelling
- ▨ H3 Smooth surface flow
- ▨ H2 Scarcely perceptible flow
- ▨ H1 Standing water
- 🟥 Dry Channel
- LWD

Substrate Categories:

- ☐ S1 Silt
- ☐ S2 Sand
- ☐ S3 Gravel
- ☐ S4 Cobble Sm.
- ☐ S5 Cobble Lg.
- ☐ S6 Boulder Sm.
- ☐ S7 Boulder Lg.
- ☐ S8 Bimodal

Form # C - ________

Figure 61. Reach sketch of EF03.

Reaches on Grouse Creek and Cabin Meadows Creek, tributaries to the East Fork Scott River, were steeper gradient, Rosgen type A2 channels (headwater, boulder channels). Figure 62 compares the longitudinal profiles on the East Fork Scott River and Grouse Creek. Differences in gradient between GC01 and EF01 can be seen, as well as distinct step pools, cascades, and runs. There were more cascades in the reaches on tributaries to the East Fork Scott River and well-sorted step pool systems were common. However, pools tended to be small (1-2 times channel width), and the high gradient of the creeks may explain this observation. Grouse Creek had a single channel that in some places was confined by bedrock but alluvial sediment deposits were present throughout. On Cabin Meadows Creek, logging practices caused logs and large-sized debris to fall into the channel causing anabranching and new channel formation (Figure 63 - 64). In some cross-section transects on tributary reaches, sediment size was bimodal, with sediment predominantly sand and boulder sized (Figure 65).

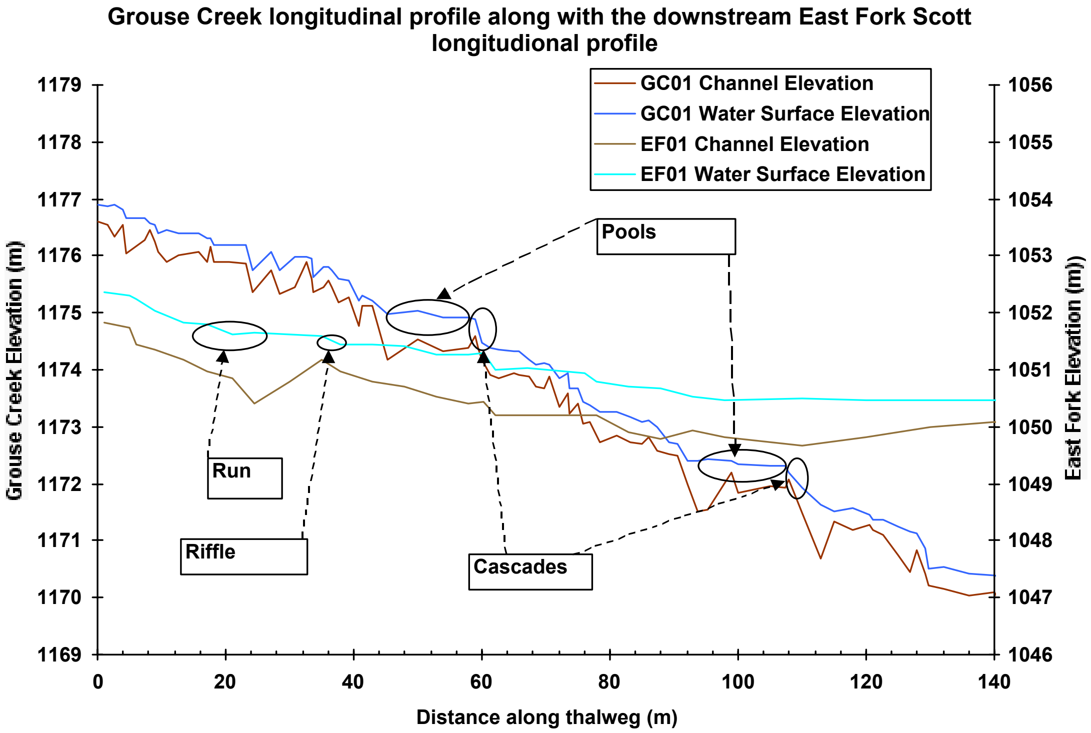
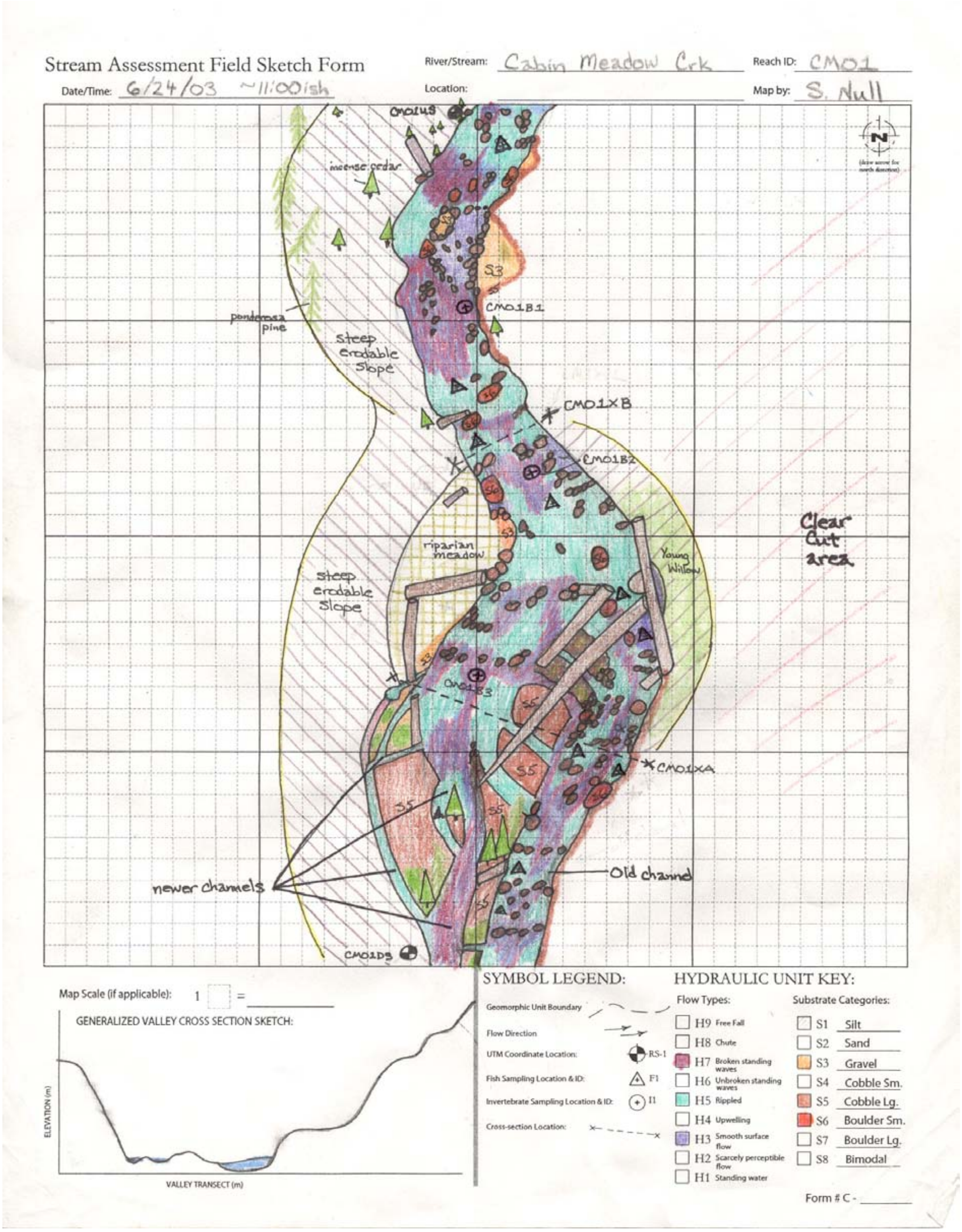


Figure 62. Comparison of lower gradient East Fork Scott River (EF01) with higher gradient Grouse Creek (GC01). Elevation has been exaggerated.



Stream Assessment Field Sketch Form

River/Stream: Cabin Meadow Crk

Reach ID: CM01

Date/Time: 6/24/03 ~11:00ish

Location:

Map by: S. Null

Map Scale (if applicable): 1 ☐ =

GENERALIZED VALLEY CROSS SECTION SKETCH:

SYMBOL LEGEND:

Geomorphic Unit Boundary

Flow Direction

UTM Coordinate Location: RS-1

Fish Sampling Location & ID: F1

Invertebrate Sampling Location & ID: I1

Cross-section Location:

HYDRAULIC UNIT KEY:

Flow Types:	Substrate Categories:
☐ H9 Free Fall	▨ S1 Silt
☐ H8 Chute	☐ S2 Sand
🟪 H7 Broken standing waves	🟧 S3 Gravel
☐ H6 Unbroken standing waves	☐ S4 Cobble Sm.
🟦 H5 Rippled	🟫 S5 Cobble Lg.
☐ H4 Upwelling	🟥 S6 Boulder Sm.
🟪 H3 Smooth surface flow	☐ S7 Boulder Lg.
☐ H2 Scarcely perceptible flow	☐ S8 Bimodal
☐ H1 Standing water	

Form # C -

Figure 63. Reach sketch of CM01.

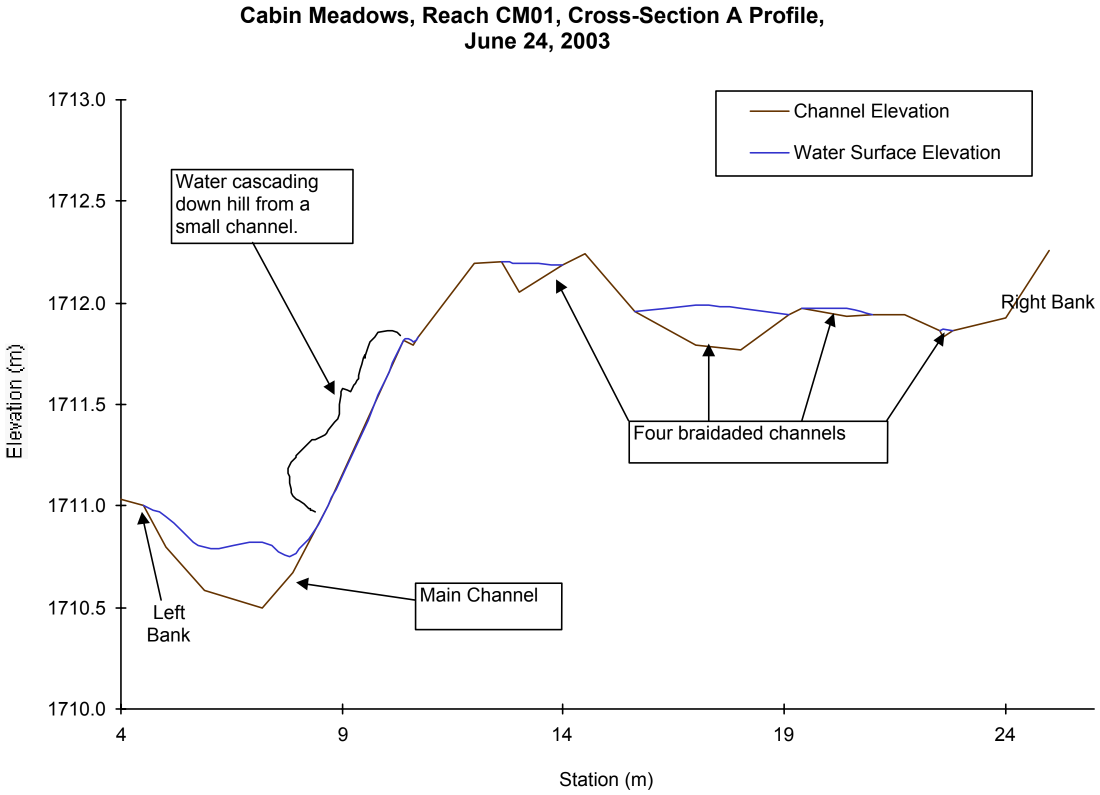


Figure 64. Cabin Meadows cross-section transect showing multiple channels. Elevation has been exaggerated.

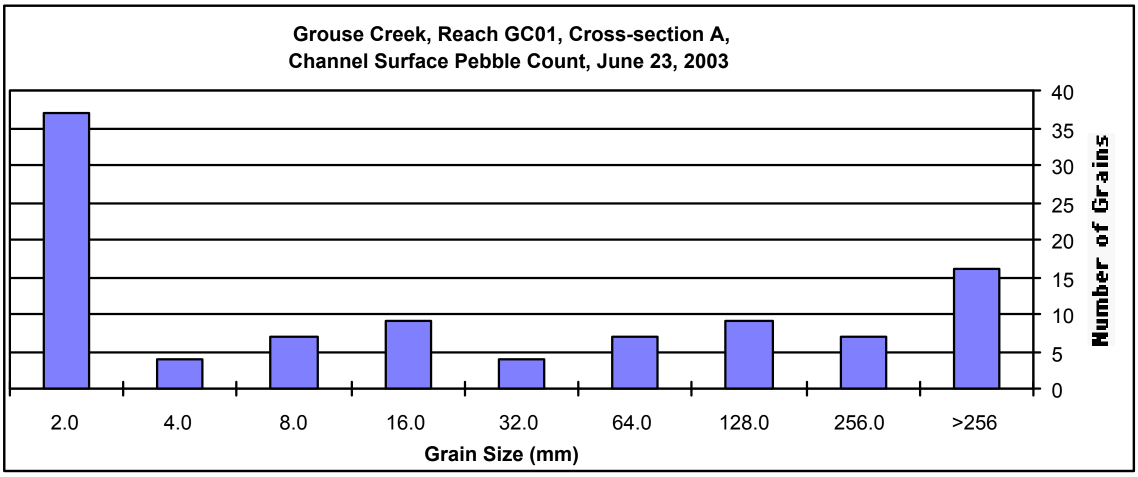


Figure 65. Bimodal pebble count on Grouse Creek

Hydrology

Late season rains contributed to abnormally high discharge on the East Fork Scott River in June 2003 (Table 19). Grouse Creek and Cabin Meadows Creek also had high discharge (for those systems), although they were substantially lower than the East Fork Scott River. The flow meters used to measure discharge produced highly variable results. In all likelihood, inflow from Grouse Creek contributes more discharge to the East Fork Scott River than is seen by our measurements for the East Fork Scott River below Grouse Creek (EF01). Flow decreased notably throughout the survey period. By late summer and fall, it is possible that there is not enough water to support anadromous salmonid spawning in all years.

Site ID	Site Description	Date	Discharge (cms)- velocity-area method	Average Discharge (cms)- float method
EF01	Downstream East Fork reach, 1 mile south of Masterson Road	6/20/03	3.16	3.85
EF02	Midstream East Fork reach, 200 meters south of Masterson Road	6/19/03	2.97	2.52
EF03	Upstream East Fork reach, above Masterson Road Bridge	6/18/03	2.45	4.5
GC01	Grouse Creek 1 mile above confluence with East Fork Scott	6/23/03	0.7	0.5
CM01	Cabin Meadows Creek 100 m below 41 N03 Road	6/24/03	0.67	0.68

Table 19. Discharge at all sample reaches.

Generally, water quality was good in the East Fork Scott River and its tributaries (Table 20). PH levels were neutral, and turbidity and salinity levels were low. Temperature is the prime concern for juvenile salmonids. It is expected that water temperatures could be slightly higher in the East Fork Scott watershed than in other tributaries to the Scott River because the East Fork Scott River drains the hotter, dryer Scott Mountains. During our sampling period, spot temperature data indicate water temperatures were in the high range for salmonid habitat (~17-19°C), but were not excessively warm. Water temperature rises in late summer and fall from higher air temperatures, less snowmelt, and less discharge (shallower pools); thus, water temperature could become a critical factor for salmonid survival. Thermal refugia, or localized cool-water areas, then become of extreme importance.

Site ID	Site Description	Time	Date	Temp (ūC)	pH	EC
EF01	Downstream East Fork reach, 1 mile south of Masterson Road	3:30pm	6/20/03	18.0	7.0	159
EF02	Midstream East Fork reach, 200 meters south of Masterson Road	2:30pm	6/19/03	19.0	7.0	138
EF03	Upstream East Fork reach, above Masterson Road Bridge	2:00pm	6/18/03	17.8	6.9	130
GC01	Grouse Creek 1 mile above confluence with East Fork Scott	1:00pm	6/23/03	12.0	N/a	128
CM01	Cabin Meadows Creek 100 m below 41 N03 Road	2:00pm	6/24/03	12.0	N/a	9

Table 20. Water quality data for all sample reaches.

Thermal refugia exist at confluences of tributaries and where cold-water springs enter the East Fork Scott River. Water quality data was taken on multiple tributaries to the East Fork Scott River (Grouse Creek, Kangaroo Creek, Rail Creek, Cabin Meadows Creek, and Houston Creek). All tributaries had cold water (12°C) that may provide refuges for salmonids at their confluence with the East Fork Scott River. In addition, there were small cold water springs that flow into the East Fork Scott River at reach EF01. Water temperatures in these springs averaged approximately 13-14°C. In the tributaries, all other water quality data was similar to that of the East Fork Scott River, except for salinity levels at Kangaroo Creek. Kangaroo Creek had a specific conductance of 320µs. Most likely, this is from irrigation return flows.

In addition to spot temperature data, continuous thermister data from our farthest upstream and downstream reaches on the East Fork Scott River was also gathered. On the East Fork Scott River, water temperatures fluctuated daily and were strongly correlated with air temperature (Figure 66). During June 2003, afternoon water temperatures were approximately 17°C. Temperatures on the upstream and the downstream portions of the East Fork Scott River were nearly identical, although downstream water temperatures could be slightly lower due to the cold-water springs that flowed into the East Fork Scott River low in the watershed. Temperature differences between the upstream and downstream portions became observable when discharge on the creek began to drop in late June. Comparison with other creeks surveyed for this report show that the East Fork Scott River has the warmest water temperatures, and water temperature in the East Fork Scott River is the most strongly correlated to air temperature (Figure 67).

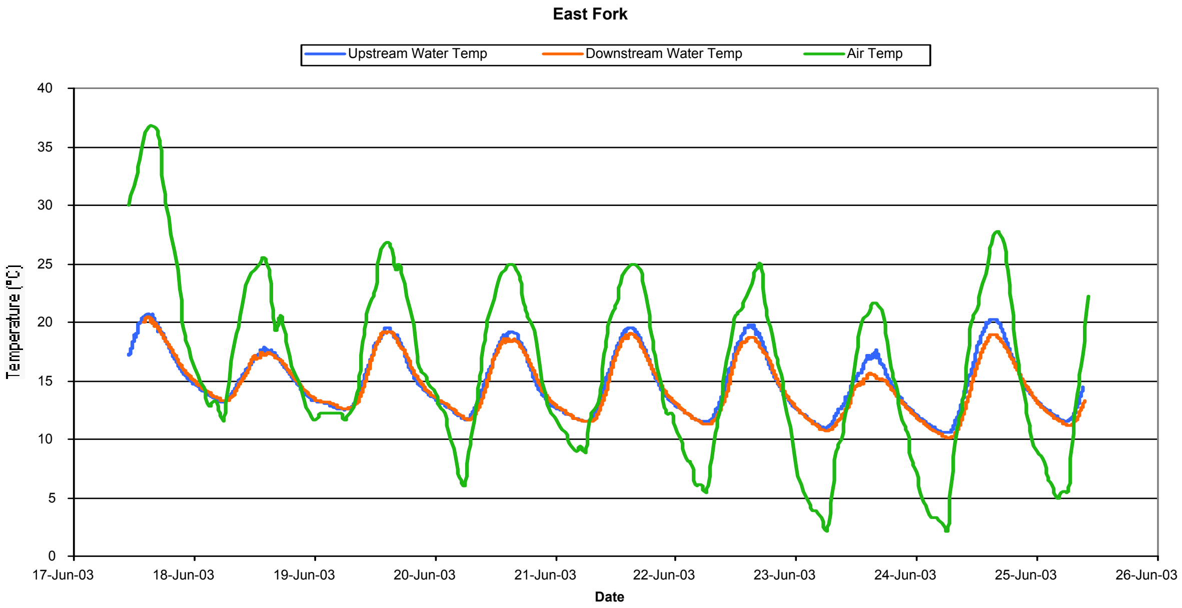


Figure 66. Air temperature and East Fork Scott River water temperature

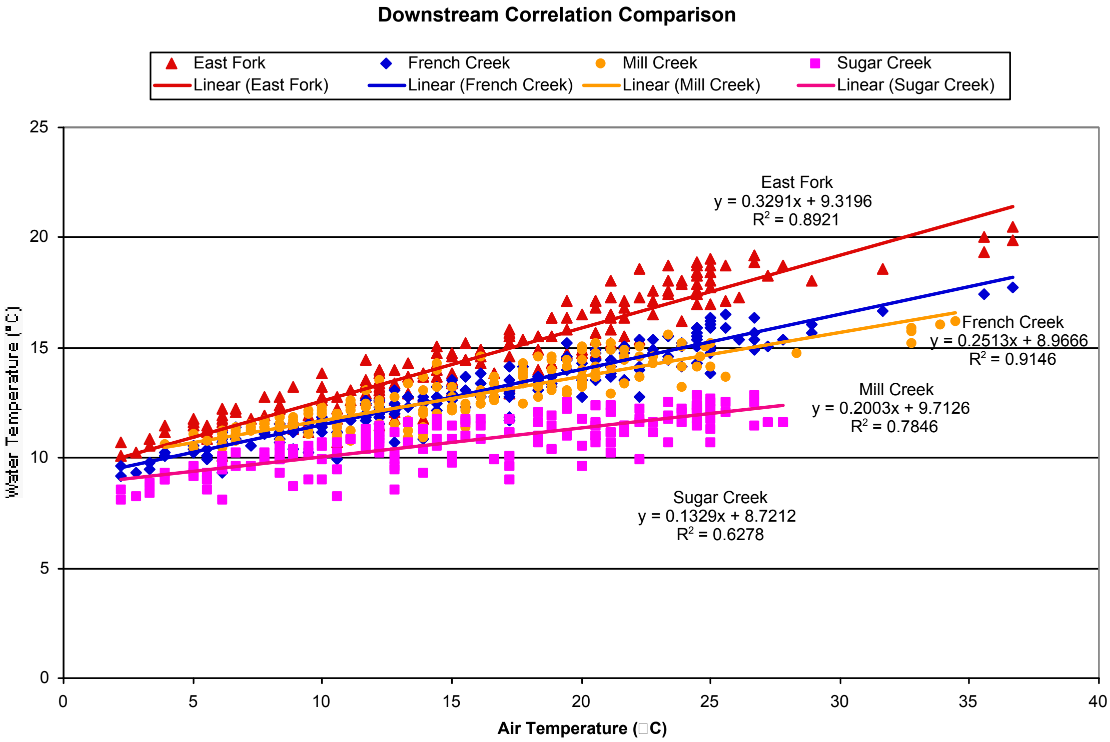


Figure 67. Air and water temperature correlation by creek

According to local landowners, flow can be as low as 0.085 cms in the East Fork Scott River above Callahan (Jay Phelps, personal communication). During these times, thermal refugia are critical, as are deep, shaded pools where fish can find cover until more favorable habitat becomes available. More importantly, flow in the East Fork Scott River can run subsurface near Callahan in dry years due to a dredged rock pile (Jay Phelps, personal communication). When this occurs, fish cannot migrate above Callahan; thus, fall spawning is impossible.

Macroinvertebrates

Three macroinvertebrate samples were taken in riffles at each reach (noted on reach sketches in Appendix D). All riffles had fast moving water, an average depth of 0.2m and average velocity of 0.8 m/s. Riffle samples were representative because the majority of the reaches had fast moving water, and were predominately riffle and run habitats. Samples were taken in cobble and gravel sized surface sediment and substrate. The macroinvertebrate samples for EF01 and EF02 have been combined and averaged due to sampling error.

There was a weak correlation between total macroinvertebrate abundance and fish abundance (Figure 68). EF01 and EF02 had the highest fish abundance and the highest invertebrate abundance. Fourteen taxa of insects were sampled at these reaches (Figure 69), so taxonomic richness was good but not the highest of the reaches. Grouse Creek (GC01) had the highest taxanomic richness, with 22 different taxa of insects. However, Grouse Creek also had the lowest fish abundance. The distribution of taxa was not uniform throughout the watershed (Figure 70). For example, mayflies (*Ephemeroptera*) were more abundant in the tributaries to the East Fork Scott River (GC01 and CM01), while flies (*Diptera*) were more abundant in the lower reaches on the East Fork Scott River (EF01 and EF02). This may indicate that different creeks offer different food choices for juvenile salmonids. The homogeneity of habitat on the East Fork Scott River may also limit the abundance and richness of macroinvertebrate species.

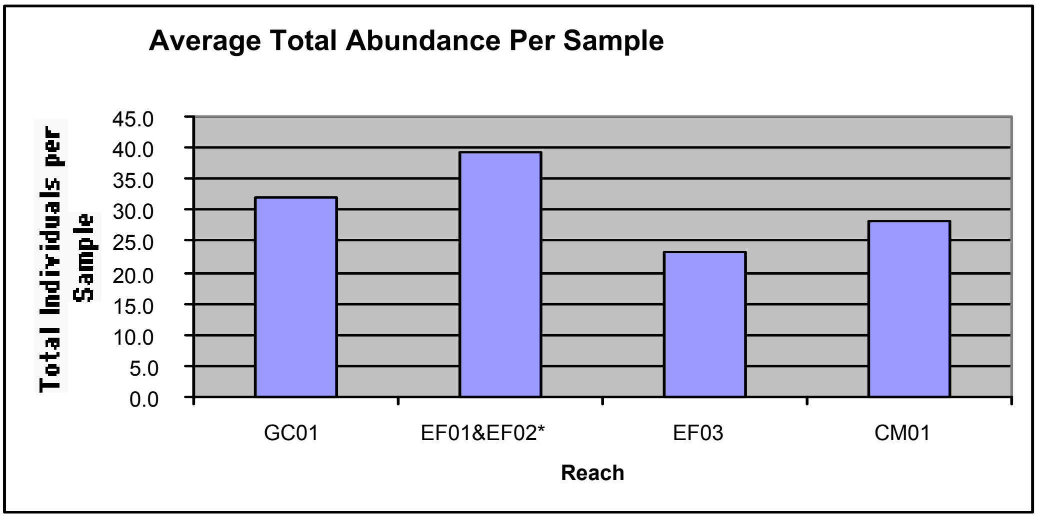


Figure 68. Macroinvertebrate abundance in the East Fork Scott River watershed

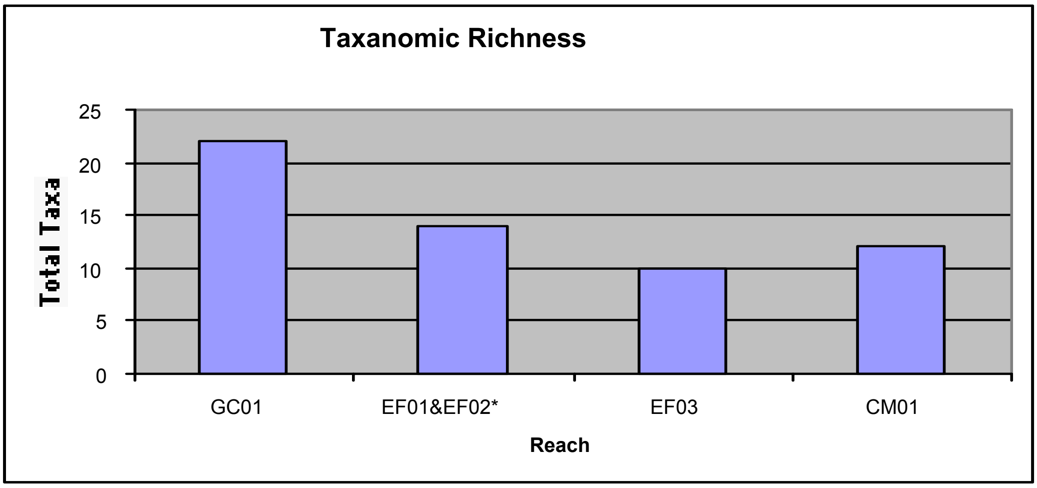


Figure 69. Macroinvertebrate taxanomic richness

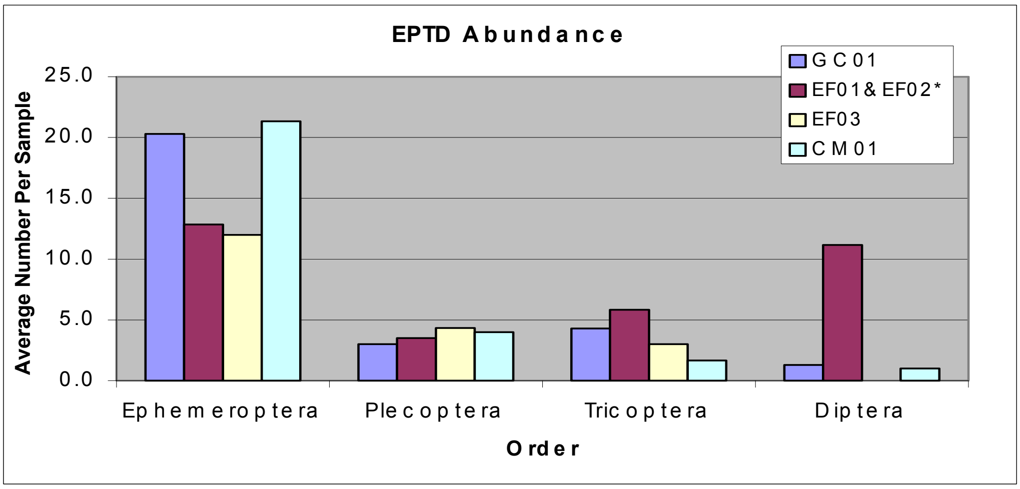


Figure 70. EPTD abundance of dominant macroinvertebrate orders

EPT ratios are used as a general indicator of stream health. This is the ratio of the abundance of mayflies, stoneflies, and caddisflies divided by the number of taxa in these orders. These orders of insects are often associated with high water quality. A lower EPT value indicates higher taxanomic richness within these sensitive orders. The EPT index calculated from the data indicates that Grouse Creek (GC01) has the highest macroinvertebrate richness (Figure 71), but it also had the fewest fish. Cabin Meadow Creek has relatively low abundance and richness of insects, but many 1 and 2 year old steelhead. Therefore, macroinvertebrate richness may be a poor indicator of potential salmonid habitat in the East Fork Scott River. Another possibility may be that young of the year fish prefer the food in tributaries, but other factors such as cover or absence of slow-moving water limit use of these habitats. The absence of a clear correlation between patterns in macroinvertebrate distribution and patterns in fish distribution indicate that other factors are more important in determining the abundance of juvenile salmonids on the East Fork Scott River.

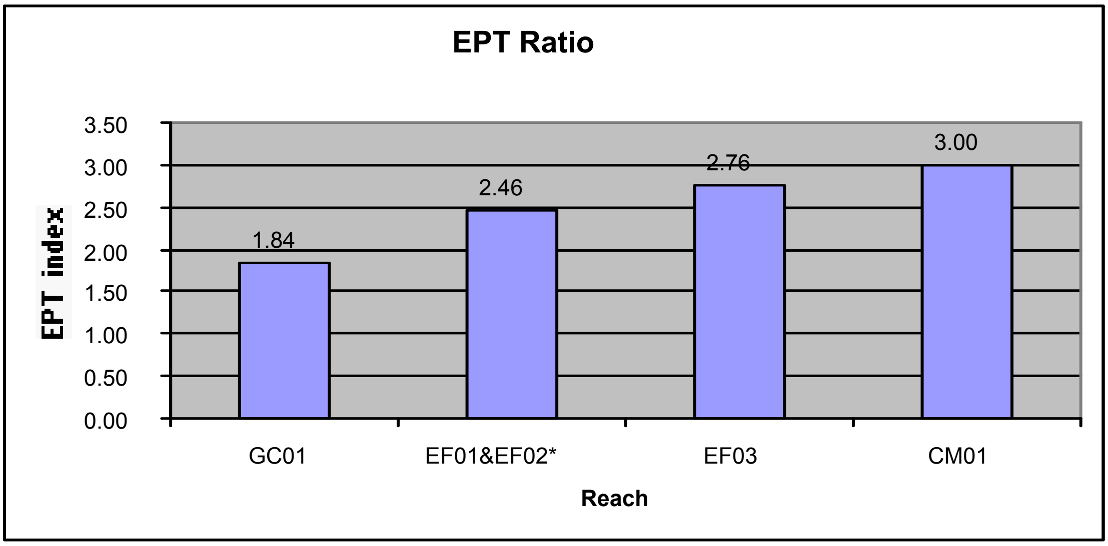


Figure 71. EPT ratio for reaches in the East Fork Scott River watershed

Fish

Four species of fish were sampled in the East Fork Scott River using both snorkel surveys and electro-fishing. All four species: coho salmon, steelhead trout, Klamath smallscale sucker, and speckled dace are native. Coho salmon were not observed with snorkel surveys; however a single coho was captured electro-fishing. It is believed an additional coho was seen but not captured during electro-fishing. The coho that was captured was in the 1+ age group. No young of the year juvenile coho were observed at any of the reaches, which supports the 2002-2003 spawner surveys, that did not find any coho spawning upstream of Callahan. During summer 2002, flow stopped at Callahan destroying connectivity between the East Fork Scott River above and below this location. This, then, acted as a barrier to fish migration and is likely the cause for coho not spawning in winter, 2002-2003, and the absence of young of the year coho during our June sampling.

Rainbow trout were the predominant species, seen in every reach that was surveyed. Steelhead and rainbow trout are genetically similar with the exception that steelhead are anadromous and rainbow trout are resident fish. It is assumed that the trout observed in the East Fork Scott River and its tributaries are migrating up the creek, indicating they are steelhead trout; or that they are young of the year fry from steelhead trout (Mauer, personal communication). For this section, all *O. mykiss* observed will be referred to as steelhead trout. In the Klamath and Scott River basins, steelhead are still common but are declining (Mount and Moyle, 2003). Klamath smallscale sucker were encountered in one reach on the East Fork Scott River (EF02). Approximately 20 individuals were observed. Klamath speckled dace were found in two reaches on the East Fork Scott River (EF02 and EF03).

In reach surveys on the East Fork Scott River, steelhead trout had the highest abundance according to data gathered in snorkel surveys (Table 21). Generally, there was high abundance in the lower reaches (EF01, EF02, and EF03). Abundance decreased in the tributary reaches (GC01 and CM01) (Figure 72). EF02 had the highest diversity with three different species present. This was also the reach that coho salmon were sampled with electro-fishing. This is perhaps due to the favorable fish habitat encountered at EF02, with the presence of large, woody debris (LWD), shaded areas, backwaters, and side channels.

Table 21. Abundance of fish by reach type (based on snorkeling data)

Reach	**Reach Type**	**Area (m2)**	**Coho salmon**	**Steelhead**	**Speckled dace**	**Klamath smallscale sucker**	**Sum**
EF01	Cascade	2340	0 (0)	508 (100)	0 (0)	0 (0)	**508**
EF02	Riffle-Run	4500	0 (0)	221 (86)	15 (6)	20 (8)	**256**
EF03	Riffle-Run	3225	0 (0)	278 (100)	0 (0)	0 (0)	**278**
GC01	Alternating Step-Pool and Bedrock	450	0 (0)	4 (100)	0 (0)	0 (0)	**4**
CM01	Alternating Cascade and Step-Pool	530	0 (0)	32 (100)	0 (0)	0 (0)	**32**
Sum			**0 (0)**	**1043 (97)**	**15 (1)**	**20 (2)**	**1079**

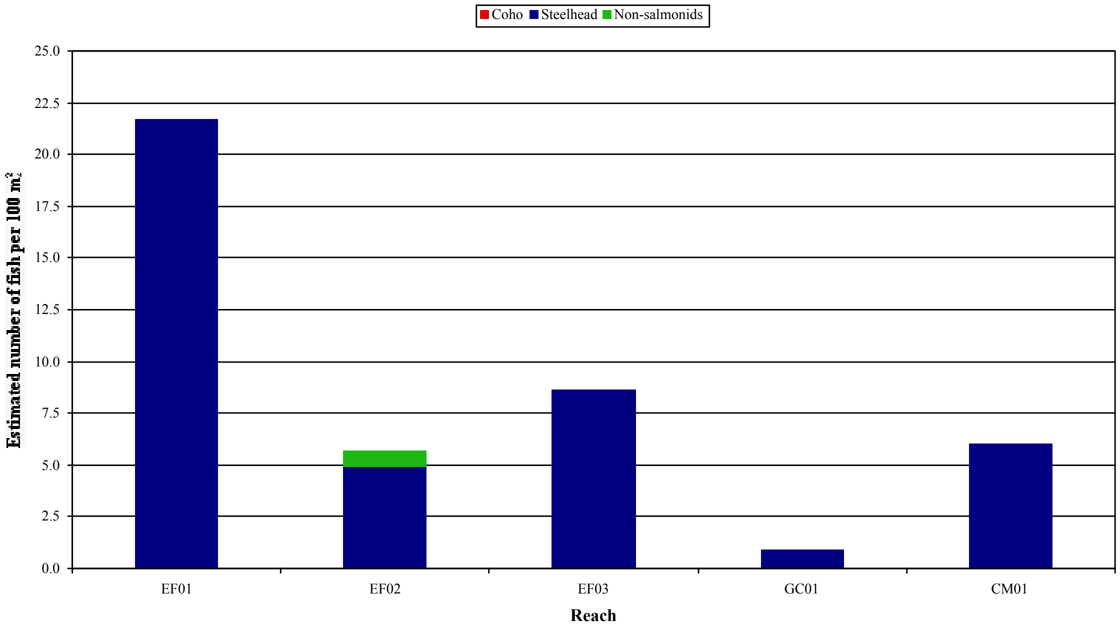


Figure 72. Relative abundance of fish

Grouse Creek (GC01) had surprisingly few fish despite the fact that coho were released in this creek in the summer of 2002 (Mauer, personal communication, 2003). Coho were not observed, and there were low numbers of steelhead. Although this reach had cool water with substantial food, the lack of instream cover may be limiting. It also had the highest proportion of bedrock of any reach surveyed, and there was little LWD. The few steelhead observed were in the deep pools with shade and LWD. In contrast, Cabin Meadow Creek had high numbers of 1+ (50-100mm) and 2+ (<100mm) trout. On this creek, logjams and boulder steps created deep pools that provided excellent habitat for steelhead. This high quality habitat had ample shade, cutbanks, and cool temperatures. Although the possibility exists that these are resident fish, Sue Mauer, a local fish biologist, believes that these fish are migrating upwards, indicating that they are in fact steelhead (Mauer, personal communication). The absence of young of the year steelhead was puzzling. One hypothesis is that the young of the year have not yet hatched due to increased incubation times from the colder water (12°C) (Alan Olson, personal communication). Another possibility is that velocities were too great for young of the year steelhead in Cabin Meadows Creek.

Size distributions could only be determined from the electro-fishing effort. There are no distributions for coho or suckers because only one specimen was gathered for each species. There appears to be a split in the frequency of speckled dace between the 44mm and 50mm size classes (Figure 73), indicating two cohorts: young of the year and 1+ age classes.

There is a bell-shaped distribution for different sized steelhead; however, all sizes sampled with electro-fishing fall within the young of the year size class (Figure 74). 1+ age class steelhead were not captured during electro-fishing; however, one 95 mm coho (at EF02, 1+) and one 85 mm smallscale sucker (above EF01 in diversion ditch) were sampled.

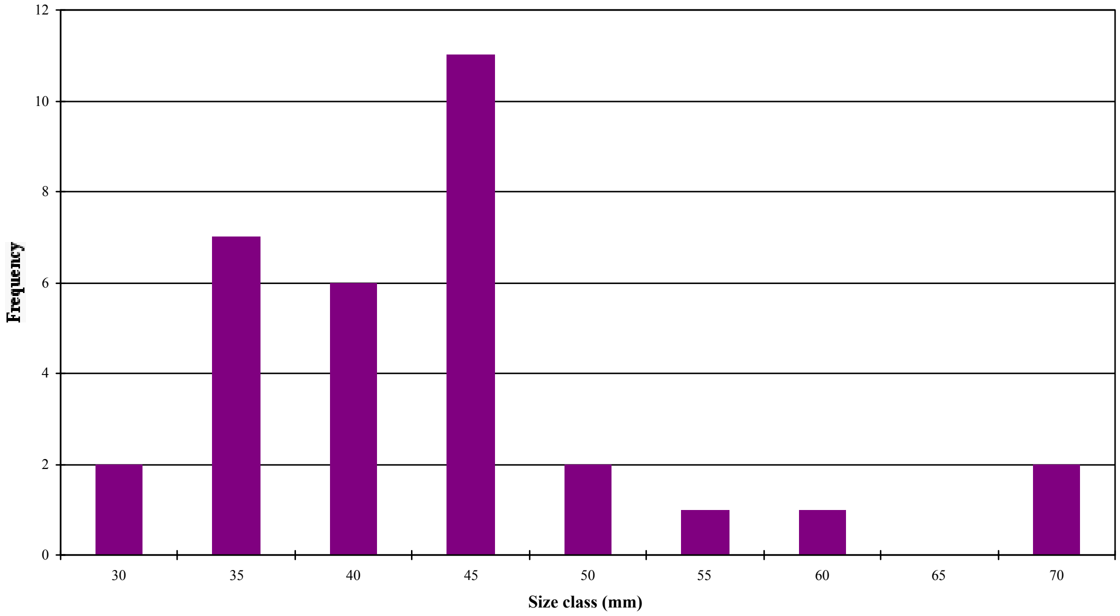


Figure 73. Speckled dace frequency versus size indicating 2 age classes.

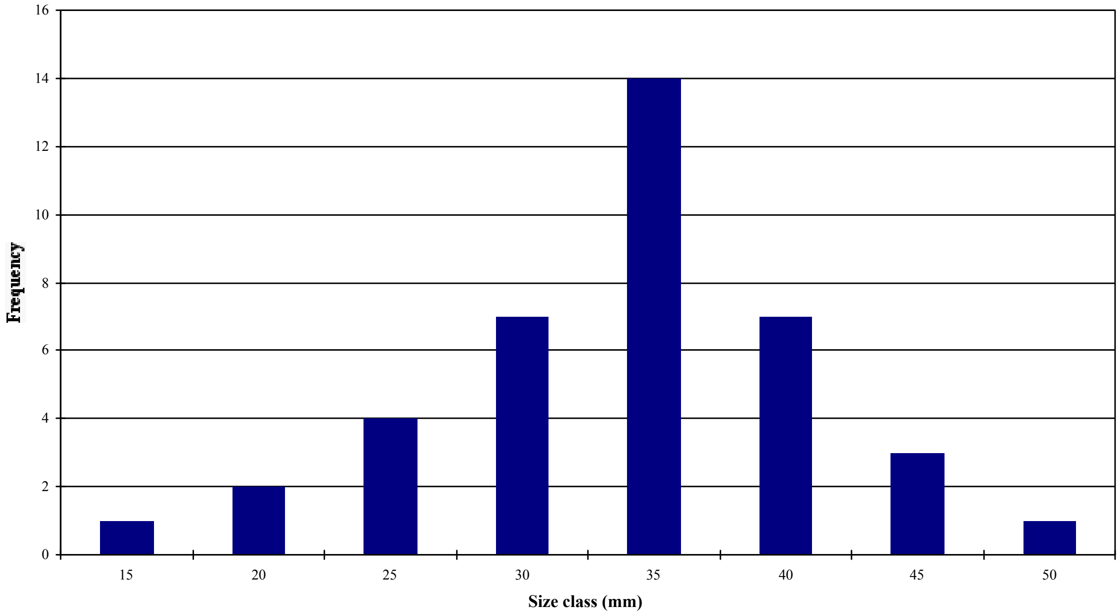


Figure 74. Steelhead trout frequency versus size indicating 1 age class.

Based on qualitative data from snorkel surveys and reach sketches, the young of the year steelhead were generally found in microhabitats sheltered from strong currents, such as eddies, root wads, cutbanks, and side channels. Steelhead in the 1+ and 2+ age classes were usually found on the lee side of boulders in riffles or feeding in pools below riffles. Speckled dace were found in backwaters and side channels similar to those used by young steelhead. Juvenile Klamath smallscale suckers were seen in root wads in a cutbank. The single coho was found in a side channel pool with substantial LWD, shaded by thick riparian vegetation. Reaches where sheltered microhabitats were lacking, such as GC01, showed low fish densities, while fish were abundant in more complex habitats, such as those found in EF01, EF02, and CM01.

Discharge for the East Fork Scott River was abnormally high during the snorkel surveys and electro-fishing. Most likely, the observed habitat preferences were influenced by higher than usual spring flows. It is likely that as flows continue to decrease during late summer and fall, some backwaters may become disconnected from the main channel, making that habitat unusable for fish rearing. In addition, as the water level drops in the channel, roots from riparian vegetation may not be submerged in the channel, also creating less favorable spawning and rearing conditions. However, reaches with many riffles and high velocity flows may become slower moving as flow decreases, increasing slow-water habitat for young of the year steelhead trout.

East Fork Scott River Conclusion

Throughout this study, data was collected in short reaches that could characterize the stream as a whole. Reaches were chosen that were representative of the larger creek. This allows broad statements to be made about coho habitat quality in the East Fork Scott River, despite the fact that only small habitats were surveyed. Generally, the habitat that was observed in the East Fork Scott River was of excellent quality for coho spawning and rearing. However, lack of connectivity at the East Fork Scott River above and below Callahan is a major concern, and is the primary limiting factor to salmonid spawning. If anadromous fish cannot access spawning grounds, spawning will not occur. A secondary recommendation for habitat improvement would be to lower instream water temperatures if possible. If salmonids can migrate above Callahan, high summer water temperatures are a significant limiting factor. While it is likely that thermal refugia exist at confluences of tributaries and cold-water springs, lower water temperature in the East Fork Scott River would reduce stress on fish, likely increasing salmonid survival. It is likely that the East Fork Scott River naturally has warmer water temperatures than other Scott River tributaries because it is on the hotter, dryer eastern side of the watershed. Nevertheless, East Fork Scott River water temperatures could probably be reduced in the hot summer and fall months when low temperatures are critical for fish. Additional riparian vegetation would create shadier channels cooling pools and runs. More discharge during the summer would deepen pools and runs, also lowering temperature.

SYNTHESIS

Recognizing the limits of a spatiotemporally confined study shaped in the form of a training exercise, we here present the dominant trends found during the weeklong survey of the selected streams in the Scott River Watershed. We further use our findings to develop hypotheses about factors that may limit salmonid abundance and density in the Scott Valley.

Dominant trends in June 2003

Surveys of 20 reaches in four sub-watersheds of the Scott River Watershed revealed a variable abundance and diversity of fish, in part reflecting the variable size and geomorphology of the different watersheds studied (Table 22). A handful of species were recorded of which steelhead (*Oncorhynchus mykiss*) was the most abundant (Figures 75 and 76). The lower gradient reaches in the respective watersheds surveyed commonly had the highest abundance and diversity of fishes compared to the higher gradient reaches. The East Fork Scott River below the confluence with Grouse Creek, for example, had an order of magnitude higher abundance of fish than Cabin Meadows Creek, further up in the East Fork watershed. Similarly, the highest species diversity in French Creek was found in the lowermost reach. Presumably the reason for this was the combination of increased habitat diversity (related to higher flows), proximity to the main Scott River, and lack of access or suitable spawning habitat for anadromous fishes in the upper reaches of the sections.

Table 22. Summarizing characteristics of the surveyed reaches.

		Measured Q		Fish found in Snorkeling Survey						Habitat Complexity		Spawning Gravel Availability	Temp Range		Dominant Fish Location
Reach ID #	Reach Type	cms	Width to Depth Ratio	Fish Density	Total #	Species #	Coho	Canopy Cover	Vegetative Protection	Vel/ Depth Regime	Cover in stream	33-128mm %	°C	Bugs	
ML01	riffle-pool	0.3	60.2	33.2	383	3	Y	partly shaded	18	19	16	0.55	16.5-12.5		coarse woody debris and emergent vegetation cover along
ML02	riffle-run	0.1	44.4	72.9	379	2	Y	partly shaded	14	19	7	0.67	16.5-12.6		cobbles in riffles, root wad scoured pools,
ML03	riffle-run	0.0	54.4	2.8	24	1	N	open	2	16	7	0.56	11.0-18.0		side channels, shallow-fast pools
ML04	riffle-pool	0.3	11..3	3.8	42	2	Y	open	4	16	10	0.50	11.0-18.0		shallow-slow pools
EM01	pool-run	N/A	30.0	24.4	112	3	Y	partly shaded	20	10	13	0.03	13.0-17.0		vegetation and large woody debris cover, shallow-slow pools
EM02	riffle-pool	N/A	6.7	90.7	194	3	Y	open	20	12	13	0.06	12.0-16.0		undercut banks, bottoms of runs
EM03	riffle-pool	0.0	5.0	210.9	155	2	Y	partly shaded	20	13	10	0.02	12.0-16.0		shallow slow pools, poor cover
FR01	riffle-pool	3.3	9.0	2.6	52	3	Y	open	11	16	13	44.00	11.8-16.3	6.67	Woddy Debris and Pools
FR02a	M. Channel= riffle-run S. Channel= riffle-pool	1.2	9.0	15.7	236	2	N	open	14	7	14	56.07	9.6-13.7	5.41	Side Channel (lower flow), and in eddies
FR02b	riffle-run	1.4	50.0	1.2	18	1	N	partly shaded	17	3	17	48.65	8.6-13.1	4.00	Shaded Eddy
FR03	riffle-run	1.1	9.6	0.8	16	2	Y	partly shaded	20	3	10	35.00	10.3-14.05	1.58	Woddy Debris and Pools
FR04	Step Pool/Cascade	0.2	23..3	0	0	0	N	shaded	17	16	19	36.28	8.2-13.6	3.69	No fish found
SG01	riffle-run	1.1	16.0	34.1	515	5	Y	partly shaded	14	10	18	53.00	10.5-13.0		edge / behind lwd
SG02	riffle-run	0.9	24.0	10.6	76	3	Y	shaded	20	12	18	42.20	10.5-13.0		edge of water
SG03	riffle-run	0.6	10.7	1.9	23	1	N	shaded	20	13	20	28.50	9.5-12.5		thalweg
EF01	riffle-run/cascade	3.2	23.0	21.7	510	1	N	partly shaded	12	15	13	30.00	11.6-19.2	1.25	banks/ deep eddies
EF02	riffle-run	3.0	25.0	5.7	256	3	N	partly shaded	16	9	18	47.00	12.5-19.5	1.25	side channels
EF03	riffle-run	2.5	2.1	8.6	278	1	N	open	4	10	9	35.00	13.0-18.0	2.80	Bank/ side channels
GC01	cascade	0.7	10.0	0.9	4	1	N	partly shaded	14	12	15	24.00	N/A	5.50	North Bank
CM01	cascade	0.7	25.0	6.04	22	1	N	partly shaded	8	12	18	25.00	N/A	3.00	Pools (big)

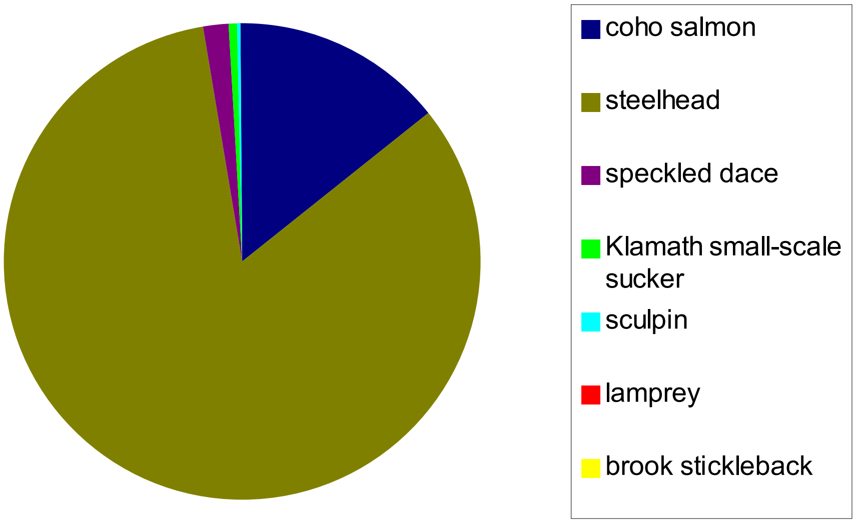
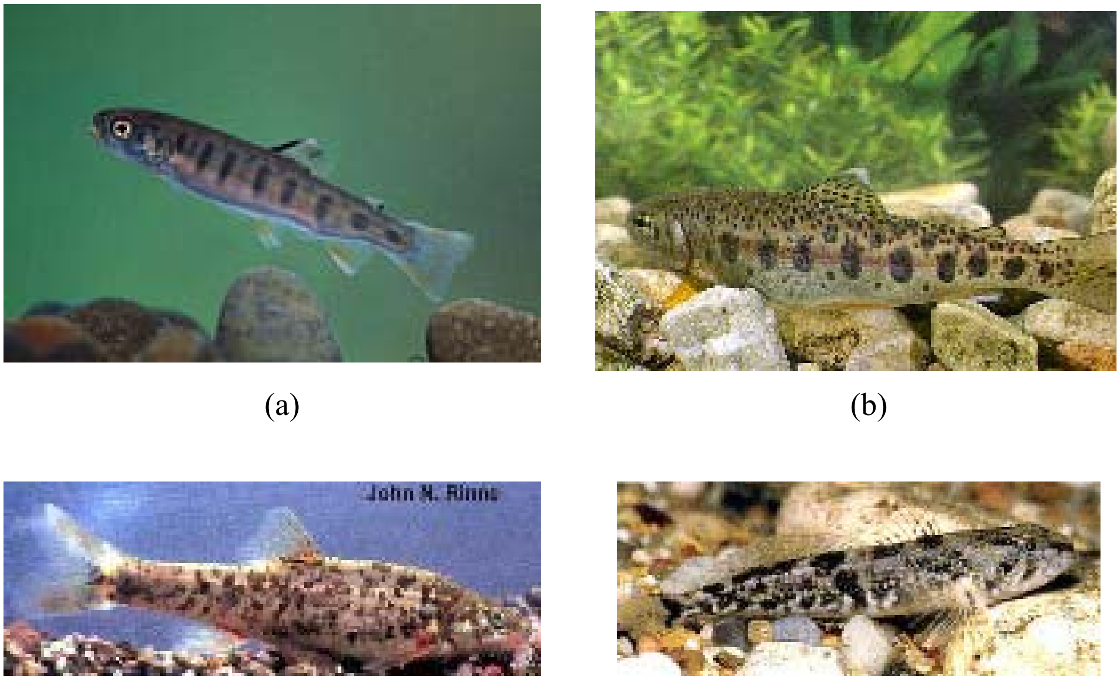


Figure 75. Relative abundance of observed species in the surveyed streams, June 2003.



(a) (b)

(c) (d)

Figure 76. The most abundant species observed. (a) Juvenile coho salmon (William Leonard, 2000), (b) juvenile steelhead/rainbow trout (by M. Lorenzoni) (c) Klamath speckled dace (The Native Fish Conservancy), and (d) sculpin (The Native Fish Conservancy).

Coho salmon (*O. kisutch*) were found in all four sub-watersheds but young of year were found only in Sugar Mill and Miner's Creeks (the latter a tributary of French Creek), while yearling fish were found in French Creek and the East Fork Scott River. In Sugar Creek, coho abundance decreased with increasing slope, i.e., more coho were found in the lower reaches compared with the upper reaches. Further, no coho were found during the snorkel survey in the East Fork, apparently because a flow dependent barrier to upstream migration near Callahan prevented spawning in 2002 (although a single yearling fish was captured through electrofishing). A general, predicted, geomorphic change was observed between the higher gradient reaches dominated by cascade and step-pool geomorphology, and the lower gradient reaches dominated by riffle-run geomorphology. The higher gradient reaches may thus in general be of limited accessibility to most salmonids, especially coho, because of the presence of geomorphic barriers in the form of alternating cascade and step-pool sequences that dominate these systems. Intra-salmonid predation by yearling steelhead on young-of-the-year coho may further limit their survival and abundance.

Reflecting the complexity of most natural systems, the issue of shade is a matter of balance rather than extremes. On the one hand, riparian vegetative cover provides shaded areas in which fish can take refuge from excessively high water temperatures in open areas. On the other hand, extensive canopy cover reduces the amount of primary productivity in the stream, which, in turn, decreases aquatic invertebrate production, thus potentially lowering fish densities. Mill Creek and Emigrant Creek exemplified this general trend, whereas Sugar Creek and French Creek did not seem to be limited by the factor of shade, potentially because of the relatively stable temperature regimes in these creeks. The assembled data suggests that vegetative protection of the stream banks in some cases correlated with high fish abundance (e.g., Mill Creek), whereas, in other cases, it seemed to be subsidiary to other interrelated factors influencing the fish abundance in that system (e.g., Sugar Creek).

The complexity of microhabitats created by rocks and woody debris generally increased in an upstream direction and resulted in increased diversity of aquatic invertebrates. However, fish abundance and diversity decreased presumably because of the shortage of deep, low velocity areas needed for holding and lack of suitable substrates for spawning.

It was observed that cascades and step-pool systems generally had lower availability of optimally sized gravel for coho spawning compared with riffle-run dominated systems. In Sugar Creek, for example, the cascades were dominated by sand, cobbles and boulder. The percent suitable gravel was overall relatively low due to the abundance of sand in most of the surveyed reaches. Because salmonid embryos need adequate, non-embedded gravel in order for flow to deliver oxygen to the developing embryos (Andersson, 2003; Graham, 2003), the presence of sand may be limiting their abundance in this system. Judging from redd surveys from previous years in the Scott Valley, coho are very selective in choosing spawning sites, but if optimal sites are limited, spawning may take place in suboptimal areas (S. Maurer, 2003 unpublished data). Thus, juveniles from the few adults able to spawn in the best patches of habitat may dominate the reach. Emigrant Creek represents an interesting anomaly in that, despite having the lowest amount of suitable spawning gravel, it had still by far the highest fish density of all surveyed streams. Potentially this high productivity is caused by a combination of the proximity of the creek to Mill Creek where adequately sized gravel is relatively abundant, and the relative proximity of the creek to the mouth of the Scott River. Due to the latter, Mill and Emigrant Creeks may receive more adults compared with the other creeks in the survey. Potentially surmounting these hypotheses, however, is the fact that Emigrant Creek is fed by cold springs thus providing ample temperature refugia, another physical need of salmonids at this latitude. It also contained few juvenile steelhead, so lack of competition and predation from steelhead may have favored increased survival of juvenile coho.

In general, the surveyed reaches presented no obvious problems for fish in terms of acidity or turbidity, but the study revealed some potential problems with temperature regimes. Data on the temperature variability between and within the surveyed creeks revealed that temperature tended to increase with increasing distance downstream in the watersheds (Figures 77-80). The East Fork and Mill Creek were relatively warm compared to French and Sugar Creeks; the latter two creeks were more shaded upstream, thereby keeping the largely snow-induced runoff at cooler temperatures (Andersson, 2003; Graham, 2003). The influence of shade over temperature can be seen by comparing the upper open warmer reaches with the lower partly shaded cooler reaches in Mill Creek.

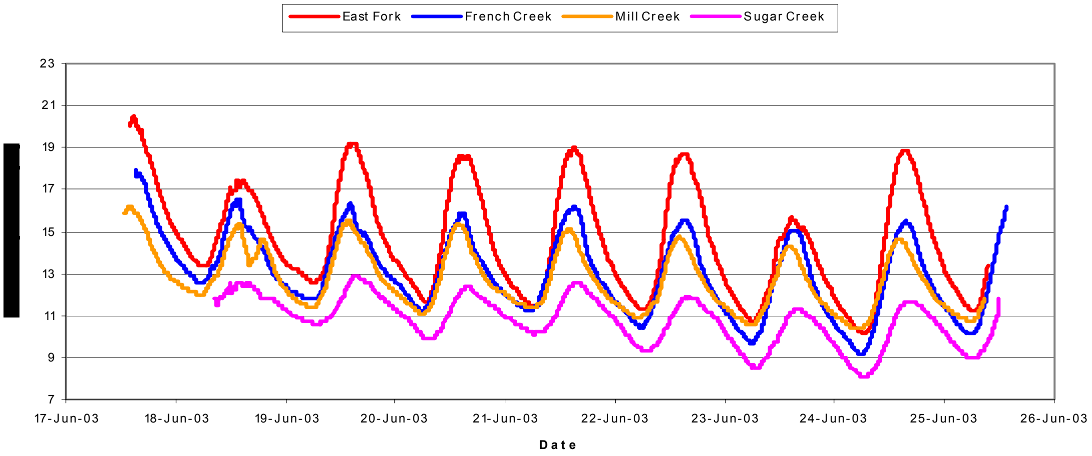


Figure 77. Comparative thermograph of the water temperatures for the downstream locations of the East Fork, Mill Creek, French Creek and Sugar Creek.

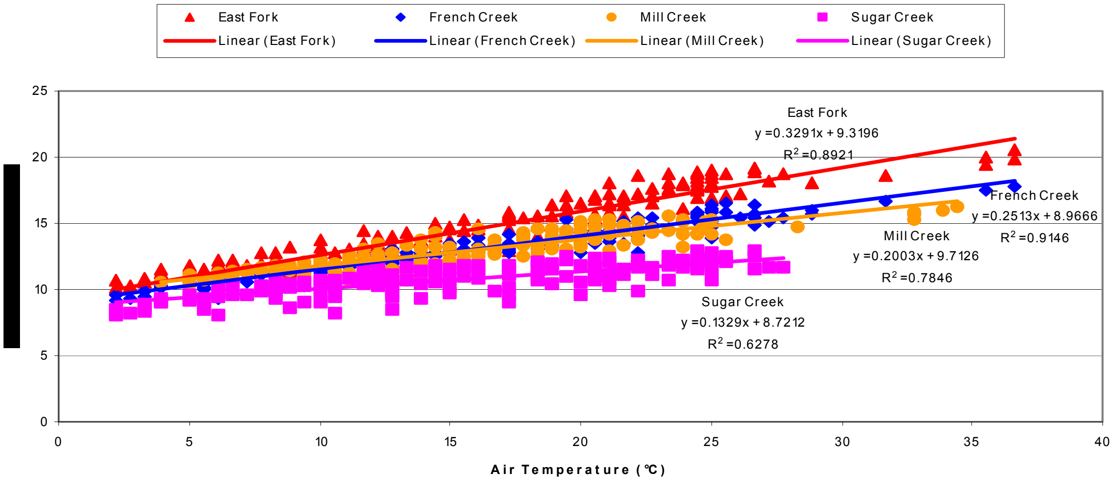


Figure 78. Correlation between water temperature and air temperature for the downstream locations of the East Fork, Mill Creek, French Creek and Sugar Creek.

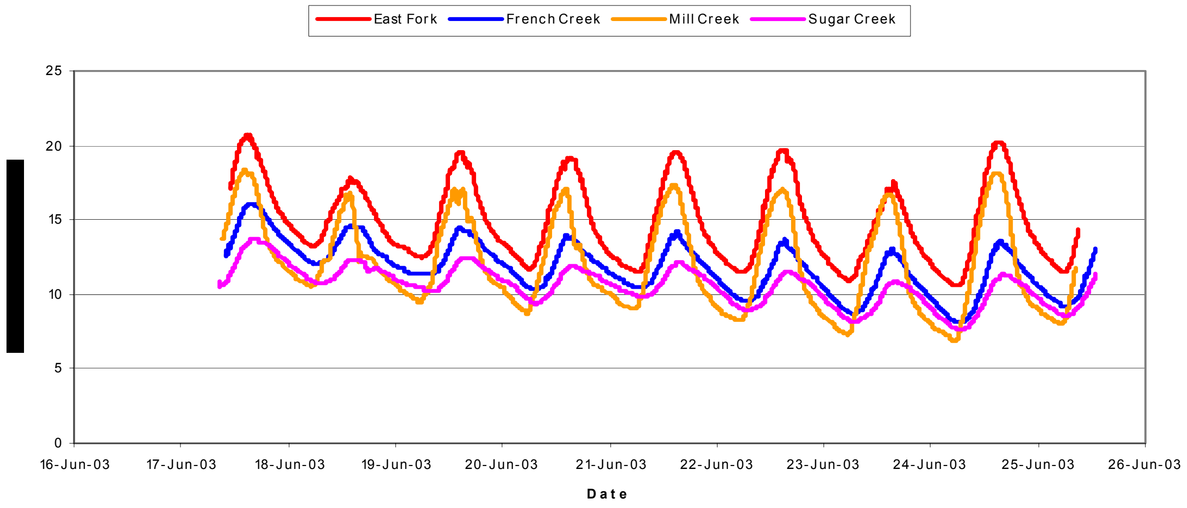


Figure 79. Comparative thermograph of the water temperatures for the upstream locations of the East Fork, Mill Creek, French Creek and Sugar Creek.

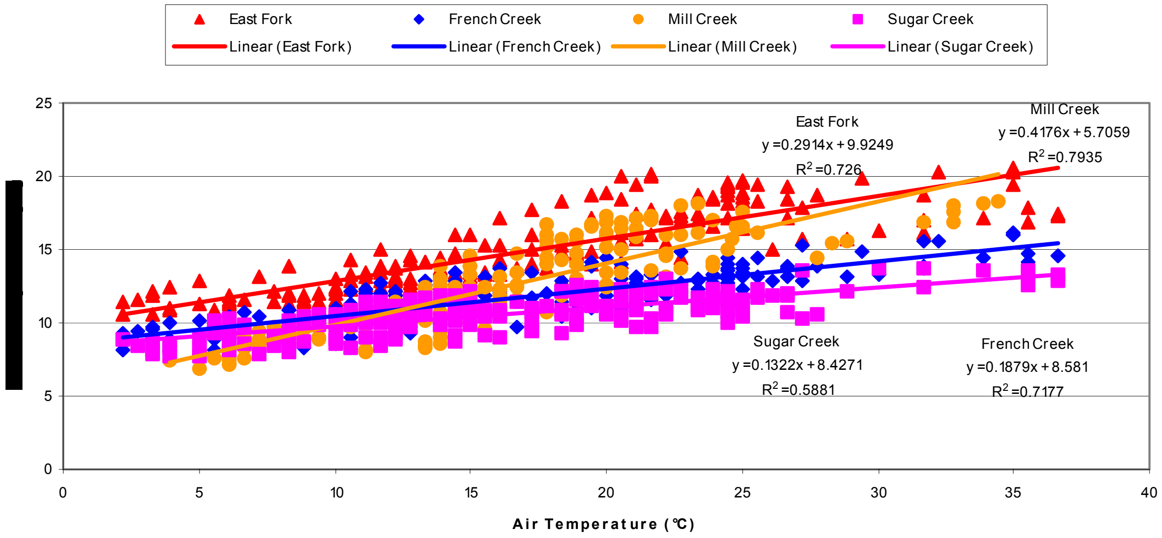


Figure 80. Correlation between water temperature and air temperature for the upstream locations of the East Fork, Mill Creek, French Creek and Sugar Creek.

The data further shows that the temperature of the East Fork and Mill Creek were more strongly correlated with air temperature variations, providing challenging temperatures for coho during the day but thermal refugia during the night, even this early in the summer. In the East Fork, the reach with the highest temperature variability and presence of significantly cooler springs had the highest fish density. The relatively cool Sugar Creek displayed higher fish densities in general than did the warmer reaches of the East Fork and Mill Creek. Similarly, cooler reaches had considerably higher fish densities than warmer reaches in Mill and Emigrant Creeks. Nevertheless, temperature did not seem to act as an overarching limiting factor for fish considering the relatively different fish densities in FR02a compared with FR02b and the relatively similar temperature range of the two reaches.

Fish food availability in the form of macroinvertebrates did not seem to limit the abundance of fish in the surveyed streams. In the upper reaches of French creek, for example, algae and bryophytes, substrate and food for invertebrates, were abundant, but fish were nonetheless not observed, presumably because of a significant cascade barrier downstream of the upper reaches. The lower reaches of East Fork Scott and Emigrant Creek tended to provide better aquatic insect habitat than the upper reaches. Total invertebrate diversity was directly correlated with total number of individuals, while the diversity of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) was inversely correlated to the total number of invertebrate individuals. Due to the inherent variability of the EPT-index in relation to stream health, no further interpretation of the data were made.

For the most part, young of the year salmonids were found in side channels, in shaded pools behind boulders or large woody debris, at the edges of the water, below undercut, shading banks and just downstream of springs flowing into the stream, whereas older fish were concentrated behind boulders and in deeper pools in the faster parts of the channel presumably in order to avoid predators. In French Creek in particular, juveniles almost exclusively resided behind the relatively sparse large woody debris in the main channel, emphasizing its importance as rearing habitat. Habitat heterogeneity in the form of large woody debris, boulders, springs and undercut banks provided cover and food that appeared to be relatively important factors for current fish densities in the study reaches.

Predicted Seasonal Conditions and Considerations

Using data collected during our early summer field investigation, we consider summer and winter habitat as limiting factors for fish in each of the tributaries.

Summer Habitat

Low temperatures (<18ºC), cover, and high food abundance are important factors that favor salmonid growth and survival during the warmer summer months. Water temperatures for all tributaries showed daily fluctuations correlating with changes in ambient air temperature. However, the East Fork of the Scott River and Mill Creek water temperatures showed the most dramatic daily temperature fluctuations. For these tributaries, summer refugia are especially important. Each of these components and its relative abundance is evaluated below.

Cover: Large Woody Debris

Large woody debris (LWD) provides cover from predators, promotes scour and formation of deep, cooler pools, and provides habitat for aquatic insects. LWD was not found in great abundance in any of the tributaries evaluated in this investigation. Mill Creek, French Creek, and East Fork Scott all had very little LWD. Sugar Creek had some, including one large log jam in the lower reach, and the upper reach of French Creek had substantial LWD. However, migration of fish into the upper part of French Creek may be limited by high gradient cascades. Overall, LWD in the tributaries to the Scott River is scarce, and an increase in LWD in each of the study creeks could provide considerable benefits as it is likely a limiting factor in salmonid abundance.

Cover: Undercut Banks

Similar to LWD, undercut banks provide essential cover for smaller salmonids as well as refuge from high velocity flows. Undercut banks were commonly found in lower Sugar Creek and lower Mill Creek; however, all other creeks surveyed showed few or no undercut banks. Based on the multiple observations of fish occupying the undercut banks on both Sugar and lower Mill Creeks in high densities, the lack of undercut banks on the remaining study creeks is a significant component of the absence of cover as a limiting factor in salmonid abundance.

Pools

In general, pools were not found in abundance in the tributaries. Only a few were found in lower French and Sugar Creeks; however, several did occur in the smaller Miner's and Emigrant Creeks. Pools were common in the East Fork Scott, but they were often not shaded. Pools typically provide habitat space for larger fish, such as 1+ steelhead, and provide essential diverse habitat for smaller fish if they contain plenty of cover. The absence of pools may thus be considered a limiting factor for salmonid production in French Creek, Sugar Creek and the East Fork Scott.

Springs

Cold springs provided East Fork and lower Mill Creek with cool water. Cold springs in combination with other summer habitat components, particularly instream cover such as LWD or undercut banks, can provide excellent summer refugia.. If in enough abundance, cold springs help maintain lower stream temperatures and can provide thermal refugia from high daytime temperatures in small streams such as Mill Creek.

Canopy/Bank Vegetation

Both canopy and bank vegetation provide shade from summer heat and aid in maintaining lower instream temperatures. However, too much shade can effectively reduce the light necessary for an abundant aquatic insect population. Canopy is defined as the ceiling of the surrounding forest, usually higher than the height of the bank vegetation. Bank vegetation along the channel banks (1) provides bank stability while allowing for bank undercutting, (2) slows velocity, and (3) provides near-bank cover with vegetation overhang. Good forest canopy cover extended the majority of the length of Sugar Creek, but bank vegetation was not as abundant or continuous. This canopy likely helps to maintain the low instream temperatures. The canopy cover on French Creek appears to limit aquatic insect production by shading, however further investigation is needed to determine the cause for low instream production. Mill Creek and East Fork lacked extensive canopy and bank vegetation, and both had more extreme daily temperature fluctuations than the other study creeks.

Biological Interactions

Biological interactions encompass the interaction of coho with other fish, birds, and beaver. Steelhead, particularly 1+ in age, can compete with juvenile coho for space and food as well as prey on smaller individuals. Although coho were observed in or near the same locations as steelhead, it is important to note that coho and steelhead historically coexisted and mutually flourished in systems such as these. Few fish-eating birds (mainly kingfishers and common mergansers) were observed over the course of the study, although this may be due to a lack of abundance of fish in the streams. Finally, signs of beaver were observed in Sugar, Mill, and French Creeks, although no beaver were directly observed. Historically beaver occupied much of the Klamath Basin but were nearly extirpated by the early 1800s. A beaver pond was observed near the mouth of Sugar Creek, and a former beaver pond existed on French Creek before it was destroyed during the 1997 floods. Beaver activity in the streams appears to be minimal but may be important for creating fish habitat.

Winter Habitat

Winter is the season when adult coho migrate upstream and spawn. Barriers to migration can limit how far upstream salmonids spawn, and sediment size can greatly affect where spawning occurs as well as the survival of embryos and small juveniles. The winter season also brings fast, turbid flow, from which yearling and newly-hatched fish require refugia. Side channels and smaller tributaries typically provide good overwintering habitat. There appeared to be adequate side channel habitat in some stream reaches, but a close examination of streams for overwintering habitat is desirable to determine the extent it may be a limiting factor.

Barriers

Mill, lower French, and lower Sugar Creeks had no apparent barriers. Upper French and Sugar Creeks had high-gradient cascade/step-pool geomorphology that may deter upstream migration of coho salmon and possibly steelhead. However, sediment size and flow regime were not optimal in this part of either watershed, both factors which likely further deter migration and spawning. The East Fork Scott also apparently has a dredge tailing barrier at the confluence with the Scott River, which may prevent upstream migration for spawning if winter flows are not high enough. While barriers do not appear to be a major factor limiting salmonids production in most of the study streams, their impact does need to be examined as they may become limiting if salmonids populations increase over present levels.

Spawning Gravel

Overall, sand eroding from upstream sources (mostly of human origin) was found in each study creek, resulting in embedded riffles and runs, and infilled pools. Sand limits the amount of oxygen flushed over salmon embryos, reduces the quantity and quality of pools, and reduces insect availability in riffles. Overall, sand greatly reduces habitat quality and quantity for coho and steelhead and is likely an important limiting factor. This suggests that extensive efforts to reduce erosion (e.g., road closures) in upstream areas are needed.

Side Channels

Except for Sugar Creek, all other creeks had some type of side channel or small tributaries to provide relief from fast and turbid winter flows. A half-mile long anabranching reach of French Creek provided particularly good overwintering habitat for coho and steelhead. Mill Creek and East Fork also had several side channels with good habitat. Side channels are likely not a major limiting factor for salmonids in most of the streams, but their role in coho survival in particular merits further investigation.

Final Remarks/Considerations

This study, although brief, suggests that coho and steelhead would benefit from efforts to improve habitat in the tributaries to the Scott River, assuming late summer flows are adequate to support the fish. We offer the following suggestions for improving conditions for salmonids, recognizing the limitations of our studies in time and space.

- Install LWD structures at select locations to offer immediate, extensive, and inexpensive benefits to all the streams studied.
- Close and rehabilitate timber harvesting roads in the upper reaches of the watersheds to reduce input of sand into streams in order to provide long-term benefits by improving habitat for fish and insects.

- Develop ways to keep summer temperatures low in all creeks or provide thermal refugia. These ways will vary among creeks, but include encouraging more riparian vegetation and increasing summer flows.
- Remove man-made barriers to movement, such as the apparent barrier at the mouth of the East Fork Scott.
- Investigate the role of side channels and other habitat types as limiting factors in salmonid production.
- Develop management plans for each tributary to find ways to increase coho salmon production. We were particularly impressed with the potential for French Creek (including Miners Creek) and Mill/Emigrant creeks for this purpose.
- Establish annual monitoring surveys for both adults and juveniles of coho and steelhead.

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