Little Springs Creek
2013-14 Baseline Assessment

A Report for
The Nature Conservancy

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1. Purpose

Flows in Little Springs Creek have historically been utilized as a seasonal irrigation water source for Shasta Big Springs Ranch pastures located south of Big Springs Creek. Due to seasonal irrigation withdrawals, April to September streamflows below the lower diversion points have historically led to downstream reaches of Little Springs Creek having little or no water. In winter 2013, juvenile salmonids (steelhead and coho) were observed rearing in Little Springs Creek, prompting the California Department of Fish and Wildlife (CDFW) to curtail irrigation withdrawals from the creek. Consequently, a baseline aquatic habitat assessment was initiated by the U.C. Davis Center for Watershed Sciences and Watercourse Engineering, Inc. to assess the conservation value of Little Springs Creek. This baseline study follows additional similar studies (Jeffres et al. 2010, Nichols et al. 2009) that have formed the basis for identifying and implementing past and ongoing recovery actions on the Shasta Big Springs and Nelson Ranches. Objectives of this study include:

- Documenting baseline aquatic habitat conditions during spring through early fall (April to September).
- Identify, where possible, factors that may limit salmonid rearing potential.
- Assess conservation value of Little Springs Creek in the context of local and regional aquatic habitat conditions.

This work was completed through field work targeting the specific aquatic system attributes of stream hydrology, geomorphology, water temperature, vegetation assemblages (macrophytes), and macroinvertebrates. General fish utilization conditions are based on data provided by CDFW and information gained from the field work collected during the study.

1.1. Report Organization

Section 1 of the report identifies the report purpose. Section 2 includes a general project area and background description as an introduction to Little Springs Creek. Section 3 provides a synopsis of findings. Included are a summary of the baseline assessment elements and a discussion of Little Springs Creek attributes as they relate to Big Springs Creek and the adjacent Shasta River. Section 4 is the technical discussion of the baseline assessment, providing details for each element including field investigations, mapping, laboratory investigations, data and information assessment, and other associated work and analyses. . The baseline assessment elements include a general site description, followed by sections addressing hydrology, geomorphology, water temperature, aquatic macrophyte, macroinvertebrate, and fisheries. The report concludes with a discussion of the elements and some general conclusions.

2. Project Area and Background

Little Springs Creek is the sole tributary to Big Springs Creek, which, in turn, is a principal tributary to the Shasta River. The creek emanates from a small, artificial lake at the spring head. Subsequently, the creek flows 2.25 km along a circuitous route roughly southeast and then northwest to join Big Springs Creek, approximately 0.8 km upstream of the confluence with the Shasta River. Little Springs Creek has been developed for agricultural purposes and includes not only the impoundment at the headwater, but two diversion structures to manage irrigation (Headgate 1 and Headgate 2) (Figure 1).

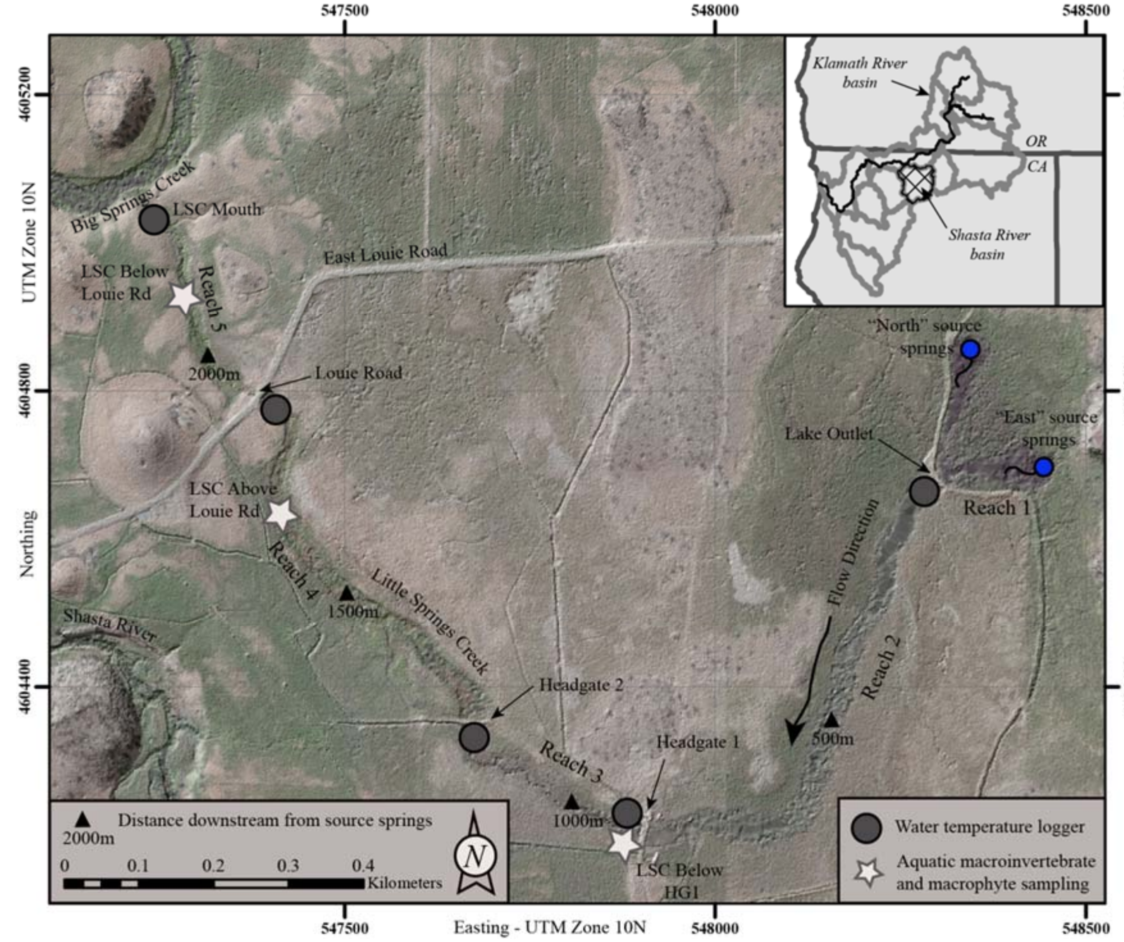


Figure 1. Little Springs Creek project area, with water temperature logger and aquatic macroinvertebrate and macrophyte sampling locations identified.

The exact date of impoundment of the spring head for irrigation is unknown, but the feature does appear on U.S. Geological Survey maps in 1921 (Figure 2) (USGS 1921). Up until 2013, Little Springs Creek was largely diverted for irrigation purposes. During irrigation season, access for anadromous fish was limited or non-existent as the creek was often dry downstream from Louie Road. Seasonal aquatic vegetation growth and senescence is a pronounced feature of Little Springs Creek. Past qualitative observations suggested that biomass associated with aquatic vegetation reached a minimum during the winter and early spring, and a maximum in the late summer. Seasonal growth patterns of aquatic vegetation play a critical role in structuring aquatic habitat conditions by moderating flow patterns, hydraulic conditions, stream shading, acting as a substrate for aquatic macroinvertebrates, and providing physical habitat for rearing salmonids.

Similar to Big Springs Creek, this baseline assessment took place after decades of water resources development. The system was fenced in 2009, and while active restoration was not started, passive restoration has followed this cattle exclusion action. The need for a baseline assessment is to characterize aquatic system conditions as they relate to anadromous fish and other aquatic conditions. This assessment forms a critical basis for restoration actions by providing necessary information to resource managers. Further, the baseline assessment identifies a benchmark to measure restoration actions through time. Finally, this assessment can be used to identify the potential for evaluating the potential impacts of water use for irrigation and other uses of Little Springs Creek.

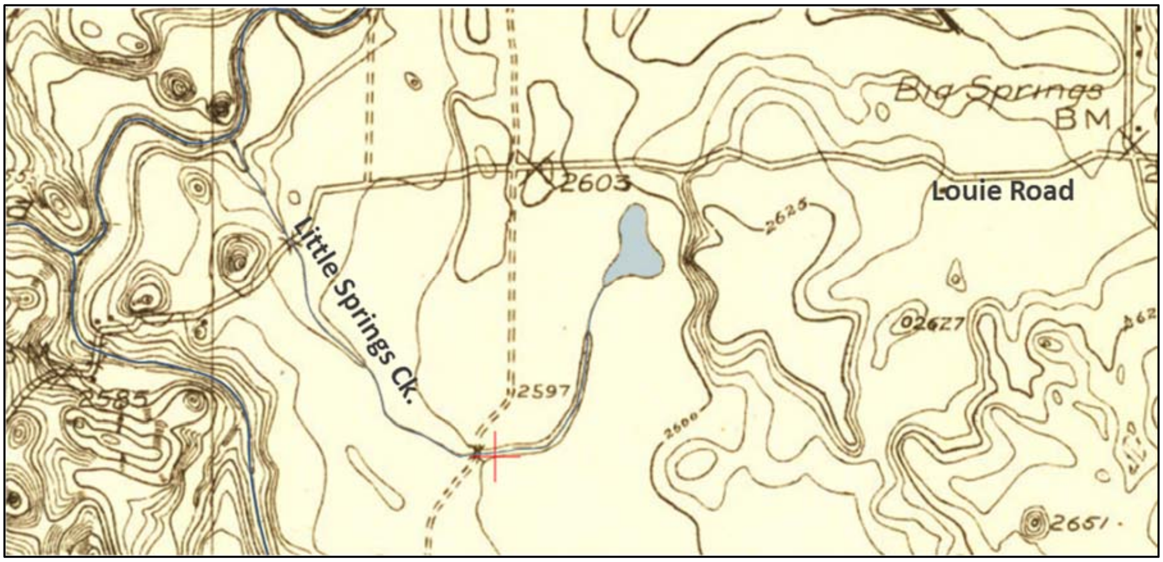


Figure 2. Little Springs Creek as depicted on the USGS 1921 Shasta Valley, Sheet No. 7, 1:24,000 Topographic Quadrangle map (no scale) (USGS 1921).

3. Little Springs Creek: Synopsis

Discrete studies were developed characterize hydrology, geomorphology, macrophytes, water temperature, and macroinvertebrates, and fish information was summarized from previous analyses and CDFW PIT tag studies. The integration of this information defines baseline conditions in the Little Springs Creek for salmonids. Outlined herein are brief descriptions of the individual activities and how they relate to one another, as well as how Little Springs Creek relates to Big Springs Creek or nearby Shasta River reaches.

3.1. Summary

Individual activities of the baseline assessment are outlined below. Details of each discrete study are included in Section 4.

3.1.1. Hydrology

Historic irrigation practices typically diverted all flow at the Lake Outlet or at Headgates 1 or 2, leaving little or no water in the lower reaches of Little Springs Creek during the

April to September irrigation season. Beginning in April 2013, diversions from the lake and downstream diversions ceased, allowing the entire source spring volume to flow down the Little Springs Creek channel and into Big Springs Creek. This current condition results in minimally variant flow regime throughout the creek. During April 2013 through April 2014 flow averaged approximately 8 cfs. No surface flow accretions to Little Springs Creek were observed below the pond at the head of the creek; however, small seeps were observed in the lowermost reach (Reach 5), below Louie Road.

3.1.2. Geomorphology

Little Springs Creek channel morphologies and hydraulic characteristics vary spatially, with differences particularly pronounced upstream and downstream from Louie Road. Channel reaches upstream from Louie Road (Reaches 1 near the spring source, downstream to Reach 4) are low gradient, wide, of moderate depth, and exhibit slow flow velocities. Downstream from Louie Road (Reach 5), channel gradient and flow velocities increase by an order of magnitude, while channel widths and depth decrease, relative to upstream reaches.

The seasonal growth of aquatic vegetation affects hydraulic characteristics throughout Little Springs Creek. When the aquatic vegetation in Little Springs Creek is at a seasonal minimum (i.e., winter and early spring), the reduced channel roughness causes channel widths and depths throughout all reaches to decrease, while allowing flow velocities to increase (for a given flow volume).

3.1.1. Water Temperature

Water temperature in the in Little Springs Creek varies both spatially and temporally. Because the source springs are at a relatively constant temperature, as waters flow downstream, they respond to meteorological conditions: during winter, the stream cools in the downstream direction, and during summer the converse occurs. During the autumnal and vernal equinoxes the stream experience little heating or cooling. However, due to impoundment of the source springs, low gradient of the creek, downstream warming is notable in the summer period. The impoundment increases residence time of spring waters and increases the surface area. While these factors lead to heating, the impoundment also increases the volume of water and may offset the rate of heating and cooling.

The near-constant temperature source springs also result in variable diurnal ranges through the creek. During the warmer periods of the years, diurnal range is moderated near in the upper reaches due to the proximity to the source springs and impoundment of waters. Diurnal range increases in the downstream reaches during the summer. However, the lower reaches (Reach 3, 4, and 5) indicate a moderated diurnal range which may be the effect of extensive vegetation which provides shading and changes water stage and stream velocity.

Overall maximum temperatures range from 19.1°C to 20.6°C at the Lake Outlet to over 22°C in the lowest reaches of the creek in late spring and summer. Over this same time period, mean daily temperatures range from 14.5°C to 15.4°C at the Lake Outlet to over 17°C in the lowest reaches of the creek.

3.1.2. Aquatic Macrophytes

Aquatic macrophytes are observed throughout Little Springs Creek, particularly downstream from Headgate 1 (Reaches 3 through 5). Channel depths upstream from Headgate 1 may appear sufficiently deep to limit macrophyte growth in Reaches 1 and 2. Seasonal patterns of macrophyte growth and senescence occur throughout Little Springs Creek, with maximum and minimum biomass generally observed in the summer and winter, respectively. Aquatic macrophytes proliferate along mid-channel areas of Little Springs Creek, while tule and sedges dominate the vegetation assemblages on the channel margins. These plants change the flow regime by increasing roughness, leading to greater depths that provide expansive aquatic habitats on the channel margins . Further, the vegetation community below Headgate 1 may provide considerable seasonal shade to the creek.

3.1.3. Macroinvertebrates

Over all, macroinvertebrate communities in Little Springs Creek exhibit high density and low diversity. Within the system there is an overall downstream gradient of increasing density, diversity, and taxa sensitivity. By and large the system is dominated by collector/gatherers and detritivore/scavengers. While many of the taxa found downstream are absent in the upper reaches, the many generalist taxa that characterize the stream still manage to proliferate in the lentic habitats of the upper reaches. Though, the entire length of Little Springs Creek supports a sufficient food web baseline needed to build complex aquatic communities, these patterns suggest that the lower reaches of Little Springs Creek provide the best habitat for macroinvertebrates and thereby the largest potential source of food for fish.

3.1.4. Fish

Fish presence and absence data indicate that Little Springs Creek is used by anadromous salmonids. Stable flows and local geomorphology, coupled with aquatic vegetation (cover) provide juvenile rearing opportunities in Little Springs Creek. Generally suitable water temperatures occur in the creek throughout the year to support juvenile rearing, particular with the level of macroinvertebrates available as a food source. Limited spawning may occur in the lower end of Reach 5, near the confluence with Big Springs Creek. Overall the number of fish using the creek appears modest, particularly with the extensive habitat available in adjacent Big Springs Creek, but additional work in this area is needed to quantify conditions in Little Springs Creek.

3.2. Little Springs Creek: Regional Context

As a spring-fed tributary to a notably larger, spring-fed Big Springs Creek, Little Springs Creek is a component of a unique and important spring complex in the Shasta Basin. The complex of spring creeks and the Shasta River in this area provide extensive, interconnected, cold water habitats during late spring, summer, and early fall periods. Coupled with the productive nature of the spring creeks and river, these conditions provide unparalleled over-summering habitats for endangered coho salmon, as well as over-summering life stages for other cool water fish species. Limiting factors and conservation value are presented below with consideration of adjacent Big Springs Creek and the Shasta River.

Through this baseline assessment, selected elements of hydrology, geomorphology, aquatic vegetation, water temperature, macroinvertebrates, and anadromous fish were explored. The interactions of these elements, as well as other conditions, form a complex relationship that define aquatic habitat in Little Springs Creek (Figure 3). Currently, Little Springs Creek functions primarily as rearing habitat; few other lifestages (e.g., spawning) are supported. Though the quality of rearing habitat is likely to improve as passive restoration progresses, the potential of this creek is limited by its natural attributes. Specifically,

1. the physical size of the stream,
2. low gradient through much of its length (above Louie Road), and
3. nominal available spawning habitat.

The role of this waterway and its function as critical salmon habitat is currently modest given its proximity to other, extensive, interconnected cold water habitat, namely Big Springs Creek and the adjacent Shasta River, which provides several kilometers of available aquatic habitat. Little Springs Creek contributes flow and water temperature to this system; however, previous analytic and empirical analyses suggest that Little Spring Creek's potential to influence water temperatures or physical habitat in Big Springs Creek is small (Willis and Deas 2014, Nichols et al. 2013). By comparison, Big Springs Creek and the adjacent Shasta River provide a complex mosaic of high primary and secondary productivity habitats, which support year-round juvenile rearing, as well as migration, spawning, and egg incubation life-stages during their respective times of year.

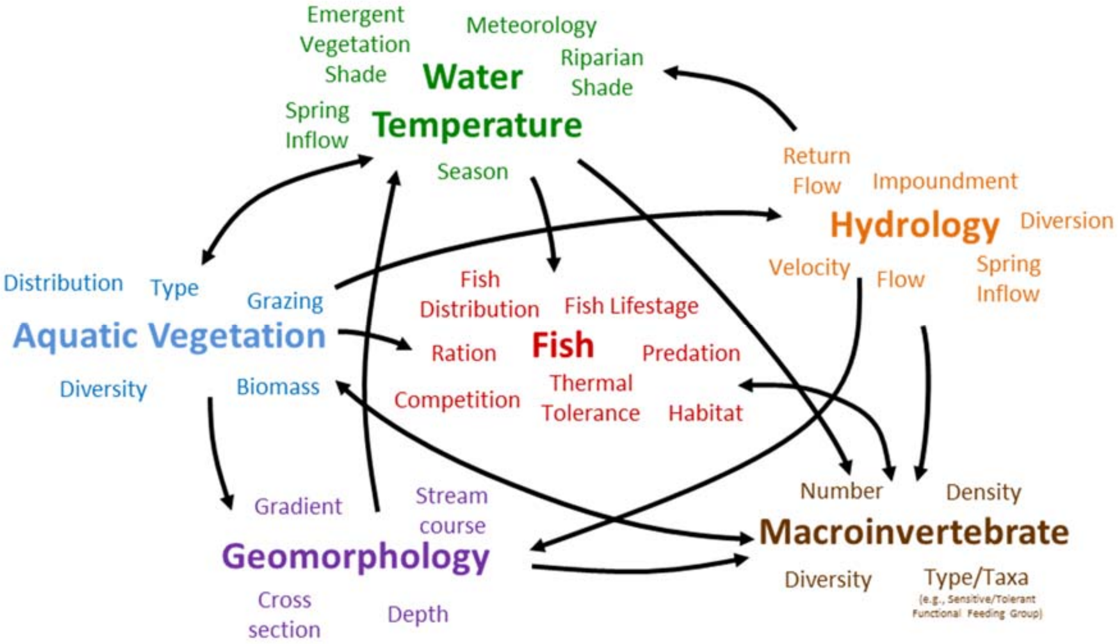


Figure 3. Basic conceptual model of the inter-relationships of hydrology, geomorphology, aquatic vegetation, water temperature, macroinvertebrates, and anadromous fish in Little Springs Creek.

This qualitative discussion of conservation values of the creek, made by comparing Little Springs Creek to Big Springs Creek and the adjacent Shasta River, allows resource scientists and planners to explore similarities and differences, and to better understand and manage these valuable systems. Specific questions that can be posed include:

- What are representative restoration goals for the creek (e.g., how much habitat is available and how many juvenile fish (of each species) can this habitat support), and how does the creek fit into regional restoration goals?
- At current fisheries levels, are habitats for the various life stages in Little Springs Creek saturated, e.g., is there a constraint on juvenile rearing capacity in the larger Big Springs Creek and adjacent Shasta River reaches? If not, what does current fish utilization suggest about Little Springs Creek's role in the overall system?
- At what level of population increase would Big Springs Creek and the Shasta River habitats reach capacity? When would that condition be expected (how long would it take)?
- Can the creek support limited, seasonal irrigation diversion (with appropriate screening and diversion facilities) and still retain juvenile rearing habitat?
- What restoration actions might be considered to improve conditions in the creek for juvenile rearing, and what benefit would individual and combined restoration actions provide?

This brief list includes only a few of the more apparent questions necessary to formulate testable hypotheses; hypothesis that are required to more fully define overall conservation strategies for Little Springs Creek. Further, the overall context of Little Springs Creek regionally – as it relates to Big Springs Creek, the adjacent Shasta River reaches and other available habitats in the area – should be carefully considered. There are several entities and individuals currently working in the upper Shasta River basin developing restoration actions and strategies that relate to ongoing land use and aquatic system activities. These efforts are considering local and reach scale conditions, and thus the role of Little Springs Creek in the broader context of upper Shasta River restoration actions, goals, and priorities is important.

4. Little Springs Creek Baseline Assessment

The methods and results from the Little Springs Creek baseline assessment for hydrology, geomorphology, water temperature, aquatic macrophytes, macroinvertebrates, and fish are addressed herein. These elements are presented as semi-independent components of the baseline assessment. A synthesis of the features is presented in the previous report section. Sampling was not coincident for all elements of the baseline study, but all sampling occurred from spring 2013 through fall 2014 (Table 1).

Table 1. Baseline assessment monitoring periods/dates.

Baseline Element	2013								2014									
***Month* =**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**
Hydrology	▨	▨	▨	▨	▨	▨												▨
Geomorphology				▨		▨												
Water Temperature	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Macrophytes					▨						▨			▨				
Macroinvertebrates				▨							▨			▨				
Fish[1]																		

[1] Fish data provided by CDFW.

Little Springs Creek emanates from a series of groundwater springs that discharge into a small impoundment at the head of the creek. Source springs are located at the heads of each of two pond “arms”, herein referred to as the “north” and “east” springs (Figure 1). From there, it flows through the Lake Outlet (Dam) and follows a roughly southwest path before turning northwest to join Big Springs Creek. For the baseline assessment elements, the Little Springs Creek study area was divided into five reaches starting from the “east” source spring to the mouth (Table 2).

Table 2. Starting and ending location for each reach on Little Springs Creek.

Reach Number	Start of Reach	End of Reach	Length (km)
Reach 1	“East” Source Springs	Lake Outlet	0.12
Reach 2	Lake Outlet	Headgate 1	0.76
Reach 3	Headgate 1	Headgate 2	0.21
Reach 4	Headgate 2	Louie Road	0.78
Reach 5	Louie Road	Big Springs Creek	0.38

4.1. Hydrology

As mentioned, streamflow in Little Springs Creek emanates from a series of groundwater springs. In the north pond arm, groundwater emerges diffusely through sandy bed sediments into an approximately 2 m deep pool (CDFW 2013b). Groundwater springs in the east arm discharge from a basalt outcrop along the lakeshore into a shallow (<1 m) pool (CDFW 2013b). Other inflow to the creek is negligible with the possible exception of local storm runoff due to the small watershed size (approximately 125 hectares (308 acres)) and relatively flat topography. Flow monitoring was completed by multiple entities (Davids Engineering, The Nature Conservancy (TNC), and the California Department of Fish and Wildlife (CDFW)) at several locations throughout Little Springs Creek during the 2013 and 2014.These flow monitoring activities are summarized below.

4.1.1. Methods

On behalf of TNC, Davids Engineering periodically measured discharge at selected locations throughout Little Springs Creek in 2013. Using seven spot discharge measurements and continuous river stage (hourly intervals) collected at Louie Road, Davids Engineering (2013) rated streamflow in Little Springs Creek. Reported percent error between flows calculated using the established rating curve and flows quantified using periodic discharge measurements were -4.99% (July 16, 2013 10:00) and -13.5% (August 22, 2013 07:00) (Davids Engineering 2013).

TNC maintained a Hach Sigma 910 portable area flow meter in the culvert at the Lake Outlet (Figure 1). Flow velocities and volumes at this monitoring location were reported at 15-minute intervals between July 3 and September 30, 2013, and at 1 hour intervals between October 1, 2013 and October 2, 2014. Furthermore, river stage (15-minute intervals) was collected by TNC at the Headgate 1 monitoring site between April 24 and October 10, 2013.

Throughout the 2013 irrigation season, CDFW performed periodic discharge measurements at Headgate 1 (21 measurements) and the mouth of Little Springs Creek (15 measurements). In 2014 CDFW completed three discharge measurements in March (March 18) and April (April 3, April 25). Measurements were performed with a Marsh McBirney Flo-mate. No rating curve was developed for these location due to confounding effects of seasonal aquatic macrophyte growth (CDFW unpublished data).

4.1.2. Results

Little Springs Creek exhibits a minimally variant flow regime in the absence of seasonal irrigation diversions. Flow management structures exist at three locations along Little Springs Creek: the Lake Outlet, Headgate 1, and Headgate 2. These structures were previously used to impound and divert water from Little Springs Creek to flood irrigate Shasta Big Springs Ranch pasturage. Historic practices often utilized all flow in the creek and the lower reaches of Little Springs Creek downstream from Louie Road often exhibited little or no flow during the April to September irrigation season. Beginning in April 2013, all structures in Little Springs Creek were opened, allowing the entire source spring volume to flow down the Little Springs Creek channel and into Big Springs Creek.

Flows were measured in Little Springs Creek from April to September 2013 and in October 2014 and ranged from 4.35 ft^3/s to 11.54 ft^3/s (Table 3).

Table 3. Flow measurements in Little Springs Creek.

Reach	Flow Rates (ft^3/s)			Period	Source
	Min	Max	Mean		
Lake Outlet	2.16	9.29	6.66	July 2013 to October 2014	TNC (2013)
Headgate 1	4.35	11.54	8.02	-	CDFW (2013a)
Headgate 2	7.28	8.75	8.16	March to April 2014	CDFW*
Louie Road Crossing	7.59	11.01	8.68	2013 Irrigation Season	Davis Engineering (2013); TNC (2013)
Mouth	5.65	10.43	7.96	-	CDFW (2013a)

* CDFW provided flow data for 3/18, 4/3, and 4/25 2014 on Little Springs Creek (C. Adams)

These data indicate 8 ft^3/s is a reasonable estimate of mean spring flow in Little Spring Creek. While the large observed flow magnitude ranges suggest that considerable flow variability exists in Little Springs Creek, much of this variability is likely related to the hydraulic effects of seasonal aquatic vegetation growth that can hinder the accurate measurement of flow velocities and the development of flow rating curves. Furthermore, the periodic cleaning of culverts blocked with aquatic vegetation often led to periodic increases of flow volumes (Ada Fowler, per. comm.) in Little Springs Creek. Interestingly, streamflow data at the Lake Outlet monitoring site from 2014 suggested small seasonal spring-flow diminishment during summer, resulting in mean late summer flows of approximately 5.5 ft^3/s.No surface flow accretions to Little Springs Creek were observed below the pond at the head of the creek; however, small seeps were observed in the lowermost reach (Reach 5), below Louie Road.

4.2. Geomorphology

The Little Springs Creek source springs emanate from the bases of several basaltic rock outcroppings, a hydrogeologic condition observed at the source of many of the large volume springs in the Shasta River valley. For the first 0.8 km of its length, Little Springs Creek flows to the southwest. Subsequently, the creek abruptly changes course and flows to the northwest for the remaining 1.5 km. For most of its length, Little Springs Creek is only slightly incised relative to the surrounding uplands. However, channel incision (relative to the surrounding uplands) increases dramatically along channel reaches between Louie Road and the confluence with Big Springs Creek.

Baseline geomorphic conditions were assessed to help understand physical aquatic habitat conditions in Little Springs Creek. Specifically, channel cross-section and longitudinal bed and water surface elevation profile surveys were conducted to:

- Characterize longitudinal variations in channel morphologies along Little Springs Creek.
- Evaluate spatial and temporal differences in channel hydraulic characteristics.

4.2.1. Methods

Topographic surveys of Little Springs Creek were completed with a TOPCON HiperLite+ Real Time Kinematic (RTK) survey unit. Methodologies used during cross-section and longitudinal profile surveys are presented below.

Longitudinal Profile Surveys

A channel thalweg survey of Little Springs Creek was conducted in August and October 2013. The 2.25 km channel thalweg profile began at cross-section (XS) 23 (downstream of “east” source spring) and ended at the mouth of Little Springs Creek (XS 1) (see Figure 4). Mean point spacing of the thalweg profile was 2.07 m. One hundred and sixty seven (167) water surface elevation points were surveyed along Little Springs Creek in the fall of 2013. Each water surface elevation was spatially joined to the nearest thalweg survey point in the geographic information system (GIS) ArcMap10. A LOESS regression (locally-weighted polynomial regression, R Statistical Package) was used to create a smoothed water surface elevation profile spatially linked to the thalweg profile. Thalweg depth at each thalweg survey point was calculated by differencing the modeled water surface elevation and the corresponding channel thalweg elevation. Water surface elevation slopes were calculated for each channel reach (see Figure 5) using simple linear regression.

Cross-Section Surveys

In August and October 2013, sixteen (16) channel cross-sections were surveyed along the length of Little Springs Creek (Figure 4). Prior to surveying, cross-sections were systematically located 100 m apart in the GIS ArcMap10. Along wadeable sections of Little Springs Creek, all systematically-located channel cross-sections (1 through 10) were surveyed in August 2013. However, cross-sections 11 through 23 (11, 13, 15, 17, 19, and 23) could only be surveyed by boat. Consequently, the spatial distance between the cross section was increased to 200 m to expedite boat-based survey efforts conducted in October 2013. Cross-section IDs were not changed from those assigned systematically prior to the survey efforts.

Channel hydraulic parameters were calculated for each surveyed cross-section to compare longitudinal differences in channel characteristics in August and October 2013. Calculated metrics included wetted width, wetted area, thalweg depth, and mean flow velocity [(Mean Discharge)/$\text{Area}_{\text{wetted}}$]. To evaluate seasonal differences in channel characteristics, hydraulic metrics were calculated for cross-sections 2 through 13 (excluding cross-section 8) by replacing water surface elevations surveyed in August and October 2013 with those surveyed in April 2014.

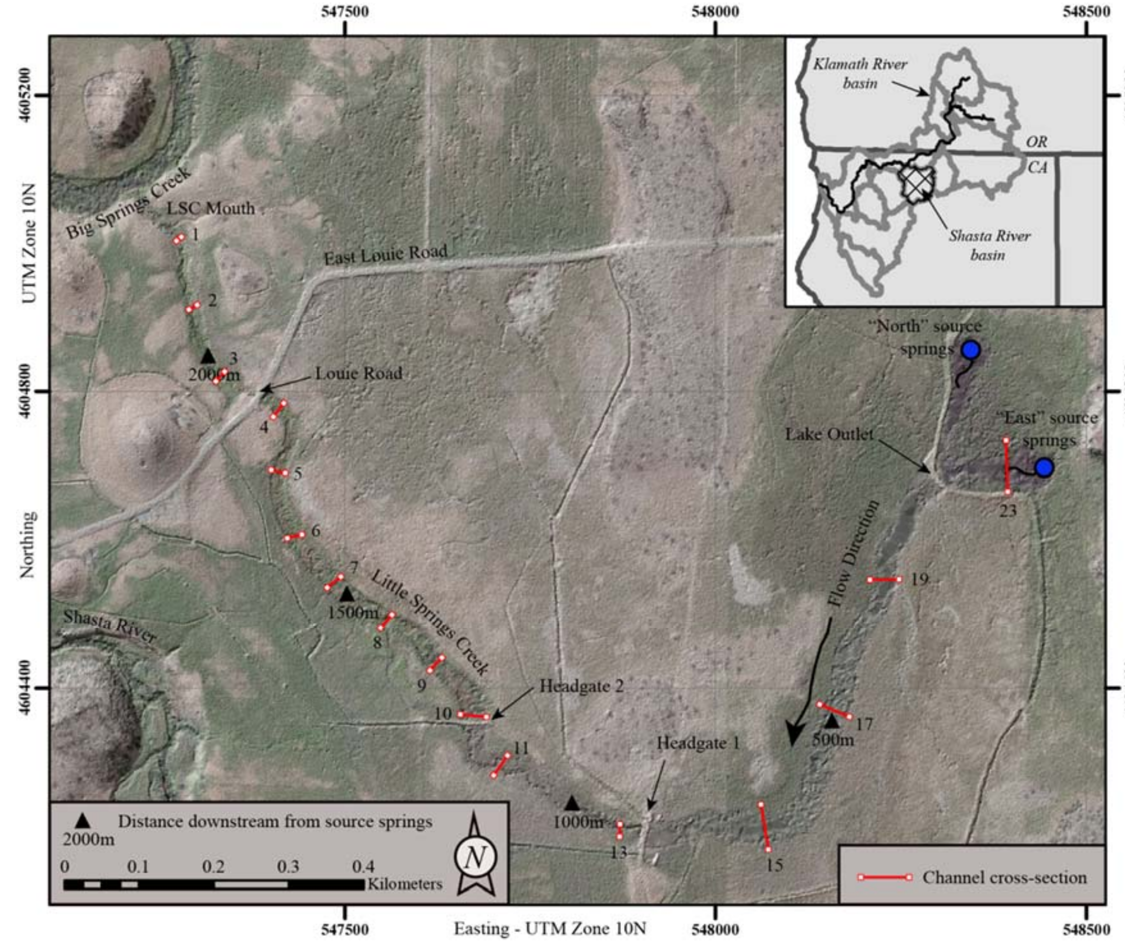
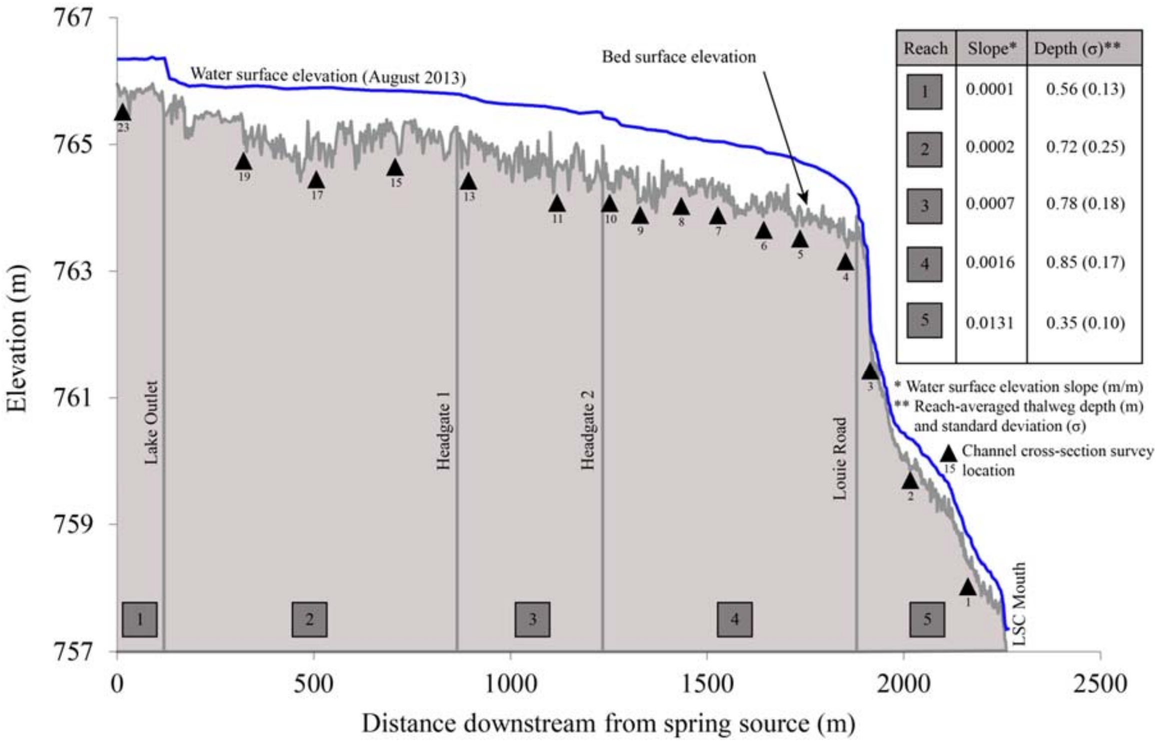


Figure 4. Little Springs Creek study site with longitudinal profile and cross-section survey sites.

4.2.2. Results

Longitudinal Profile Surveys

Prominent geographic landmarks allow Little Springs Creek to be divided into five (5) distinct channel reaches (see Table 2 and Figure 5). Little Springs Creek exhibits large longitudinal differences in channel slope and thalweg depth across the five reaches. Channel reaches extending from the source springs to Louie Road (Reaches 1 through 4) are remarkably low-gradient, with water surface slopes ranging from 0.0001 along Reach 1 to 0.0016 along Reach 4, and mean thalweg depths between 0.56 and 0.85 m (Figure 5). Water and channel bed surface gradients in Little Springs Creek increase by an order of magnitude downstream from Louie Road, where reach-average water surface slopes are 0.0131. Reach 5 also exhibits much shallower thalweg depths (mean = 0.35 m) relative to upstream reaches.



Reach	Slope*	Depth (σ)**
1	0.0001	0.56 (0.13)
2	0.0002	0.72 (0.25)
3	0.0007	0.78 (0.18)
4	0.0016	0.85 (0.17)
5	0.0131	0.35 (0.10)

Figure 5. Little Springs Creek water surface and channel bed elevation longitudinal profiles. Water surface slope (m/m; simple linear regression) and mean channel thalweg depth (m) are presented for each of five (5) channel reaches.

Like most spring-fed creeks, Little Springs Creek exhibits minimal local variation in channel bed morphology. The near constant streamflow of the creek prevents the generation and maintenance of channel bed features, such as pools and riffles, common to alluvial streams (e.g., Reiser *et al.* 2004). Consequently, local variation in water surface slope and channel thalweg depth is low, with local deviations in channel slope generally only observed in the vicinity of the headgates (Figure 5). Channel reaches upstream of Louie Road are uniformly deep and low gradient, and channel depths are similar to pool depths observed in a selected group of northern California, southern Oregon and northeast Alaska streams (Buffington *et al.* 2002). As such, channel reaches above Louie Road appear to provide expansive "pool-like" habitats. Channel reaches downstream from Louie Road are considerably steeper and shallower. Along this reach, a steep bedrock cascade (mean slope = 0.1) transitions into a "run" habitat with mean thalweg depths of approximately 0.35 m. Alluvial bed features (i.e., riffles and pools) are largely absent in the channel reach below Louie Road.

Cross-Section Surveys

Channel cross-section morphologies in Little Spring Creek vary by channel reach. Generally, the wide and deep channel morphologies of Reaches 1 through 4 abruptly transition to narrower and shallower morphologies of Reach 5 (downstream from Louie Road) (Figure 6). Reach-scale differences in channel cross-section morphology are discussed herein.

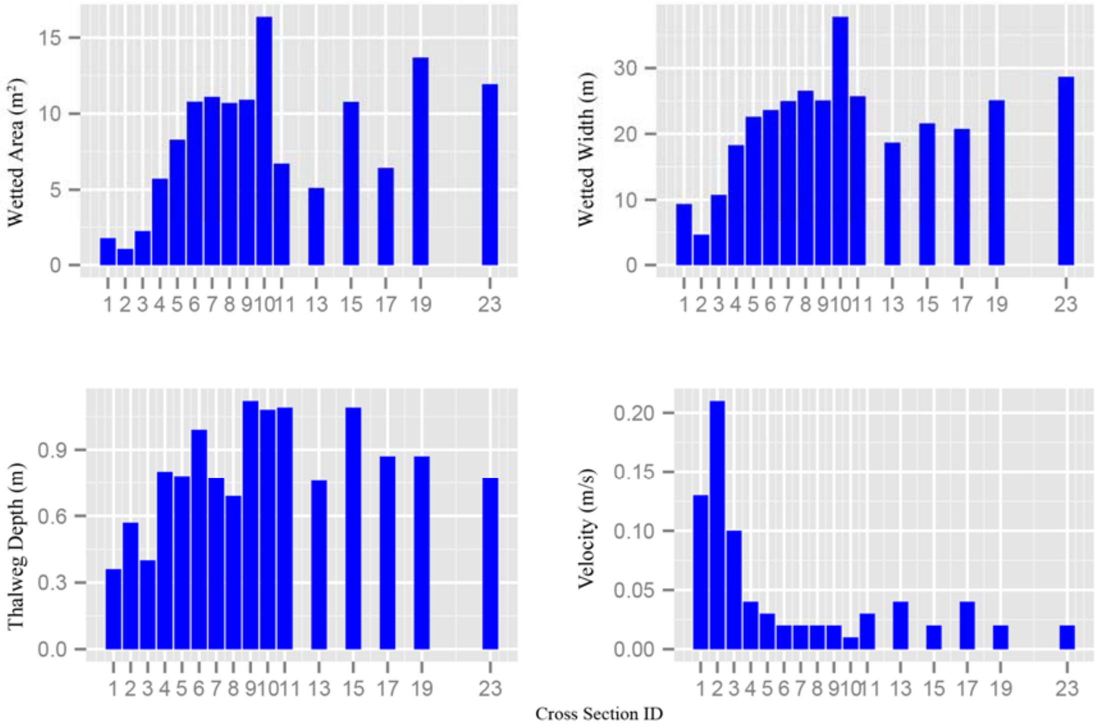


Figure 6. Little Springs Creek channel cross-section metrics (see Figure 1 for survey locations). Cross-sections 1 through 10 were surveyed in August 2013, while cross-sections 11, 13, 15, 17, 19 and 23 were surveyed in October 2013.

Reach 1 – East Spring Source to Lake Outlet (XS23)

Little Springs Creek upstream from the Lake Outlet (Reach 1, 0.12 km reach length) is remarkably wide (wetted width = 28.7 m) and of moderate depth (thalweg depth = 0.77 m). Even when the culvert at the Lake Outlet is open, the existing irrigation impoundment creates a local backwater that generates low mean flow velocities (0.019 m/s) and elevated water depths. Cross-section 23 exhibits a remarkably high width to depth ratio (wetted width divided by mean depth) of 68.8. Channel cross-sections throughout Reach 1 exhibit minimal instream vegetation, and moderate growth of large tules on the channel margins (Figure 7).

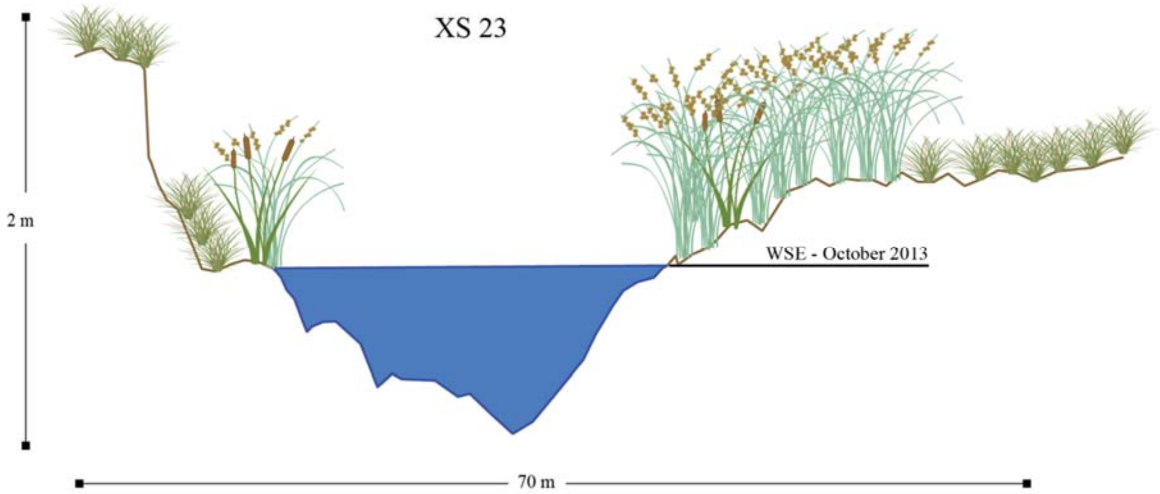


Figure 7. Graphic representation of cross-section 23 (XS 23) in October 2013. The channel bed is devoid of aquatic vegetation, and 1 to 2 m tall tules occupy the channel margins.

Reach 2 – Lake Outlet to Headgate 1 (Cross-Sections 15, 17, 19)

Little Springs Creek between the Lake Outlet and Headgate 1 (Reach 2; 0.76 km reach length) exhibits cross section channel morphologies similar to those observed in Reach 1. Reach-averaged wetted width and thalweg depth are 22.5 m and 0.94 m, respectively (Figure 8). Similar to Reach 1, the downstream impoundment at Headgate 1 creates a large backwater characterized by low mean flow velocities (0.024 m/s) and elevated water depths. While cross-section width to depth ratios along the reach average 52.1, these elevated width to depth ratios are strongly influenced by shallow "inundated benches" along the channel margins that are occupied by tule colonies (Figure 5).

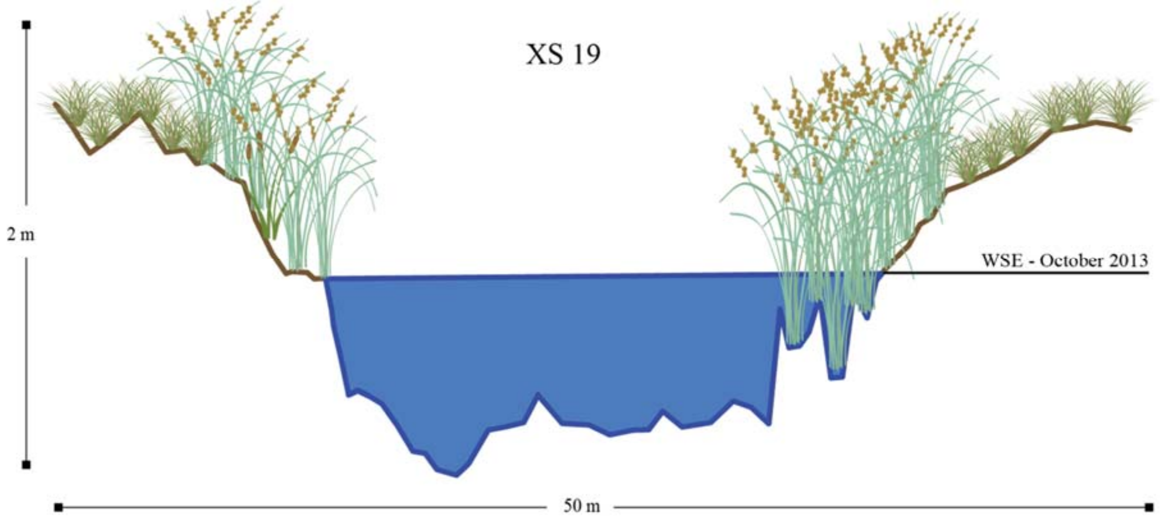


Figure 8. Graphic representation of cross-section 19 (XS19) in October 2013. An "open water" channel thalweg is devoid of aquatic vegetation, and 1 to 2 m tall tules occupy the channel margins, including "inundated benches" exhibiting minimal flow.

Reach 3 – Headgate 1 to Headgate 2 (Cross-Sections 11 and 13)

Cross-section morphologies between Headgate 1 and Headgate 2 (Reach 3; 0.21 km reach length) exhibit mean wetted widths and thalweg depths (22.2 m and 0.92 m, respectively) similar to those observed in Reaches 1 and 2. Elevated widths and depths appear influenced by backwater effects associated with the irrigation impoundment at Headgate 2. Mean flow velocities through Reach 3 remain low (0.04 m/s), and width to depth ratios average 83.4. However, more than half of the measured wetted channel widths throughout Reach 3 are found on extensive, tule-covered "inundated benches" along the channel margins (Figure 9). However, the width to depth ratio of cross-section 11 calculated using only "open water" channel areas not occupied by tules ($\text{Width}_{\text{open water}}/\text{Depth}_{\text{thalweg}}$) is reduced by more than an order of magnitude to 2.2. This suggests much of the water flowing through Reach 3 is conveyed along a narrow and deep portion of the channel.

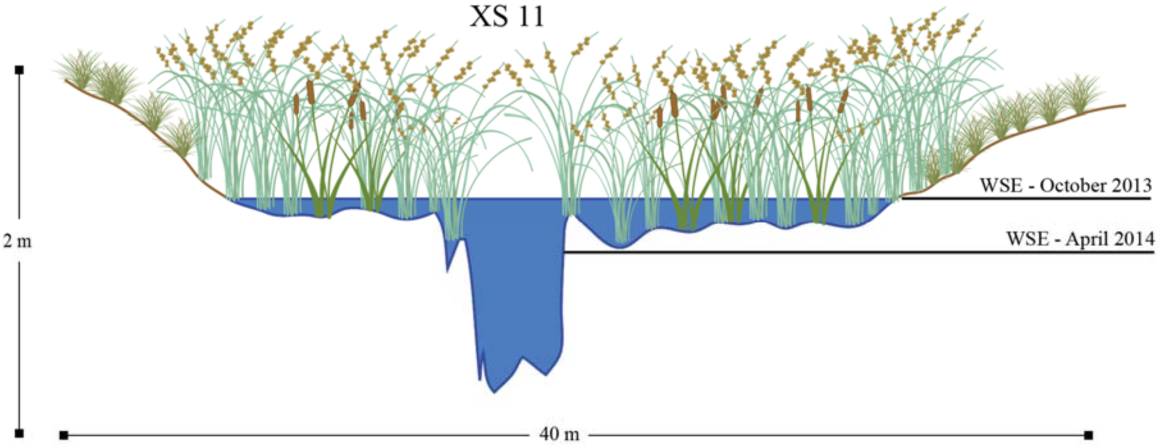


Figure 9. Graphic representation of cross-section 11 (XS 11) in October 2013. An "open water" channel thalweg exhibits minimal aquatic vegetation, while tules occupy extensive channel margin areas inundated by shallow water.

Reach 4 – Headgate 2 to Louie Road (Cross-Sections 4 through 10)

Channel morphologies between Headgate 2 and Louie Road (Reach 4; 0.78 km reach length) exhibit large wetted widths and thalweg depths (25.6 m and 0.89 m, respectively) (Figure 10). However, much like upstream reaches, elevated wetted widths are strongly influenced by "inundated benches" on the channel margins (Figure 7), where shallow water (<0.5 m depth) flows slowly (0.023 m/s) through dense stands of tules and other emergent aquatic vegetation. The presence of such inundated benches generates elevated width to depth ratios (mean = 62.7) throughout the reach. However, a small thalweg channel, approximately 2 to 3 meters wide and 1 to 2 meters deep, meanders through Reach 4. As an example, the width to depth ratio calculated for cross-section 6 using only the observed thalweg of "open water" ($\text{Width}_{\text{open water}}/\text{Depth}_{\text{thalweg}}$) is 2.6. The wide, shallow and slow waters throughout Reach 4 are similar to hydrologic conditions found in wetlands.

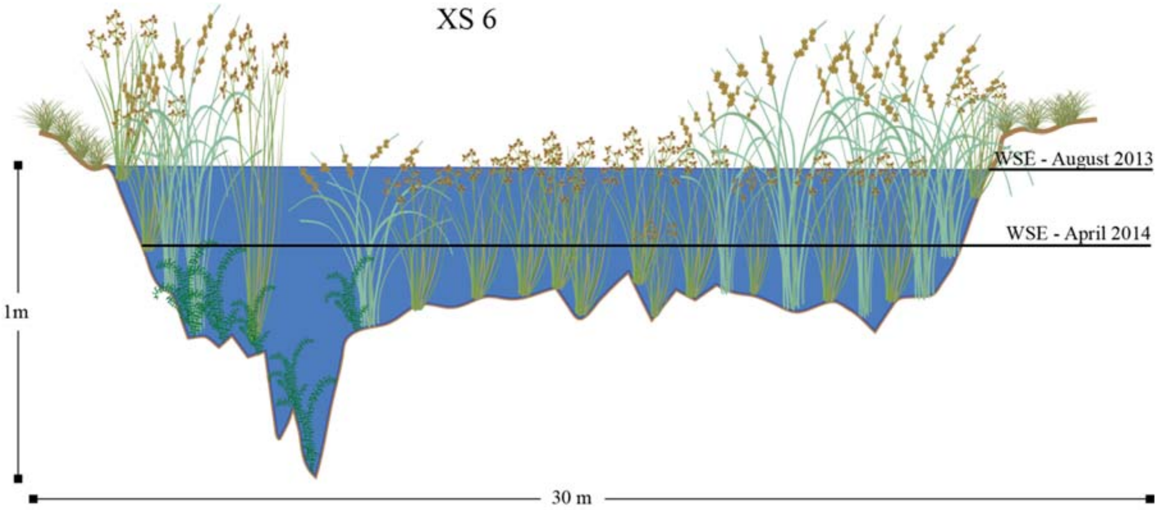


Figure 10. Graphic representation of cross-section 6 (XS 6) in August 2013. From late spring to early fall, nearly the entire channel is obscured by tules, sedges and emergent aquatic macrophytes. A deep thalweg meanders through the channel reach.

Reach 5 – Louie Road to the Mouth of Little Springs Creek (XS 1-3)

Downstream form Louie Road (Reach 5, 0.38 km reach length), mean cross section morphologies are much narrower (8.2 m) and shallower (0.44 m) relative to upstream reaches (Figure 11). Furthermore, flow velocities (mean = 0.15) are higher relative to upstream reaches. Seasonal aquatic vegetation growth retards velocities enough, such that marginal channel areas occupied by stands of tules and sedges are inundated by 10 to 30 cm of slowly moving water (Figure 11). While width to depth ratios that include marginal benches are elevated (mean = 40.1), width to depth ratios calculated using only the “open water” areas are considerably reduced (2.56 for cross-section 2).

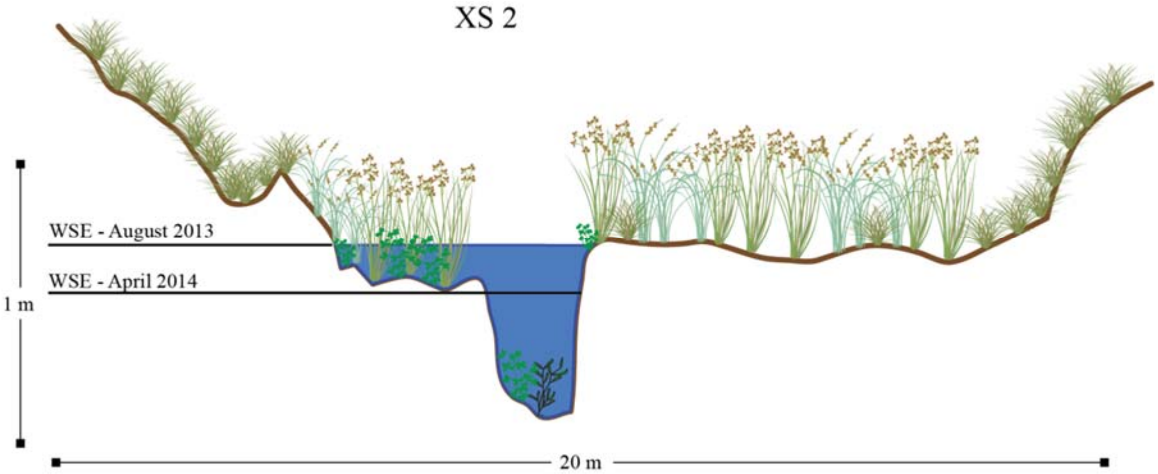


Figure 11. Graphic representation of cross-section 2 (XS 2) in August 2013.

Seasonal Differences in Hydraulic Parameters

Seasonal growth of aquatic macrophytes in lotic waterways typically increases channel roughness and the resistance to flow (e.g., Champion and Tanner 2000; De Doncker *et al.* 2009), resulting in an increase of river stage for a given flow volume. With flows in

Little Springs Creek largely stable (mean of approximately 8 ft^3/s) throughout the project period, comparison of cross section hydraulic variables from August 2013 and April 2014 were used to quantitatively evaluate the influence of seasonal senescence of instream vegetation on available aquatic habitat. The senescence of aquatic vegetation between August 2013 and April 2014 resulted in decreased wetted area (-56%), wetted width (-46%) and thalweg depth (-28%), and increased mean flow velocities (+234%) (Figure 12). The largest hydraulic changes were observed in cross-sections 5, 10, 11 and 13, where expansive "inundated benches" on channel margins were largely dewatered following the senescence of aquatic vegetation in the winter of 2014.

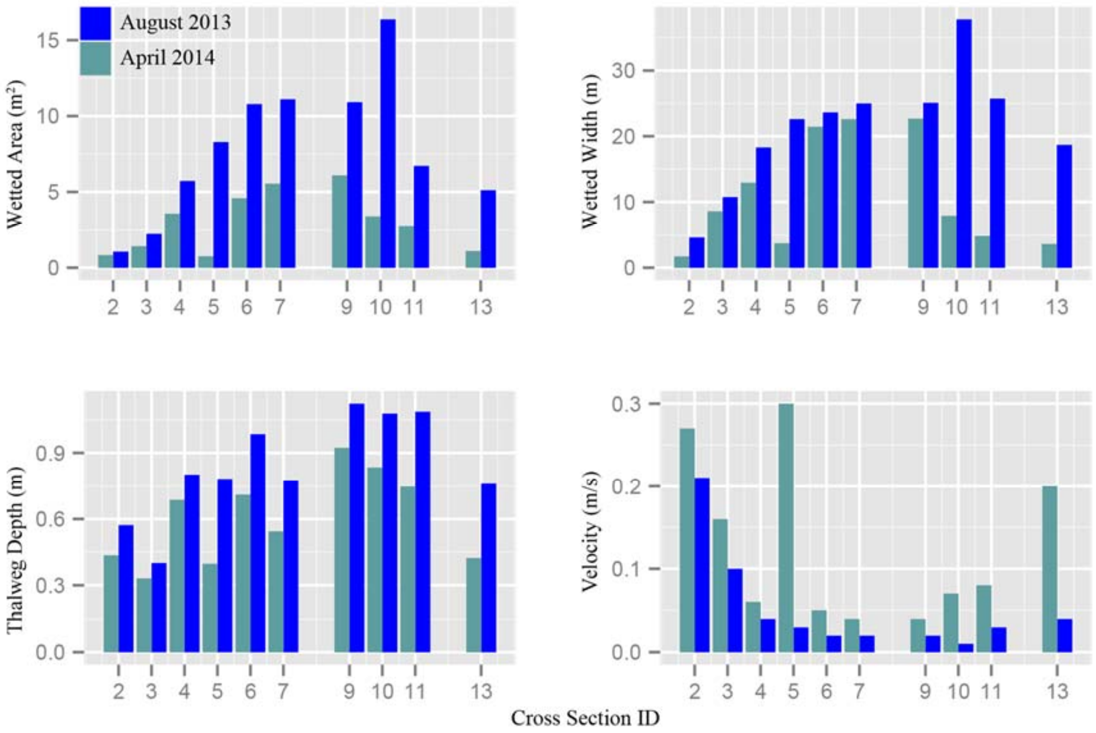


Figure 12. Seasonal comparison of Little Springs Creek channel cross-section metrics (see Figure 1 for survey locations).

Reach 4 experiences dramatic seasonal differences in hydraulic conditions due to the growth and senescence cycle of aquatic vegetation. In August 2013, Reach 4 was characterized by a relatively deep channel thalweg flowing through a large expanse of shallowly inundated channel margin habitats (see Figure 10). During this summer period, the channel thalweg was not visible from the channel banks due to overhanging tules and other aquatic vegetation (Figure 13). However, following the winter senescence of aquatic plants and concomitant reduction in river stage, the channel margins became only minimally inundated, and almost all of the flow of Little Springs Creek was contained within the deeper channel thalweg (Figure 14).

Figure 13. Cross-section 6 (Reach 4) in August 2013. Macrophytes and tules/scirpus occupy much of the wetted channel.

Figure 14. Little Springs Creek Reach 4 in March 2014.

Mean flow velocities in Little Springs Creek increased following the winter senescence of aquatic vegetation (Figure 12 and Table 4). This effect was particularly pronounced in channel Reaches 3 and 4 (Table 4), where flow velocities increased by 266 and 300%, respectively between August 2013 and April 2014. Flow velocities in Reach 5 experienced a much smaller increase of 47%. Reduced summertime flow velocities dramatically increased the travel time of spring water through Little Springs Creek. In August 2014, it took more than 22 hours for water emanating from the Little Springs Creek source springs to travel down the creek and into Big Springs Creek.

Table 4. Seasonal flow velocities and travel times in Little Springs Creek by reach.

		Mean Velocity (m/s)[1]		Travel Time (hours)[1]	
Reach (Reach #)	**Length (m)**	**April**	**Aug/Oct**	**April**	**Aug/Oct**
Source Springs to Headgate 1 (1 & 2)	880	N/A	0.023	N/A	10.63
Headgate 1 to Headgate 2 (3)	210	0.143	0.039	0.41	1.50
Headgate 2 to Louie Road (4)	780	0.092	0.023	2.36	9.42
Louie Road to Mouth (5)	380	0.215	0.146	0.49	0.72

[1] Water surface elevations were not surveyed along Reaches 1 and 2 in April 2014, precluding estimates of mean flow velocities and travel times during that period.

4.2.3. Summary

Little Springs Creek channel morphologies and hydraulic characteristics vary spatially, with differences particularly pronounced upstream and downstream from Louie Road. Channel reaches upstream from Louie Road (Reaches 1 to 4) are low gradient, wide, of moderate depth, and exhibit slow flow velocities. Downstream from Louie Road (Reach 5), channel gradient and flow velocities increase by an order of magnitude, while channel widths and depth decrease, relative to upstream reaches.

The seasonal growth of aquatic vegetation affects hydraulic characteristics throughout Little Springs Creek. When the aquatic vegetation in Little Springs Creek is at a seasonal minimum (i.e., winter and early spring), the reduced channel roughness causes channel widths and depths throughout all reaches to decrease, while allowing flow velocities to increase (for a given flow volume).

4.3. Water Temperature

Water temperature is a physical property defining the thermal energy in an aquatic system. Heat transfer across the air-water interface, to or from the stream bed, as well as energy inputs into the system from upstream sources and tributary inputs, all play a role in the water temperature regime of streams. Water temperature influences physical and chemical properties of water, and has direct effects on biological activities including photosynthetic production and metabolic rates of aquatic organisms (Perlman 2013, Wilde 2006, USEPA 1997).

Water temperature was monitored at five locations along Little Springs Creek: below the Lake Outlet, below Headgate 1, below Headgate 2, below the Louie Road crossing, and at the mouth, above the confluence with Big Springs (Figure 1). Direct monitoring of source spring temperatures was not possible due to a lack of direct access. The north source springs are submerged, while the east source springs are not located on Shasta Big Springs Ranch. Field monitoring was conducted from May 1, 2013 through October 1, 2014 (Table 1 and Table 5). These data were examined at several time intervals, spanning from sub-daily (e.g., hourly) to seasonally. For the seasonal comparison, summer, fall, winter, and spring were defined as July-September, October-December, January-March, and April-June, respectively. While not precisely coincident with meteorological seasons (defined by the solstices and equinoxes), these periods are consistent with previous work in the basin (Willis and Deas 2012, Willis *et al*. 2011, Jeffres *et al*. 2010), effectively capture the seasonal characteristics, and coincide with land and water use practices in the basin that typically commence April 1 and terminate September 30. Outlined below are the methods for field monitoring and results based on these observations.

Table 5. Water temperature monitoring locations, reach, and river kilometer.

Monitoring Location	Reach	River Kilometer
Below Dam (at Lake Outlet)	2	2.13
Below Headgate 1	3	1.37
Below Headgate 2	4	1.16
Below Louie Road	5	0.38
Mouth	5	~0.0

4.3.1. Methods

Water temperature field monitoring occurred primarily through the direct deployment of remote logging thermistors in the stream. HOBO® Pro v2 Water Temperature Data Loggers from Onset Computer Corporation were used to collect information at 30-minute intervals throughout at the five sampling sites. These loggers have a resolution of approximately 0.02°C (0.02°C at 25°C) and an accuracy of ±0.2°C over the range from 0°C to 40°C, and a 90% response time of 5 minutes in water (Onset 2009). Instruments were deployed consistent with protocols developed on the Nelson Ranch (Jeffres *et al.* 2008).

4.3.2. Results

Source waters from the creek are almost exclusively derived from the spring sources at the head of the system. This relatively constant creek flow at relatively constant temperature has clear implications for temporal variability at individual locations as well as longitudinal water temperature patterns from upstream to downstream.

Temporal Variability in Water Temperatures

Water temperature at discrete locations along Little Springs Creek varied with time in response to meteorological conditions. Distinct seasonal, short-term (days/weeks), and sub-daily (hourly) variations occur at each location. This section focuses on the data from July 1, 2013 to September 30, 2014, representing a summer through summer period Field data were also collected from May 1, 2013 to June 30, 2014, but it is not included in this section to avoid drawing conclusions from an incomplete season (April is missing from spring of 2013).

Below Lake Outlet (Dam) – Top of Reach 2

The below Lake Outlet (Dam) site represents the most upstream location monitored along Little Springs Creek, and is closest to the spring head. As such, water temperatures experienced a moderated signal throughout the year under the assumption that the spring sources experienced minimal changes through the year. The seasonal average temperatures ranged from 12.0°C in winter 2013 to 15.4°C in summer 2014 (Table 6). The warmest water temperatures were generally observed in summer and the coolest in winter (Figure 15). However, the coolest period of the year extends from late fall into mid-winter, and the warmest period occurred in late spring and early summer. Average seasonal diurnal range at this location ranged from 2.7°C in winter 2013 to 5.4°C in summer 2013 and 2014. The proximity of this location to the relatively constant temperature source springs tends to moderate the diurnal signal when compared to downstream locations. However, the impoundment above the dam appears to facilitate heat exchange, providing an increased residence time and surface area, resulting in a diurnal signal at this location that is most likely larger than that emanating directly from the source springs.

Absolute daily maximum temperatures ranged from 16.0°C in winter to 20.6°C in summer of 2014, while minimum temperatures ranged from 9.4°C in spring to 11.9°C in summer 2014. The absolute minimum temperatures, particularly during late fall through early spring, suggests that the lake volume is largely replaced each night by the source spring contributions. Source spring temperatures, though not measured directly, appear to be similar to those found in the adjacent Big Springs Creek watershed, which ranged from approximately 10.4°C to 11.8°C.

Table 6. Average seasonal average, maximum, minimum water temperatures, seasonal average diurnal range, and absolute maximum and minimum seasonal water tempeature for the Lake Outlet (RKM 2.13).

	Water Temperature (°C)					
	Average				Absolute	
Season	Average	Maximum	Minimum	Diurnal Range	Maximum	Minimum
Summer 2013	14.5	17.9	12.5	5.4	19.1	11.8
Fall 2013	12.5	14.5	11.4	3.1	17.4	9.7
Winter 2013	12.0	13.7	11.0	2.7	16.0	9.9
Spring 2014	14.2	16.9	12.0	4.9	19.9	9.4
Summer 2014	15.4	18.5	13.1	5.4	20.6	11.9

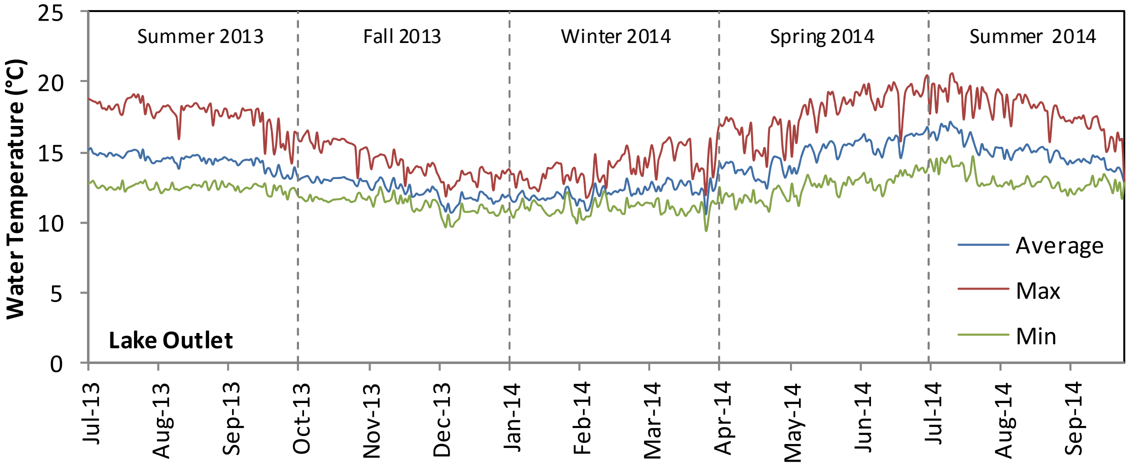


Figure 15. Daily maximum, average, and minimum water temperature on Little Springs Creek below the Lake Outlet for summer 2013 through summer 2014.

Headgate 1 – Bottom of Reach 2, Top of Reach 3

Headgate 1 is located 1.37 kilometers upstream of the mouth (0.76 kilometers downstream of the Lake Outlet). The seasonal average temperatures ranged from 11.2°C to 16.3°C (Table 7). The coolest period of the year was late fall to early winter, and the warmest period occurred in late spring and early summer. Seasonal average temperatures experience both lower and higher values than the Lake Outlet site (Figure 16), suggesting the travel time from the Lake Outlet to Headgate 1 allows waters in the warmer and cooler periods of the year to heat and cool, respectively, as waters flow through this reach. Average seasonal diurnal range at this location ranged from 3.4°C in winter 2013 to 7.3°C in summer 2013. The diurnal signal at this location was 25 to 35% larger than at the Lake Outlet.

Absolute daily maximum temperatures ranged from 16.6°C in winter to 22.8°C in summer 2013, while minimum temperatures ranged from 7.2°C in fall 2013 to 13.6°C[1] in summer 2014. As reflected in the seasonal average temperatures, absolute temperatures were highest in summer 2013 and coolest in winter 2013.

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[1] Lack of diurnal signal in late September 2014 suggest logger was partially or completely buried, moderating daily fluctuations in water temperature (See Figure 16).

Table 7. Average seasonal average, maximum, minimum water temperatures, seasonal average diurnal range, and absolute maximum and minimum seasonal water tempeature for Little Springs Creek at Headgate #1 (RKM 1.37).

	Water Temperature (°C)					
	Average				Absolute	
Season	Average	Maximum	Minimum	Diurnal Range	Maximum	Minimum
Summer 2013	16.0	20.0	12.7	7.3	22.8	11.0
Fall 2013	11.7	13.9	10.0	3.9	17.7	7.2
Winter 2013	11.2	13.2	9.8	3.4	16.6	8.3
Spring 2014	14.5	18.2	11.7	6.6	21.6	8.7
Summer 2014*	16.3	18.1	14.6	3.5	20.6	13.6

*Possible partially or completely buried logger in late September.

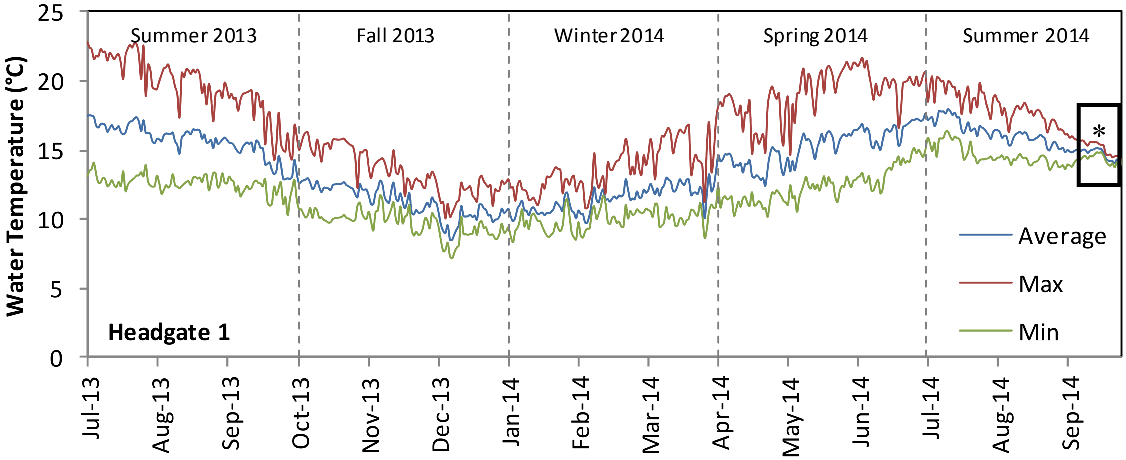

Figure 16. Daily maximum, average, and minimum water temperature on Little Springs Creek at Headgate 1 for summer 2013 through summer 2014.

Headgate 2 – Bottom of Reach 3, Top of Reach 4

Headgate 2 is located approximately 1.16 kilometers upstream of the mouth (and 0.97 kilometers downstream of the Lake Outlet). The seasonal average temperatures ranged from 11.2°C to 16.5°C (Table 8). The coolest period of the year was late fall, and the warmest period occurred in late spring and early summer (Figure 17).

Seasonal average temperatures experience both lower and higher values than the Lake Outlet site (Figure 16), but were only slightly warmer than Headgate 1, suggesting that Reach 2 experiences higher heating rates that Reach 3 (Headgate 1 to Headgate 2). Comparing Reach 2 and 3 illustrates that Reach 3 is considerably shorter, reach gradient is about 3.5 times greater, and average velocities are higher (see Figure 6). These are features that would generally lead to smaller changes in temperature in Reach 3 than in Reach 2. Average seasonal diurnal range at this location ranges from 3.5°C in winter to 6.9°C in summer 2013. The diurnal signal at this location is similar to that at Headgate 1.

Absolute daily maximum temperatures ranged from 16.7°C in winter 2013 to 22.8°C in summer of 2014, while minimum temperatures ranged from 6.8°C in fall 2013 to 11.3°C in summer 2014.

Table 8. Average seasonal average, maximum, minimum water temperatures, seasonal average diurnal range, and absolute maximum and minimum seasonal water tempeature for Little Springs Creek at Headgate 2 (RKM 1.16).

	Water Temperature (°C)					
	Average				Absolute	
Season	Average	Maximum	Minimum	Diurnal Range	Maximum	Minimum
Summer 2013	16.1	19.7	12.9	6.8	22.6	10.9
Fall 2013	11.5	13.7	9.8	3.8	17.4	6.8
Winter 2013	11.2	13.2	9.7	3.5	16.7	7.9
Spring 2014	14.6	18.5	11.5	6.9	22.0	8.6
Summer 2014	16.5	20.3	13.3	6.9	22.8	11.3

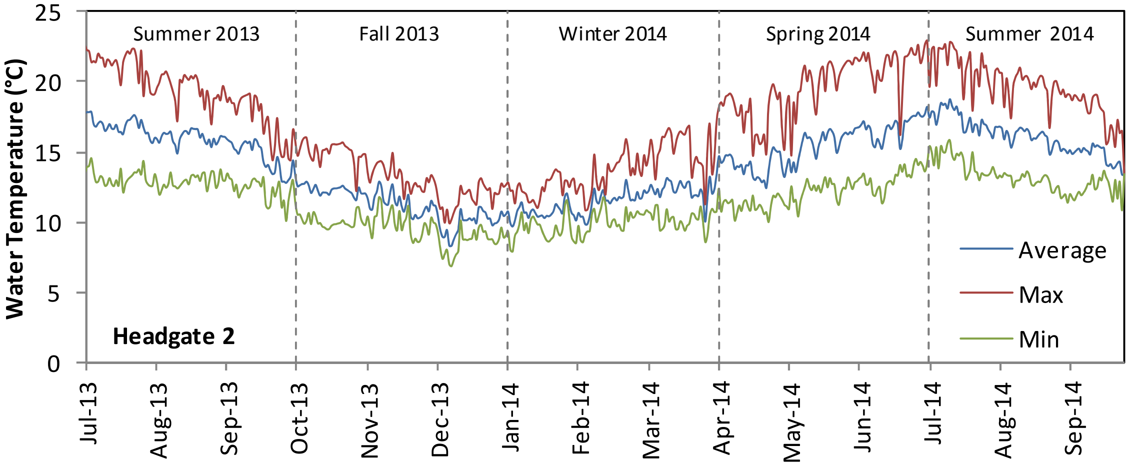

Figure 17. Daily maximum, average, and minimum water temperature on Little Springs Creek at Headgate 1 for summer 2013 through summer 2014.

Louie Road Crossing – Bottom of Reach 4, Top of Reach 5

The Louie Road crossing is located approximately 0.38 kilometers upstream of the mouth (and 1.75 kilometers downstream of the Lake Outlet). The seasonal average temperatures ranged from 10.7°C to 17.2°C (Table 9). The coolest period of the year was late fall, and the warmest period occurred from mid-spring into early summer (Figure 18). Seasonal average maximum and minimum temperatures were similar to the nearest upstream site at Headgate 2, with the exception of winter that was 0.7°C colder (winter). This reach experiences considerable vegetation growth during spring and early summer that persists into fall. This condition is evident in Reach 3 (see Figure 9), between Headgate 1 and 2. However, below Headgate 1, the creek experiences heavy seasonal vegetation growth and the channel can be heavily shaded (see Figure 10 and Figure 13), potentially reducing reach scale water temperatures during summer. Average seasonal diurnal range at this location ranges from 3.4°C in fall 2013 to 8.1°C in spring 2014. This location experiences the highest diurnal range of all reaches.

Absolute daily maximum temperatures ranged from 16.1°C in fall 2013 to 23.4°C in summer 2014, while minimum temperatures ranged from 4.9°C in winter 2013 to 11.4°C in summer 2014.

Table 9. Average seasonal average, maximum, minimum water temperatures, seasonal average diurnal range, and absolute maximum and minimum seasonal water tempeature for Little Springs Creek at the Louie Road crossing (RKM 0.38).

	Water Temperature (°C)					
	Average				Absolute	
Season	Average	Maximum	Minimum	Diurnal Range	Maximum	Minimum
Summer 2013	16.4	18.7	14.3	4.4	21.2	11.3
Fall 2013	10.7	12.4	9.0	3.4	16.1	4.9
Winter 2013	10.7	12.9	9.0	3.9	17.1	4.9
Spring 2014	14.8	19.3	11.2	8.1	23.3	7.5
Summer 2014	17.2	20.3	14.1	6.2	23.4	11.4

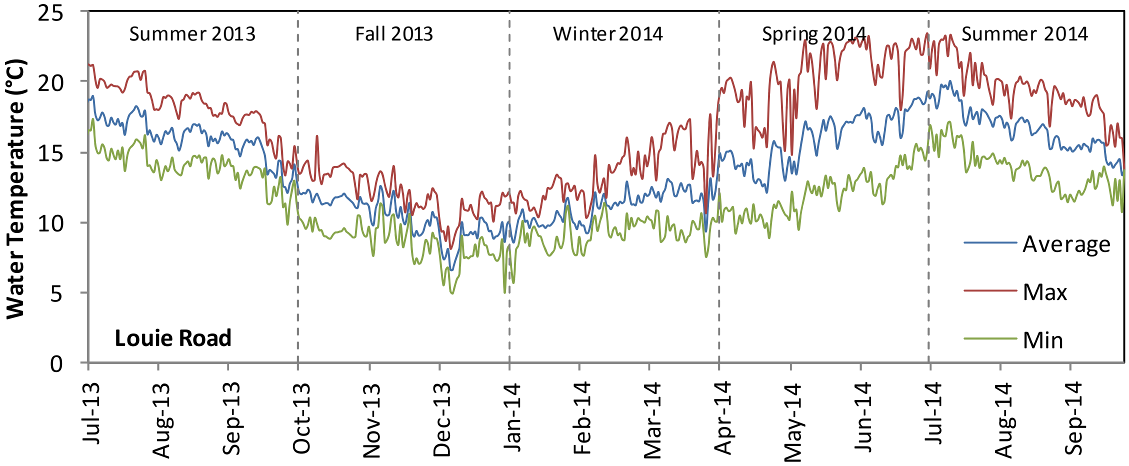

Figure 18. Daily maximum, average, and minimum water temperature on Little Springs Creek at the Louie Road crossing for summer 2013 through summer 2014.

Mouth – Bottom of Reach 5

Temperature was monitored just upstream of the confluence of Big Springs Creek and Little Springs Creek, approximately 2.13 kilometers downstream of the Lake Outlet. Channel gradient and width are steeper and narrower than in any other reach, resulting in higher velocities and shorter travel times. The seasonal average temperatures ranged from 10.4°C to 17.1°C (Table 10). The coolest period of the year was late fall, and the warmest period occurred from mid-spring into early summer (Figure 19). Seasonal average maximum and minimum temperatures were similar to the Louie Road site, with slightly cooler maximums and minimums. Average seasonal diurnal range at this location ranges from 3.3°C in fall 2013 to 6.9°C in spring 2014.

Absolute daily maximum temperatures ranged from 15.9°C in winter 2013 to 23.0°C in spring 2014, while minimum temperatures ranged from 4.4°C in fall 2013 to 13.3°C in summer 2014.

Table 10. Average seasonal average, maximum, minimum water temperatures, seasonal average diurnal range, and absolute maximum and minimum seasonal water tempeature for Little Springs Creek at the mouth.

	Water Temperature (°C)					
	Average				Absolute	
Season	Average	Maximum	Minimum	Diurnal Range	Maximum	Minimum
Summer 2013	16.4	18.6	14.3	4.3	21.5	11.3
Fall 2013	10.5	12.1	8.8	3.3	15.9	4.4
Winter 2013	10.4	12.6	8.7	3.9	17.0	5.2
Spring 2014	14.8	18.5	11.6	6.9	23.0	7.8
Summer 2014	17.1	19.0	15.2	3.8	22.5	13.3

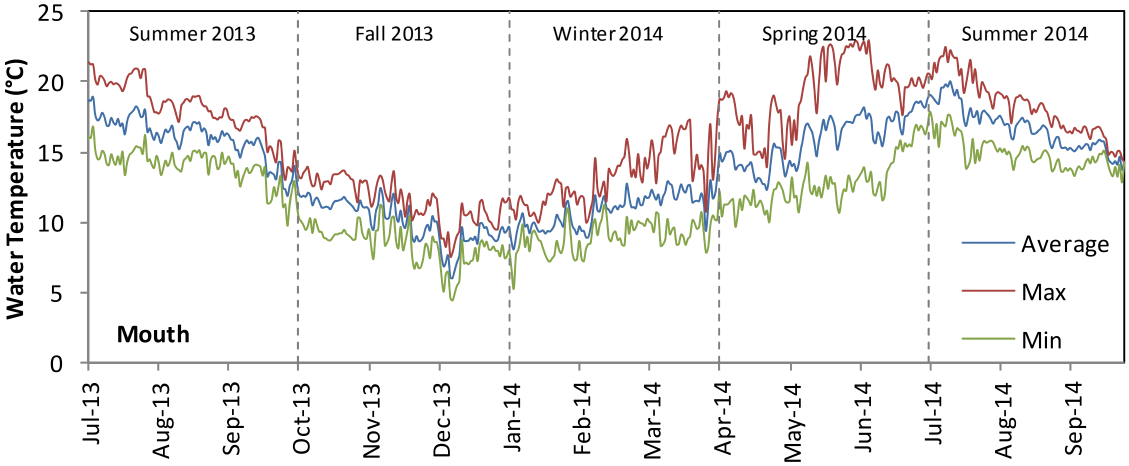

Figure 19. Daily maximum, average, and minimum water temperature on Little Springs Creek at the mouth for summer 2013 through summer 2014.

Annual Variability: Late Spring and Summer Comparison

As noted above, monitoring occurred from May 1, 2013 through September 30, 2014, providing an overlap of five months (Figure 20) among the two different years that allowed an inter annual comparison. Plotting the average daily and maximum daily water temperatures at the site below the Lake Outlet and the Mouth (Figure 20 and Figure 21, respectively) indicate that daily average water temperature below the Lake Outlet was notably warmer in 2014 (approximately 1 to 2°C) from mid-May through August, and maximum daily water temperature was generally warmer through this period as well. However, at the Mouth, daily average temperatures, while warmer in 2014, were not consistently greater than 2013. Further, maximum daily temperatures were remarkably warmer in the spring of 2014 (up to 4°C), and then were similar to 2013 temperatures from mid-July through September.

Air temperature at Big Springs Ranch was examined (Figure 22), and while there were short duration differences, the data did not indicate systematic differences between 2013 and 2014 (solar radiation, wind, and relative humidity were also examined with modest difference among the two years). In general, both years were similar: average, maximum, and minimum air temperature for May through September 2013 were 18.6°C, 38.7°C, and -2.1°C, respectively; for May through September 2014, average, maximum, and minimum air temperatures were 18.9°C, 38.3°C, and -1.6°C, respectively. Other factors appear to have played a role in the different temperature regimes and may include different source spring flow rates or temperatures, different vegetation and hydraulic conditions associated with ongoing recovery of the creek, or other factors.

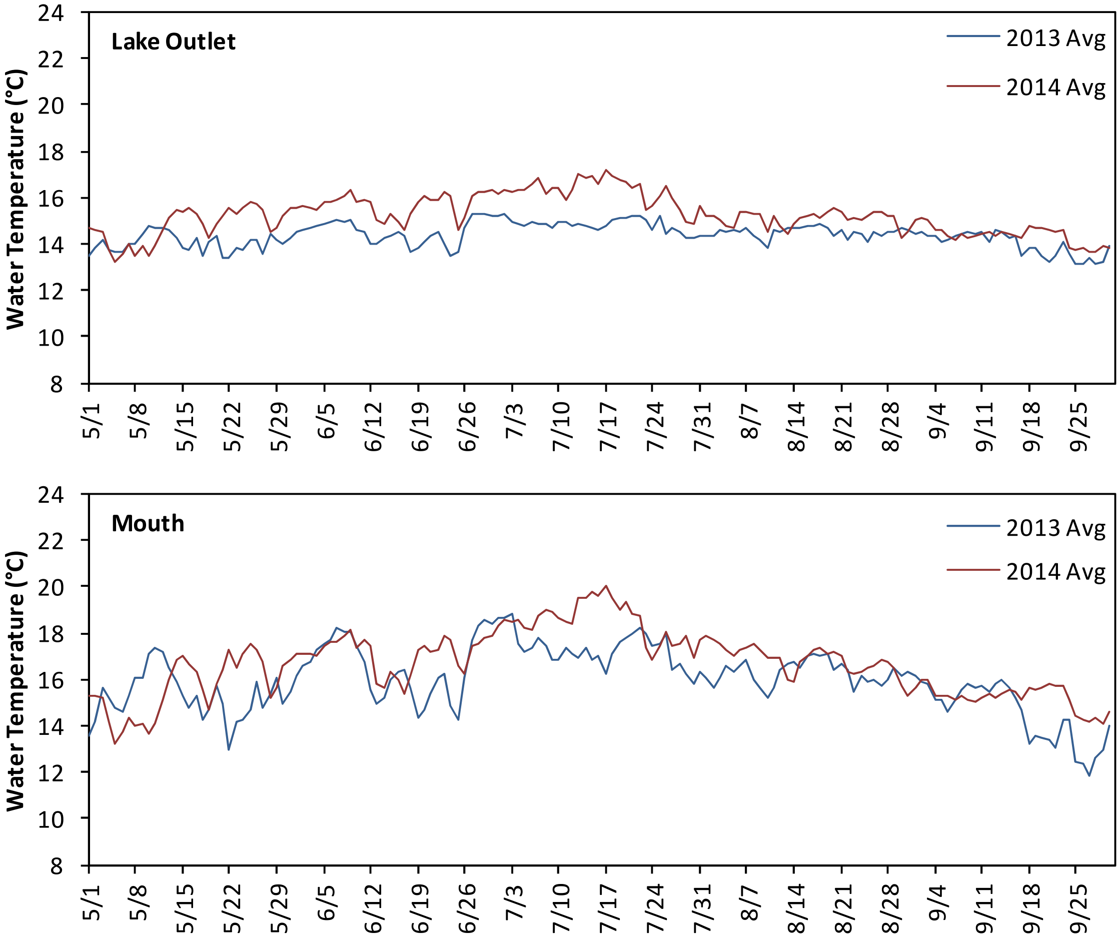

Figure 20. Daily average water temperature below the Lake Outlet (top) and at the Mouth (bottom) in Little Springs Creek, May through September: 2013 and 2014.

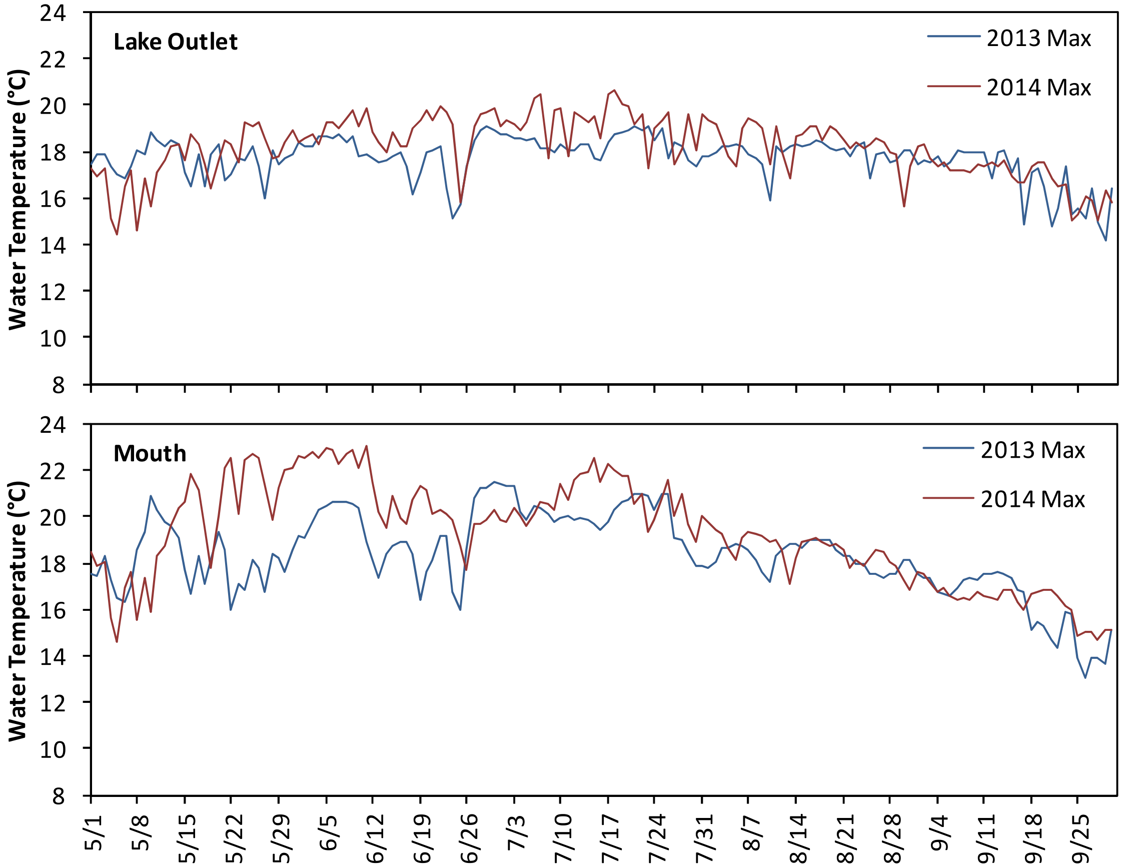

Figure 21. Daily maximum water temperature below the Lake Outlet (top) and at the Mouth (bottom) in Little Springs Creek, May through September: 2013 and 2014.

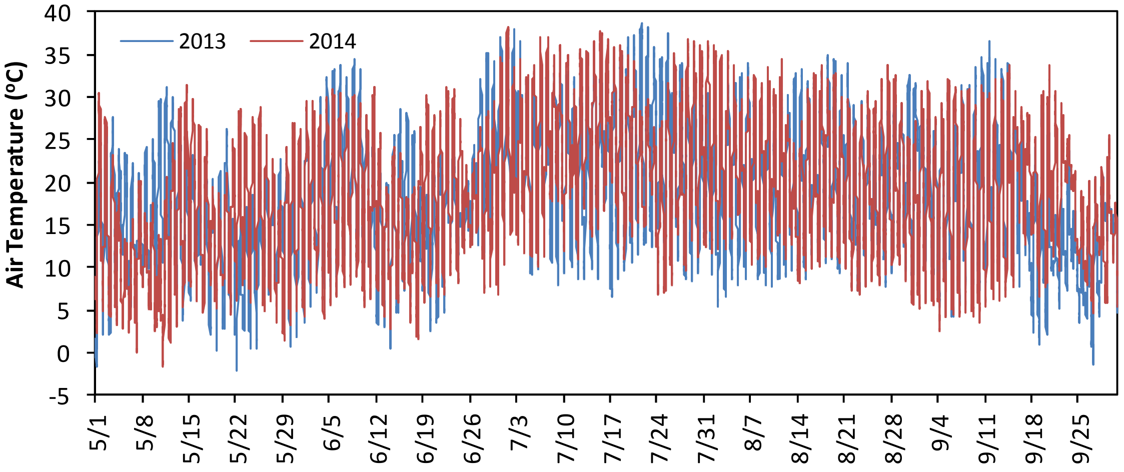

Figure 22. Hourly air temperature on Shasta Big Springs Ranch, May through September: 2013 and 2014.

Longitudinal Variability Little Springs Creek

The longitudinal temperature assessment explored changes in temperature from upstream to downstream at multiple locations between the Lake Outlet and the confluence with Big Springs Creek. Daily average water temperatures at the five monitoring locations are shown for the period July 2013 through September 2014 (Figure 23). Little Springs Creek blow the Lake Outlet is typically the coolest location during spring and summer and the warmest in fall and winter. In general, as water flows further downstream from the Lake Outlet, water temperatures increase in spring and summer and decrease in fall and winter (i.e., with increasing distance from the relatively constant source springs, water temperatures warm during the spring and summer, and cool during fall and winter). There are two periods of the year when the creek does not exhibit appreciable longitudinal heat gain or loss: near the vernal and autumnal equinoxes. This is illustrated by the intersection of the below Lake Outlet temperature trace and the downstream temperature traces, which occurs in late-September and late-March (Figure 23).

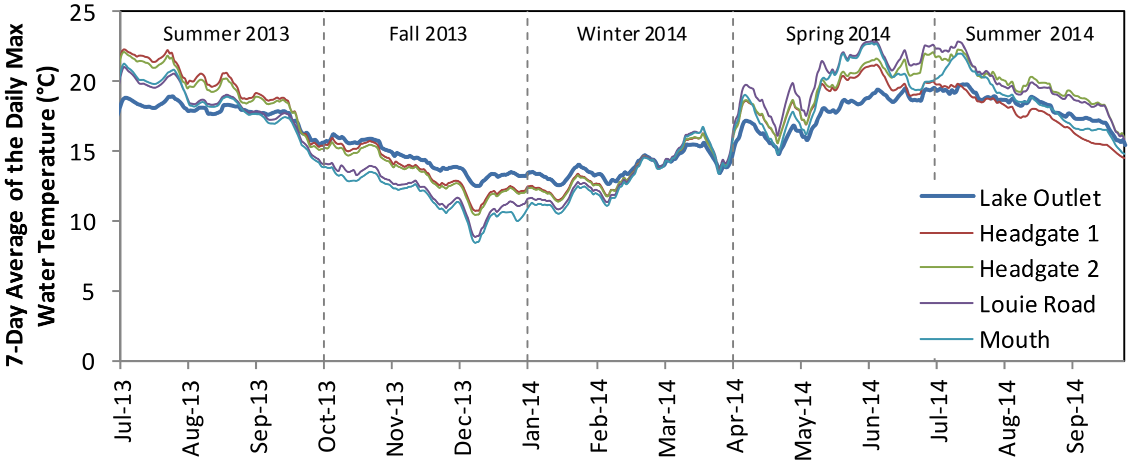

Figure 23. Summer 2013 through summer 2014 seven-day average of the daily maximum water temperature at the five monitoring locations in Little Springs Creek.

Longitudinal conditions were also presented using daily average temperatures at the 1st and 15th of the month throughout any given season. While single days can misrepresent seasonal conditions due to short term anomalous meteorological conditions, this suite of bimonthly plots represents a sufficient number of days to illustrate not only the general seasonal longitudinal trends, but also provides insight into changes through an individual season. These profiles are shown for the summer 2013 through summer 2014 seasons in Figure 24, where Little Springs Creek water temperatures are represented from upstream to downstream with the below Lake Outlet site on the right and the mouth on the left.

During summer 2013, all profiles show heating in the downstream direction, with the highest rate of heating in July. The profile from September 15 shows the lowest rate of heating as this date is near the autumnal equinox. These data also suggest that the highest heating rates occur in the upper reaches, where the stream is furthest from equilibrium temperature[2]. During summer, water temperature from Louie Road to the mouth indicate little or no heating, and may even cool slightly as the creek drops into a higher gradient, narrow, and seasonally well-shaded channel.

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[2] Equilibrium temperature refers to the unique water temperature that is in “equilibrium” meteorological conditions. This is a theoretical temperature because meteorological conditions are constantly changing. Nonetheless, on a daily average basis (or other appropriate time scale) this concept is useful for interpreting temperature data.

During fall 2013, the profile for October 1 is practically flat, indicating no appreciable heating in the downstream direction. Subsequently, all profiles indicate fairly uniform cooling throughout the reach, with the most rapid cooling occurring on December 15.

During winter 2014, the longitudinal temperature profiles all indicate cooling with distance downstream from the source springs. January 1 has the highest cooling rate. From January 15 to March 15, the cooling rates are less, and March 15 has almost no cooling due to being near the vernal equinox.

During spring 2014, all profiles indicate heating with distance from the source springs downstream after April 1, while April 1 suggests no appreciable heating longitudinally in the creek. Heating rates appear to be fairly uniform along the creek for much of spring. In June reach 5 begins to take on summer period characteristics of little or no heating.

Finally, summer 2014 is similar to 2013 with all profiles indicating downstream heating. From Louie Road to the mouth, temperatures indicate little or no heating, and may even cool slightly as the creek drops into a higher gradient, narrow, seasonally well-shaded channel.

These profiles indicate that the approximately constant water temperature source springs provide relatively cooler water to the creek in summer, relatively warmer water to the creek in winter, and have minimal effect during the periods roughly coincident with the vernal and autumnal equinoxes. Further, within the any particular season, water temperature conditions are not constant, but rather transition from one state to another (i.e., warmer to cooler from summer to winter and vice versa for winter to summer) through the year.

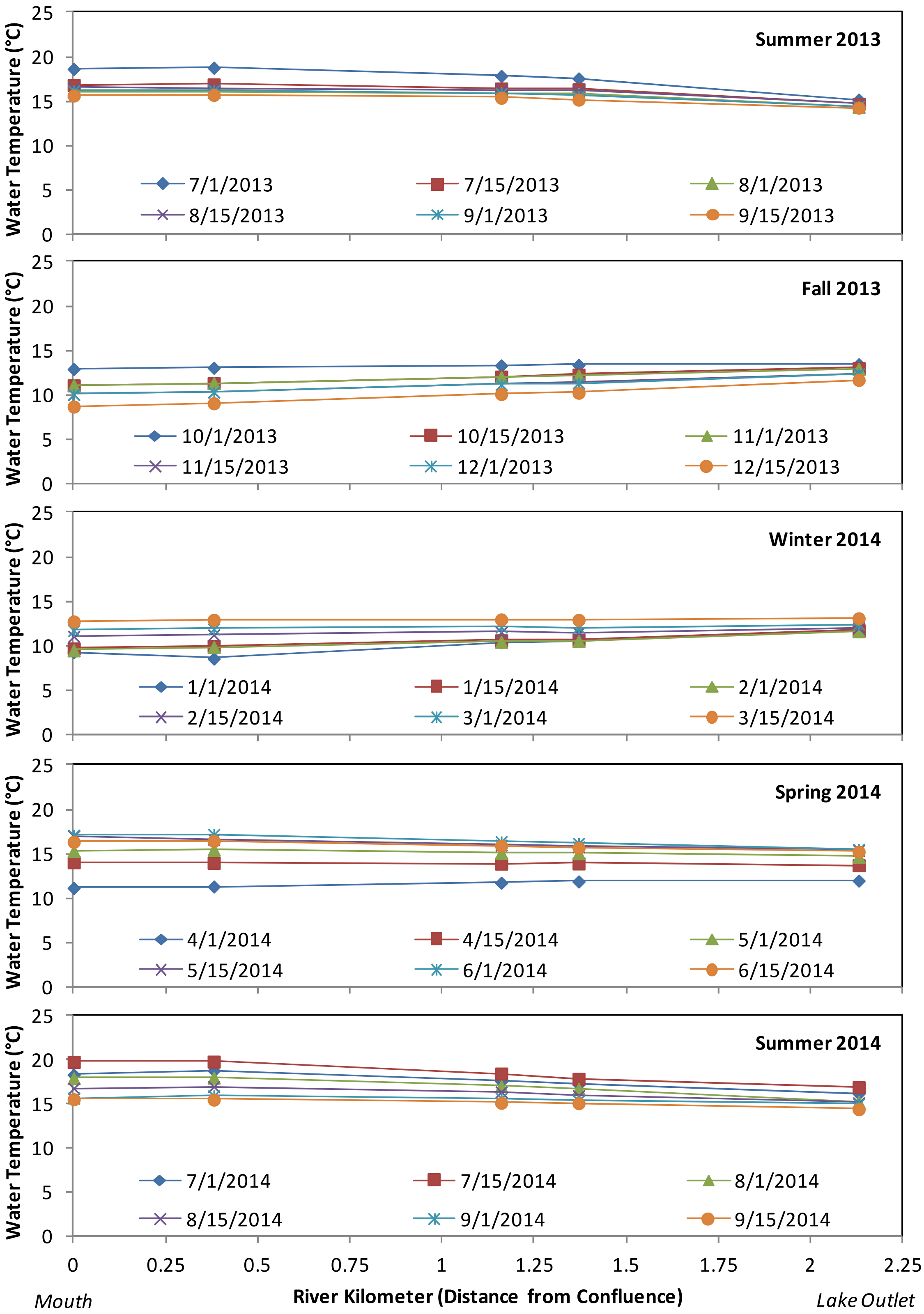

Figure 24. Longitudinal daily average water temperature profiles from the Lake Outlet to the, with profiles for the 1st and 15th of each month within the season for summer 2013 through summer 2014.

4.4. Aquatic Macrophytes

The seasonal growth and senescence of aquatic macrophytes can have profound effects on channel hydraulics in lotic waterways (e.g., Champion and Tanner 2000). Furthermore, aquatic macrophytes provide important ecosystem services such as shading from solar radiation loads, habitat for aquatic macroinvertebrates, and overhead cover and velocity refuge for fishes. Aquatic macrophytes were sampled in Little Springs Creek to assess seasonal variations in macrophyte biomass.

4.4.1. Methods

Aquatic macrophytes were harvested from three wadeable locations along Little Springs Creek in September 2013, March 2014 and June 2014. Sampling locations are identified in Table 11 and on Figure 1.

Table 11. Macrophyte sampling locations, abbreviation, and reach

Location	Abbreviation	Reach
Little Springs Creek below Headgate 1	LSC Below HG1	Reach 3
Little Springs Creek above Louie Road	LSC Above Louie Rd	Reach 4
Little Springs Creek below Louie Road	LSC Below Louie Rd	Reach 5

All macrophyte biomass above the streambed was harvested from within a 0.37 m^2 sampling quadrat randomly placed at six replicate locations along a 100 m channel reach. Selected locations that contained perennial emergent aquatic vegetation (e.g., tules and sedges) were discarded, and thus only locations containing seasonally emergent macrophytes during the sample collection effort were used. Individual samples were placed in labeled bags prior to transport to the analytical laboratory[3]. Samples were dried to a constant mass at 65°C for over 72 hours and subsequently weighed. Dried samples were ashed in a muffle furnace for 4 hours at 475°C, cooled to a constant mass, and reweighed to derive ash-free dry mass (AFDM). Mean AFDM (g AFDM m^{-2}) is reported for each seasonal sample location.

4.4.2. Results

Macrophyte standing crop in Little Springs Creek exhibited seasonal patterns at all locations (Figure 25). Standing crop in Little Springs Creek above Louie Road and below Headgate 1 were highest in September 2013 (Table 12 and Figure 25), while the highest standing crop in Little Springs Creek below Louie Road was observed in June 2014 (Table 12 and Figure 25). The lowest standing crop for all sites was observed in March 2014 following winter senescence. Mean standing crop below Headgate 1 and above Louie Road sites decreased by 77% and 99% (Table 12), respectively, between September 2013 and March 2014. Mean standing crop below Louie Road site decreased by 27% (Table 12) across the same September to March period. Seasonal patterns of macrophyte growth (spring and summer) and senescence (fall and winter) in Little Springs Creek are similar to observations of macrophyte growth patterns in Big Springs Creek and the upper Shasta River in the region of Big Springs Creek.

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[3] Soil Biogeochemistry Laboratory in Land Air and Water Resources Department and the Center for Watershed Sciences at the University of California, Davis;

Table 12. Maximum and minimum macrophyte ADFM by site.

Site[1]	Maximum		Minimum		Percent Change from Max to Min (%)
	AFDM (g AFDM m^{-2})	Date	AFDM (g AFDM m^{-2})	Date	
Below Headgate 1	259.3±154.4	September 2013	60.3±34.3	March 2014	-77
Above Louie Road	260.8±65.9	September 2013	0.15±0.15	March 2014	-99
Below Louie Road	178.6±41.2	June 2014	98.8±56.2	March 2014	-27

[1]Sample size (*n*) is 6.

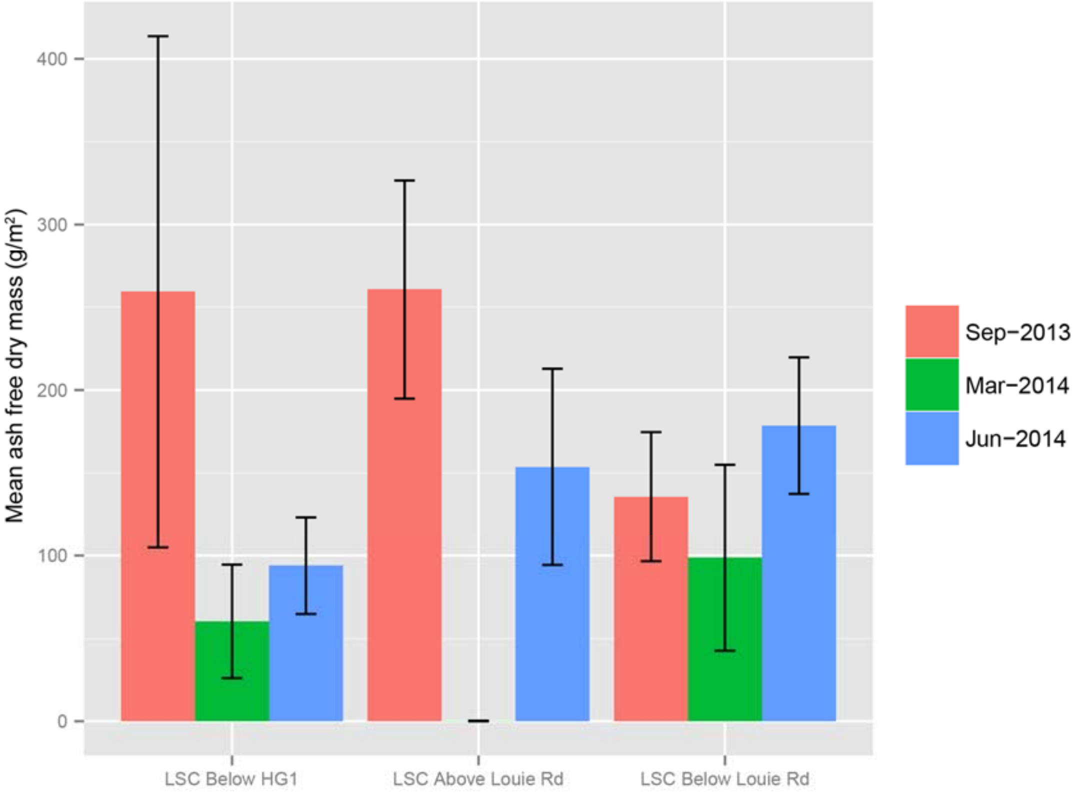

Figure 25. Mean standing crop (g AFDM m^{-2}) of aquatic macrophytes at three sampling locations for each seasonal sampling period. Bars represent the mean ± sample error of 6 replicate samples.

4.4.3. Summary

Aquatic macrophytes are observed throughout Little Springs Creek, particularly downstream from Headgate 1 (Reaches 3 through 5). Increased channel depths upstream from Headgate 1 may limit macrophyte growth in Reaches 1 and 2. Seasonal patterns of macrophyte growth and senescence occur throughout Little Springs Creek, with maximum and minimum biomass generally observed in the summer and winter, respectively. Aquatic macrophytes proliferate along mid-channel areas of Little Springs Creek, while tule and sedges dominate the vegetation assemblages on the channel margins.

4.5. Macroinvertebrates

Macroinvertebrates are macroscopic aquatic organisms that lack a backbone, and include organisms such as crustaceans, mollusks, worms, and aquatic insects. Benthic macroinvertebrates serve as an important part of aquatic food webs, and are often useful as an indicator of the aquatic ecosystem health. Densities (total and relative), diversity, richness, sensitive and tolerant taxa, functional feeding groups and other metrics are used to assess water quality, food availability, or other habitat conditions in streams and rivers.

4.5.1. Methods

Benthic macroinvertebrates were sampled at three locations in Little Springs Creek using a modified Hess sampler (Figure 1). Reach three was sampled below Headgate 1 (LS-HG1), Reach 4 was sampled above Louie Road (LS-ALR), and Reach 5 was sampled below Louie Road (LS-BLR). Reach 3 and 4 generally exhibited slow water velocities and high sediment deposits, while Reach 5 exhibited faster water velocities and sediment deposits more comparable to Big Springs Creek. The sites were sampled in August 2013, March 2014, and June 2014. Transects of three composited 1-minute Hess samples were taken at each reach and replicated three times (*n*=3), totaling 9 samples per sampling period. Preserved invertebrate samples were stored in 95 percent ethanol, and processed at the U.C. Davis Center for Watershed Sciences.

Samples were processed in lab under a dissecting microscope. Due to time constraints, only one June 2014 replicate was processed for each site. Replicates were sub-sampled with a Folsom splitter such that a minimum of 500 invertebrates were extracted per replicate. Sub-sampled invertebrates were then identified to genus (or to the lowest taxon possible) and quantified using a suite of common metrics that help describe macroinvertebrate communities and their respective habitats by location and season. A description of these metrics is provided in Table 13. The last five metrics in the table are calculated for completeness and are used to assist in interpretation of the other metrics or general interest to research scientists that may find these informative. For example, the “traditional” 4 functional feeding groups that generally interest stream ecologists are included, as is a percent non-insect taxa indicator metric for which higher values generally indicate higher disturbance conditions.

Table 13. Macroinvertebrate metrics, metric group, and general descriptions.

Macroinvertebrate Metric	Metric Group	Metric Description
Density (Organisms/m^2)	Density	Average number of individual organisms per square meter. Calculated as total densities and those for influential taxa.
Functional Feeding Groups	Functional Feeding	Relative Densities of 7 functional feeding groups: Scrapers, Shredders, Collector-Gatherers, Collector-Filterers, Piercer-Herbivores, Detritivore-Scavengers, and Predators.
Taxonomic Richness	Richness/ Diversity	The number of taxa per sample is a measure of richness. The more taxa present, the richer (more diverse) the sample.
Simpson's Evenness	Richness/ Diversity	Evenness is a measure of the relative abundance of the different species making up the richness of a sample. Calculated as taxonomic diversity weighted by relative abundances: SEI=(1-D); $D = \sum(n / N)^2$; where n = number of organisms of a particular species and N = total number of organisms of all species. SEI is the probability that two randomly selected organisms will belong to different taxa. Values range from 0 (least diverse) to 1 (most diverse).
Percent EPT Taxa	Indicator	Percent taxa representative of the orders Ephemeroptera, Plecoptera, and Trichoptera. Streams with good water quality tend to have a high proportion of these orders present.
Percent Sensitive Taxa	Indicator	Percent of taxa with sensitivity values of 0, 1, and 2. Values are ranked 0-10, with "0" representing extreme sensitivity to organic pollution and "10" representing extreme tolerance to organic pollution. High proportions of sensitive taxa indicate good water quality. Assemblage based index, utilizing only presence/absence information (vs. density).
Percent Tolerant Taxa	Indicator	Percent of taxa with tolerance values of 8, 9, and 10. Values are ranked 0-10, with "0" representing extreme sensitivity to organic pollution and "10" representing extreme tolerance to organic pollution. High proportions of tolerant taxa indicate poor water quality. Assemblage based index, utilizing only presence/absence information (vs. density).
Percent Collector Taxa	Functional Feeding	Percent taxa that process fine particulate organic matter (FPOM) via gathering or filtering.
Percent Predator Taxa	Functional Feeding	Percent taxa that consume other macroinvertebrates.
Percent Scraper Taxa	Functional Feeding	Percent taxa that specialize on rock surface epilithon.
Percent Shredder Taxa	Functional Feeding	Percent taxa that process coarse particulate organic matter (CPOM).
Percent Non-Insect Taxa	Indicator	Percent macroinvertebrate taxa that are not insects. Streams with high disturbance are expected to have higher percentages of non-insect taxa.

4.5.2. Results

The suite of macroinvertebrate metrics employed used either density or richness (or both) in their calculations. Density metrics refer to the average number of organisms calculated to occupy a square meter in the stream bed, while richness refers to the number of taxa present. Evenness is a measure of the relative abundance of the different species making up the richness of a sample. As many of the metrics used are related to one another, we present them in the following four groups (Table 13):

- Densities (including total density and the densities of influential taxa),
- Functional feeding groups,

- Richness and diversity (including total richness and evenness), and
- Indicator metrics (including percent sensitive taxa, percent tolerant taxa, and percent EPT).

Densities

Macroinvertebrate densities were highest above Louie Road (LS-ALR), peaking in June of 2014 at approximately 70,000 organisms/m^2. Densities were lowest below Headgate 1 (LS-HG1) with approximately 8,600 organisms/m^2 in March of 2014. With exception of the above Louie Road site density in June (LS-ALR), there seemed to be an overall downstream gradient of increasing macroinvertebrate density, with highest overall productivity in early summer (Figure 26).

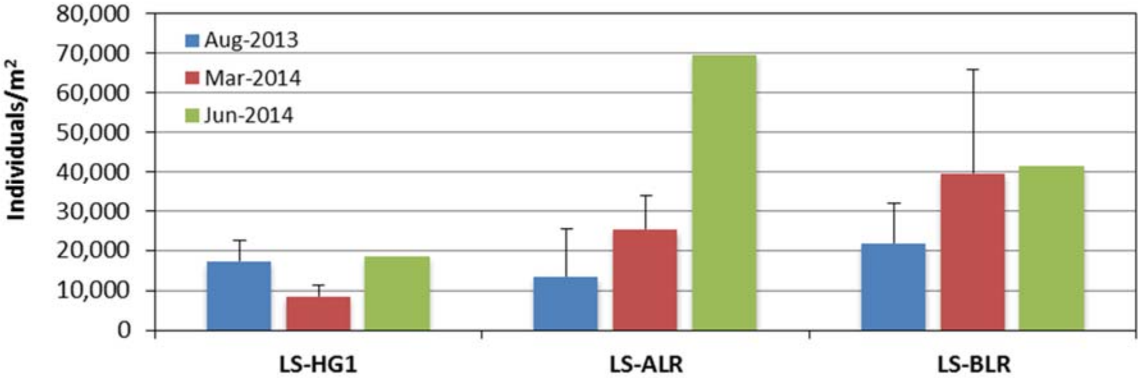

Figure 26. Seasonal macroinvertebrates densities of Little Springs Creek.

Overall density was higher at the beginning of the growing season (March 2014) compared to the annual maximum macrophyte biomass of the previous year (August 2013). This pattern seemed to be largely influenced by the disproportionally high densities of the amphipod *Hyalella azteca* (Figure 27) and of Chironomid midges (Figure 28). *H. azteca* was the most prevalent species found in the samples, and densities did not appear to correlated with macrophyte density. The highest densities of *H. azteca* occurred in March of 2014 at the downstream reach (LS-BLR), averaging 23,000 organisms/m^2, despite the seasonally lowest macrophyte biomass. These amphipods were absent from the middle reach (LS-ALR) in August 2013, despite annual peak macrophyte biomass at the same time. The inconsistency of *H. azteca* density trends across sites and sampling periods suggests that the densities were not seasonally dependent. Their densities were more likely affected by reach specific parameters, such as change in localized channel hydraulics (e.g., effects of diversion structures (culverts) and macrophyte growth) and possibly by predation. On the other hand, Chironomid densities appeared to be seasonally dependent, as their densities across all sites were highest in June 2014, with a maximum of approximately 31,600 organisms/m^2 in the middle reach (LS-ALR). However, their densities were also lowest at all sites in August 2013, despite high macrophyte biomass. Chironomids numbers in the samples may be influenced by seasonal life stage or interactions with other biota such as predation. The combined influences of the early proliferation and decline of larval chironomid densities, and the seasonally sporadic patterns of *H. azteca* densities could account for higher total densities in early spring and lower densities in late summer.

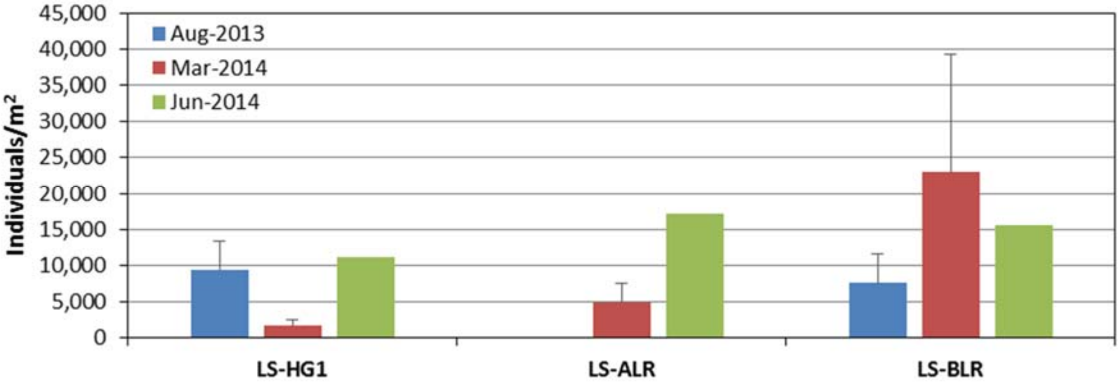

Figure 27. Seasonal densities of *Hyalella Azteca* in Little Springs Creek

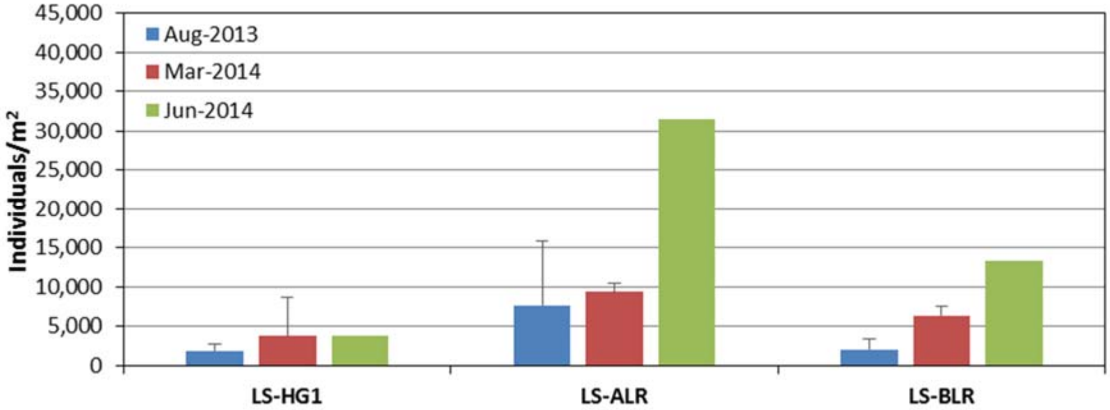

Figure 28. Seasonal densities of Chironomid midges in Little Springs Creek.

Functional Feeding Groups

Collector/Gatherers and Detritivore/Scavengers were the dominant functional feeding groups in the Little Springs Creek for all sites and sampling periods (Figure 29). In contrast, specialized functional feeding groups, such as shredders, scrapers, and collector/filterers had relatively low densities. This pattern is consistent with the dominance of Amphipods and Chironomids, noted above, which are representative of Detritivore/Scavengers and Collector/Gatherers, respectively. Also, the criteria of these two functional groups are less specific than the other groups, and therefore include more generalist taxa with diets that overlap with other functional groups. Due to the high density of generalist species throughout the stream, it is difficult to determine the relative importance of key food sources (feeding groups). Amphipods, for instance, are opportunistic taxa that feed on filamentous algae and diatoms as well as on dead plant and animal tissue (Hargrave 1970; Macneil *et al*. 2000). The range in diet of these dominant taxa, makes it challenging to pinpoint whether fine particulate organic matter (FPOM), coarse particulate organic matter (CPOM), or epilithon are the prime sources of invertebrate production in this stream. A future study on epilithon and particulate organic matter at these reaches would provide insight on which food sources are readily available to macroinvertebrates.

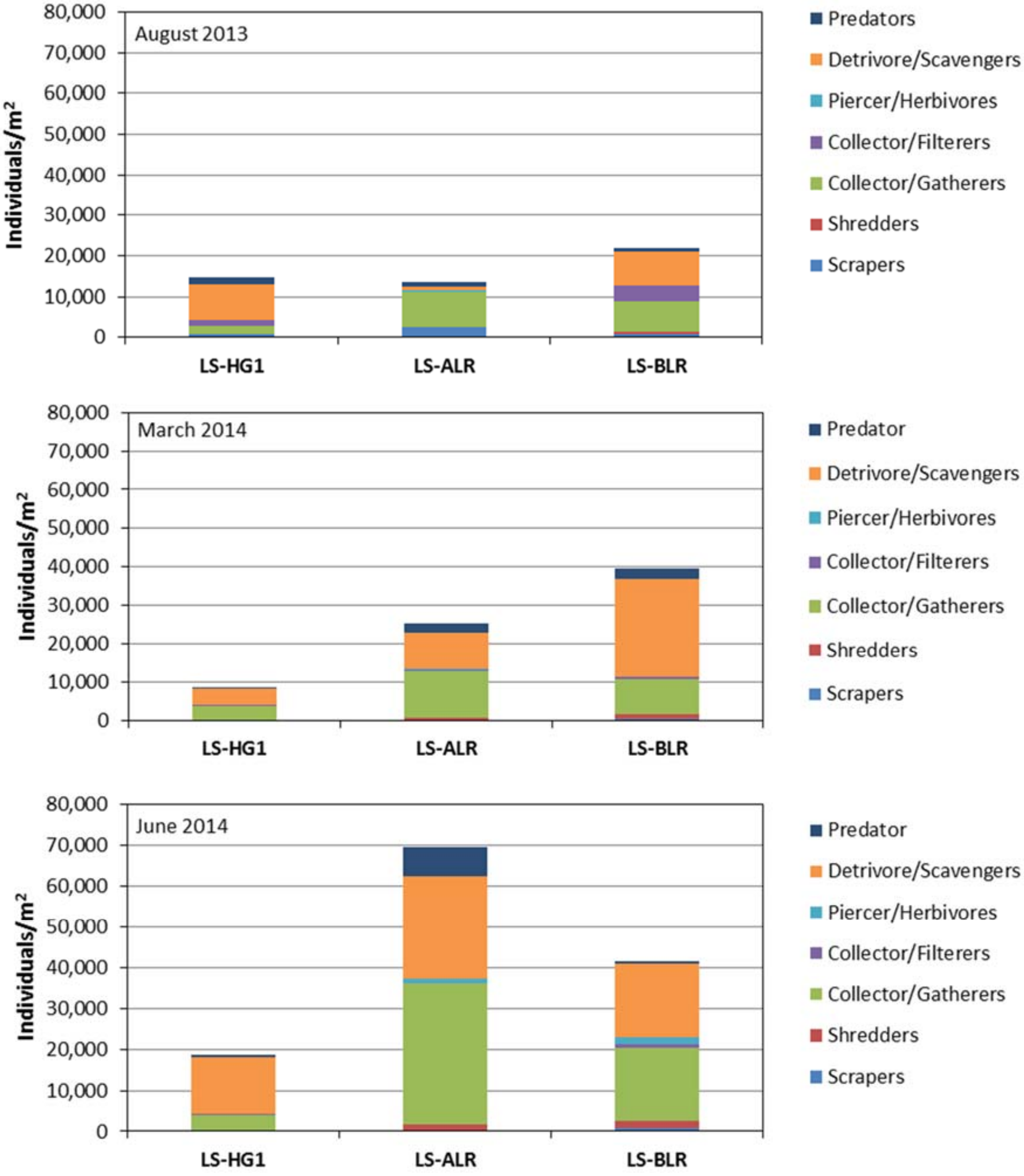

Figure 29. Densities of functional feeding groups in Little Springs Creek for August 2013 (top), March 2014 (middle) and June 2014 (bottom).

Richness and Evenness

Little Springs Creek exhibited an overall downstream trend of increasing taxonomic richness. Taxonomic richness was lowest at LS-HG1 (10 taxa) in March 2014 and was highest at LS-BLR (26 taxa) in August of 2013. The uppermost sample reach experienced the most inter-seasonal variation, with twice as many taxa in August 2013 as in March 2014 (Figure 30).

Evenness followed a similar trend, with a relatively low Simpson's evenness value of 0.59 at Reach 3 in June of 2014, and a high value of 0.83 at Reach 5 in August of 2013 (Figure 31).

The relatively low diversity and evenness at Reach 3 is indicative of lower ecological stability and stable flow and temperature conditions in this spring creek. In August 2013, LS-BLR and LS-ALR only shared about 32% of their combined taxonomic assemblage (Figure 32), despite only being 0.3 kilometers apart . Many of the genera restricted below the culvert tended to have strong lotic affinities (e.g. *Argia sp*), while many of those restricted above tended to have strong lentic affinities (e.g. *Callibaetis sp*) (Merritt *et al*. 2008).

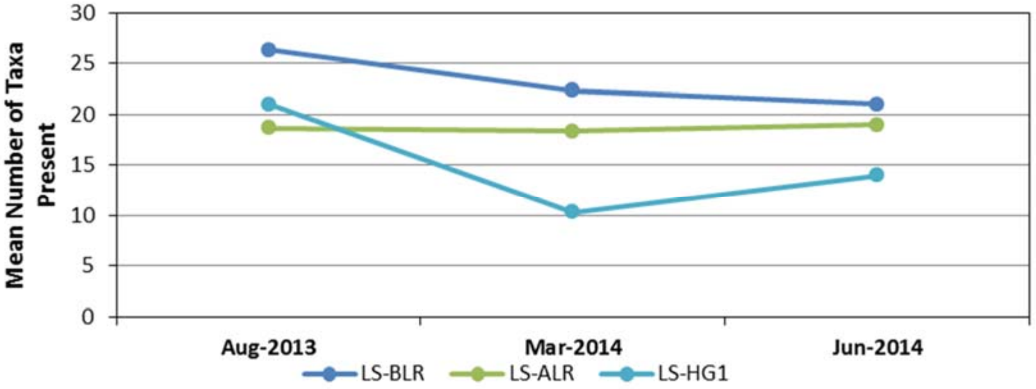

Figure 30. Seasonal taxa richness for Little Springs Creek at all sampling locations.

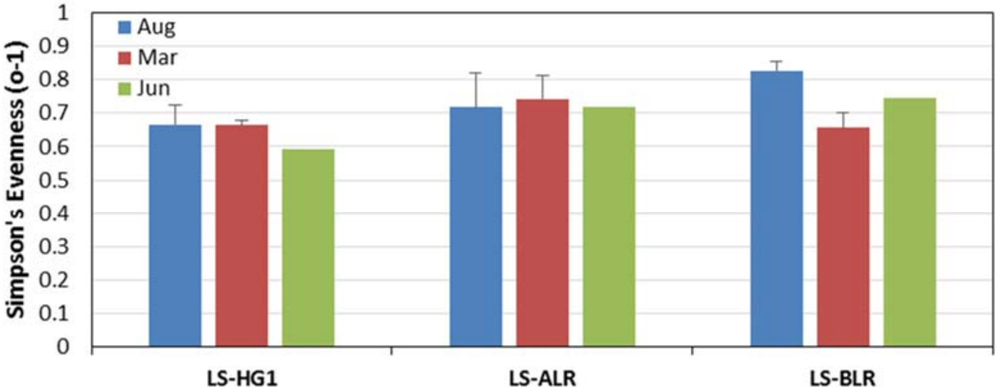

Figure 31. Simpson's evenness for Little Springs Creek at all sampling locations.

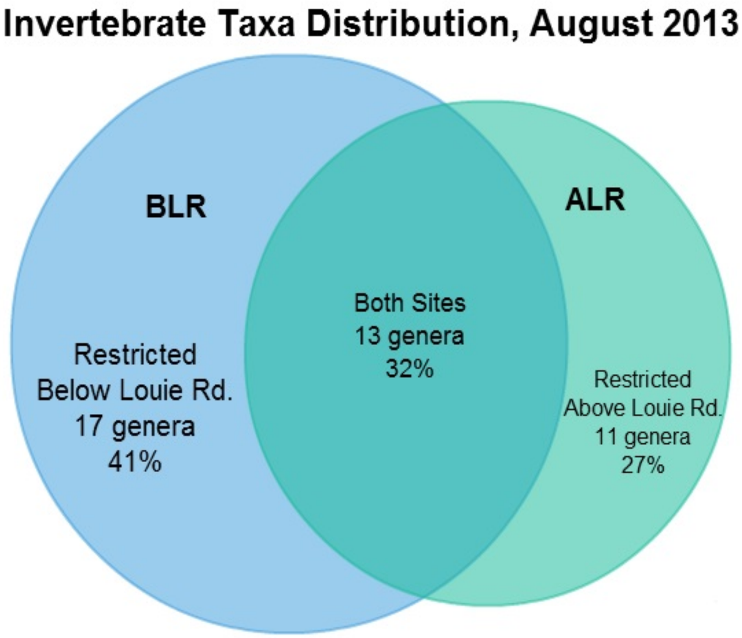

Figure 32. Venn Diagram highlighting percent taxa shared between Little Springs Creek below and above Louie Road. Size of circles represents richness at each site.

Indicator Metrics

The indicator metrics used herein include the percent EPT, sensitive, and insensitive taxa (Figure 33). Percent EPT was highest in the lower reaches of the stream (up to 50.3%). There was relatively little seasonal variation of EPT within any given reach, but differences were high between reaches. The differences in EPT are likely explained by the differences in hydraulic conditions between the sampling sites. The upper two sites have lower gradient, slower moving water and the lowest site has higher gradient faster moving water. The habitat in the lowest reach was the type of habitat where higher percentages of EPT would be expected to be found.

Sensitive taxa (those with tolerance values of 0, 1, or 2) represented up to 25.4% of the taxonomic assemblages of the lower reach (LS-BLR) while representing 7% in the upper reach (LS-BD). During August 2013 and March 2014, there were no sensitive taxa present at LS-BD. In contrast, tolerant taxa (those with tolerance values of 8, 9, or 10) were more prevalent in the two upper reaches (LS-ALR and LS-BD), with a maximum of up to 39.3% in August 2013 (Figure 34).

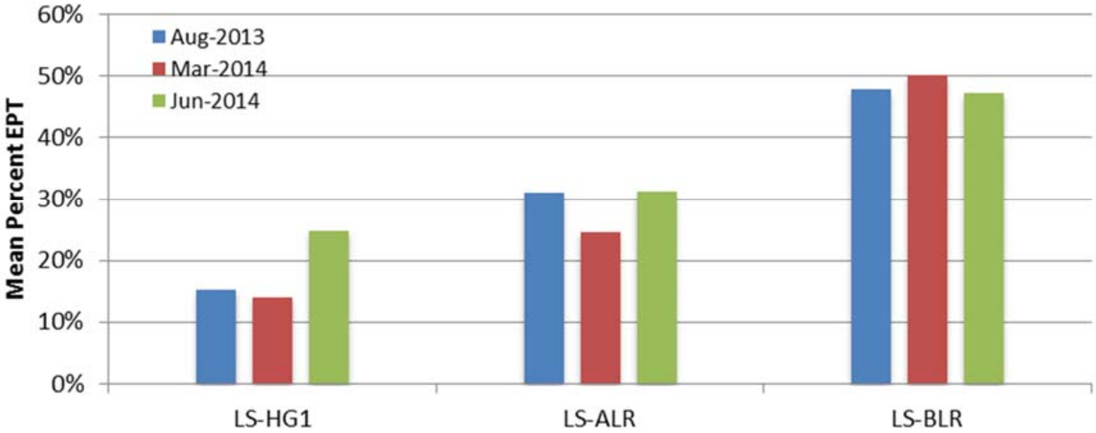

Figure 33. Little Springs Creek seasonal percentages of EPT.

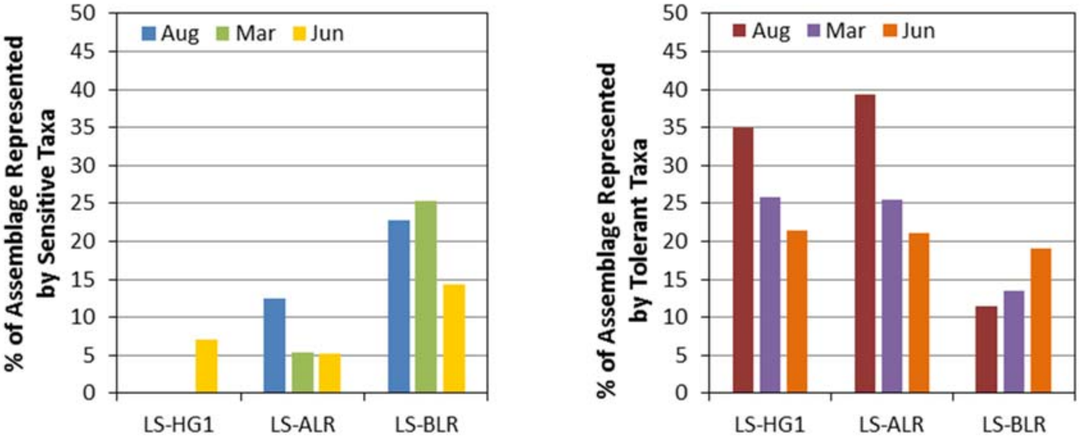

Figure 34. Little Springs Creek seasonal percentages of sensitive (left) and tolerant taxa (right).

Table 14. Mean values of Little Springs macroinvertebrate metrics for each site and sampling period. Percent values presented for indicator metrics and functional feeding groups refer to percentage of the total taxa present (i.e. taxonomic richness) during a sample period.

August, 2013			
Macroinvertebrate Metric	**LS-HG1**	**LS-ALR**	**LS-BLR**
Density (organisms/m^2)	17,186	13,350	21,833
Taxonomic Richness	21	19	26
Simpson’s evenness	0.67	0.72	0.83
Percent EPT	15.29%	31.23%	47.9%
Percent Sensitive Taxa	0%	12.5%	22.78%
Percent Tolerant Taxa	34.92%	39.29%	11.39%
Percent Collector Taxa	42.86%	44.64%	51.90%
Percent Predator Taxa	28.57%	25%	13.92%
Percent Scraper Taxa	14.29%	19.64%	18.99%
Percent Shredder Taxa	11.11%	10.71%	13.92%
Percent Non-Insect Taxa	55.56%	37.5%	27.85%
March, 2014			
Macroinvertebrate Metric	LS-HG1	LS-ALR	LS-BLR
Density (organisms/m^2)	8,613	25,424	39,520
Taxonomic Richness	10	18	22
Simpson’s evenness	0.66	0.74	0.66
Percent EPT	14.07%	24.63%	50.32%
Percent Sensitive Taxa	0%	5.45%	25.37%
Percent Tolerant Taxa	25.81%	25.45%	13.43%
Percent Collector Taxa	64.52%	41.82%	50.75%
Percent Predator Taxa	22.58%	30.91%	19.40%
Percent Scraper Taxa	9.68%	9.09%	13.43%
Percent Shredder Taxa	3.23%	16.36%	16.41%
Percent Non-Insect Taxa	61.29%	41.82%	31.34%
June, 2014			
Macroinvertebrate Metric	LS-HG1	LS-ALR	LS-BLR
Density (organisms/m^2)	18,593	69,754	41,498
Taxonomic Richness	14	19	21
Simpson’s evenness	0.59	0.72	0.75
Percent EPT	25%	31.25%	47.37%
Percent Sensitive Taxa	7.14%	5.26%	14.29%
Percent Tolerant Taxa	21.43%	21.05%	19.05%
Percent Collector Taxa	57.14%	36.84%	57.14%
Percent Predator Taxa	14.29%	21.05%	14.29%
Percent Scraper Taxa	7.14%	15.79%	9.52%
Percent Shredder Taxa	21.42%	26.31%	19.04%
Percent Non-Insect Taxa	50%	42.11%	28.57%

Over all, macroinvertebrate communities in Little Springs Creek exhibit high density and low diversity, similar to Big Springs Creek and the adjacent Shasta River. Within the system there is an overall downstream gradient of increasing density, diversity, and taxa sensitivity. Of these metrics, only density appears to show a general temporal pattern, with highest densities in early summer and lowest densities in late summer. Proportions of the different functional feeding groups are relatively constant by location and season. By and large the system is dominated by collector/gatherers and detritivore/scavengers. These patterns suggest that the lower reaches of Little Springs Creek provide the best habitat for macroinvertebrates and thereby the largest potential source of food for fish. Reach 5 (LS-BLR) exhibits a high gradient, complex substrate (consisting of boulders, cobbles, gravel, sand, silt, and organic matter), and ample vegetation needed to produce dense and diverse communities. Upstream of Louie Road the creek exhibits a low gradient and accumulations of fine sediment and organic matter. According to subjective observations, vegetation here is largely dominated by tule and *Juncus sp;* and less by watercress, *Ranunculus sp*, and *Polygonum sp*. It is possible that the combination of these conditions cause the density and diversity to be generally lower in the upper reaches, though further studies would be needed to understand the relationships between substrates, vegetation types, and the observed invertebrate metrics. While many of the taxa found downstream are absent in the upper reaches, the many generalist taxa that characterize the stream still manage to proliferate in the lentic habitats of the upper reaches. Hence, the entire length of Little Springs Creek supports a sufficient food web baseline needed to build complex aquatic communities.

4.6. Fish

Fish are often the keystone species that is the target of management actions, yet they are entirely dependent on physical conditions within the stream environment and the other biota that makes an aquatic ecosystem. Because of this interdependence, understanding of how fish fit into the stream community is critical to making successful management decisions. Spring-fed systems provide unique habitats compared to other non-spring-fed environments. The relatively stable flow and temperature regime allows for a unique biotic assemblage and this results in novel habitat usage and life history strategies as has been observed in Big Springs Creek (Jeffres *et al*. 2009, Jeffres *et al*. 2010, Willis *et al*. 2011, Lusardi *et al*. unpublished data). Due to the management focus, within this section the focus is on the salmonids that utilize Little Springs Creek. Other fishes inhabit the creek, but a thorough survey was not part of this study nor was it included in the data that was available. Because CDFW has been monitoring fish utilization of the creek, fish studies in were not included as part of this baseline assessment. Rather, outlined herein is a brief discussion of CDFW collected data (CDFW unpublished data) and a general species discussion, including species that may use the creek based on the physical and ecological conditions as well as a presence-absence review based on condensed CDFW fish studies.

4.6.1. CDFW Monitoring

CDFW has been monitoring fish movement and utilization of the Little Springs Creek as part of a larger effort to assess anadromous fish studies in the upper Shasta River region. Specifically, CDFW has employed collection nets, and passive integrated transponder

(PIT) tagging and PIT antenna data collection in Little Springs Creek. A PIT tag consists of an integrated circuit chip, capacitor, and antenna coil encased in glass (Roussel *et al.* 2000), and provides a unique identification code for an individual animal (Gibbons & Andrews 2004). Internal PIT tags are inserted via large-gauge needles or surgically implanted either subcutaneously or into a body cavity. PIT tags do not require an internal power source, but are activated using a low-frequency radio signal emitted by a scanning device (e.g., antenna). When the PIT tag is activated, the unique alpha-numeric code is transmitted back to a reader (Keck 1994), providing a means to track when fish move past a point in the stream. CDFW provided processed PIT tag information for fish at two monitoring locations in Little Springs Creek between March 2013 and October 2014 (near the mouth and immediately downstream from Headgate 1).

4.6.2. General Conditions for Salmonids in Little Springs Creek

Based on conditions identified in this baseline study, Little Springs Creek appears to provide suitable habitat for juvenile salmonids throughout the year. Water temperatures generally remain within suitable ranges, or are at least consistent with conditions in Big Springs Creek and the Shasta River where salmonids persist through all seasons of the year. Further, with invertebrate densities range from 8,600 to 70,000 organisms per m^2 the stream provides extensive food resources for rearing salmonids. Both water temperature ranges and invertebrate densities were similar to those found in Big Springs Creek and in downstream Shasta River reaches in the proximity of Big Springs Creek, both locations where juvenile salmonids have been found to have robust growth rates (Jeffres *et al.* 2009, Jeffres *et al.* 2010, Willis *et al.* 2011, Lusardi *et al.* unpublished data).

The principal habitat for anadromous fish found in Little Springs Creek is largely non-natal rearing habitat. Spawning habitat is absent throughout the low gradient upper reaches (above Louie Road) due to lack of appropriate substrate. Below Louie Road the creek is too steep and lacks suitable spawning substrate and area, with only the extreme lower reaches suitable for limited spawning habitat.

Steelhead were detected in Little Springs Creek throughout the year. Because steelhead/rainbow trout do not necessarily leave fresh water for the ocean like salmon, they can remain in the rivers their entire life or leave anywhere between age-0 and 3 years. Due to the diversity of life history strategies in steelhead, there are more likely to be several age classes of fish found in the rivers throughout the year. Similar to other streams throughout the Shasta River watershed, the data collected by CDFW in Little Springs Creek confirmed this finding.

Juvenile Chinook salmon utilized Little Springs Creek only from the Louie Road crossing down to the confluence with Big Springs Creek. Of the nineteen fish detected at the confluence array, eighteen left in May and one remained until October (CDFW unpublished data). This behavior is typical of juvenile Chinook salmon found in the Shasta River where the majority of the fish leave during the first spring to emigrate to the ocean, while a small number remain to over-summer and either spawn in the fall or leave the following spring. Chinook salmon were only observed below the Louie Road crossing, which is consistent with the higher velocity habitats normally occupied by juvenile Chinook salmon.

Coho salmon were detected in Little Springs Creek throughout the year. It appears that coho salmon utilize Little Springs Creek as both over-summering and over-wintering habitat. The approximately constant flow and temperature of Little Springs Creek provides relatively cool over-summer water temperatures and warm over-winter water temperatures conditions. Coho in the Shasta River watershed generally have both a late spring and late fall redistribution. Many of the coho salmon detected in Little Springs Creek were tagged in the Shasta River or in Big Springs Creek and then moved into Little Springs Creek. In summer, the interconnected cold-water habitats associated with Big Springs Creek restoration and downstream Shasta River reaches provide reach scale habitat conditions allowing coho to freely move among desirable locations in response to local conditions and fish needs. Without other local detection data, it is unknown if fish that were detected in Little Springs Creek later distributed to other locations within the area. Combining the data collected in Little Springs Creek with other detection locations will provide an increased understanding of how coho salmon use Little Springs Creek in the context of the larger system.

Salmonids commonly move among inter-connected habitats throughout their freshwater residency. Thus Little Springs Creek is essentially an extension of the larger upper Shasta River system. Salmon within the Shasta River behave akin to a meta-population where, as a whole, they are a single population, but habitats are utilized differently in space and time by different individuals. To understand Little Springs Creek in the context of the larger watershed for these migratory fish, detection information from other PIT tag arrays will be necessary.

5. Acknowledgements

Several agencies and individuals provided field support and data that directly benefitted this report.

- California Department of Fish and Wildlife provided PIT tag fish information for Little Springs Creek as well as measured flows during the project period.
- Beyond sponsoring the project, The Nature Conservancy provided measured flow and facilitated information transfer.
- Davids Engineering provided measured flow.

These and contributions from others were critical in the development and completion of this report.

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