BENTHIC MACROINVERTEBRATES IN UVAS CREEK, CALIFORNIA, DOWNSTREAM OF A RESERVOIR

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ABSTRACT

BENTHIC MACROINVERTEBRATES IN UVAS CREEK, CALIFORNIA, DOWNSTREAM OF A RESERVOIR

By Carole A. Foster

I sampled macroinvertebrates in May, July, and October 2008 in Uvas Creek, a reservoir-regulated stream in south Santa Clara County, California, to assess what factors (including canopy closure, turbidity, and stream flow) downstream of the reservoir were related to food availability for rearing juvenile Steelhead (*Oncorhynchus mykiss*). I found benthic and drifting macroinvertebrate biomass was considerably greater during most months in the more open-canopied two sites in the downstream reach as compared to the densely shaded, more turbid and silty two sites in the upstream reach. Abundance of important drifting aquatic invertebrates in May (chironomids, simuliids, and baetids) was proportional to benthic abundance, but large hydropsychids were relatively scarce in the drift. Terrestrial drift abundance correlated with canopy density, but differences were small compared to the substantial increase in aquatic drift in sunnier sites. Thinning of the canopy at select locations and reduction of sediment input to Uvas Creek and its tributaries due to vineyard and other operations could increase benthic macroinvertebrate productivity in the upstream reach, which would increase food availability for rearing juvenile Steelhead.

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INTRODUCTION

Uvas Creek in south Santa Clara County, California, is a small reservoir-regulated stream managed by the Santa Clara Valley Water District (SCVWD) for groundwater recharge and flood control. The Uvas Creek run of Steelhead (*Oncorhynchus mykiss*) belongs to the South-Central California Coast (S-CCC) Steelhead Distinct Population Segment (DPS), which was listed as a threatened species under the Federal Endangered Species Act in August of 1997. The National Marine Fisheries Service (NMFS) lists the improvement of Steelhead freshwater habitat quantity and quality as a Priority Recovery Action for the Steelhead S-CCC DPS (NMFS 2013). Understanding current habitat conditions and instream productivity, as well as how those conditions may affect existing Steelhead populations, is necessary for identifying the best approach for habitat improvement. Uvas Creek Steelhead are currently confined to the main stem of Uvas Creek and its tributaries located downstream of Uvas Reservoir, since Uvas Dam prevents migration to upstream habitats (Smith 2007). Therefore, understanding the factors that affect stream productivity and current habitat conditions in the main stem of Uvas Creek downstream of the reservoir is essential for the management and conservation of the Uvas Creek Steelhead population.

The quantity of food available to rearing juvenile Steelhead, along with water temperatures and other environmental factors, affect Steelhead growth, abundance, and survival rates (Smith and Li 1983; Sogard et al. 2012). Slow growing juvenile Steelhead may need two years rearing in the stream before outmigrating as smolts (Satterthwaite et al. 2009). Juveniles rearing in habitats with qualities that enable them to grow rapidly can smolt after one year in the stream (Smith 1982; Smith and Li 1983; Satterthwaite et al. 2009). Bond et al. (2008) analyzed fork length (FL) of Steelhead smolts in a central California coastal stream prior to outmigration and later found that 87 to 95.5% of returning adults were from larger, summer estuary-reared juveniles (195.9 mm mean FL) compared to smaller spring migrants (102.2 mm mean FL), indicating that smolt size is important for ocean survival. Therefore, managing for habitat which encourages optimal growth rates may increase adult Steelhead numbers and population health.

Benthic (streambed) macroinvertebrates (BMIs), which are a dominant food of Steelhead (Weber et al. 2014), have been used in numerous stream ecology studies with varied objectives, such as water quality assessment (Freund and Petty 2007), determining habitat effects on aquatic insect assemblages (Carter et al. 1996), or assessing the availability of food for fish (Romaniszyn et al. 2007). BMIs can be found either within the stream substrate or within the water column as drift (Waters 1972). BMIs can be categorized into different functional groups based on their method of feeding: collector-gatherers feed on fine particulate organic matter (FPOM); collector-filterers trap and feed on organic matter suspended in the water column or in stream flow; scrapers harvest organic films, including algae, growing on stream substrates; shredders feed on living plant material or decomposing plant coarse particulate organic matter (CPOM); and predators feed on living animals (Merritt and Cummins 1996; Hawkins et al. 1982).

By identifying organisms to family or genus and measuring body lengths, several community attributes can be assessed. Water quality monitoring may use attributes such as taxa richness or other diversity metrics, total and relative abundance, or the EPT

(Ephemeroptera, Plecoptera, Trichoptera) index. Standing-stock biomass can be calculated using length-mass relationships (Benke et al. 1999) in studies of secondary production or food availability. These factors then can be used to compare different streams, different reaches within a stream, or different habitats within a reach (Merritt et al. 1996). Secondary productivity, the biomass produced by a particular insect population over a period of time, is a useful measure of the availability of food for insect feeding fish (Benke 1984). However, its accurate determination requires large numbers of samples and a thorough understanding of life history features of insect taxa, such as number of broods per year or insect lifespan (Hynes and Coleman 1968; Benke 1984). Therefore, determining annual stream production can be difficult and time consuming, especially if examining several taxa.

Sampling drift can be used to study BMI life histories, food availability for drift-feeding fish, or to make comparisons between streams or stream reaches (Waters 1972; Weber et al. 2014). Drifting macroinvertebrates are generally benthic organisms that have detached from the substrate and ended up in the stream flow. Although any BMI may end up in drift, the most common taxa typically found in drift include Ephemeroptera (mayflies), Diptera (especially black flies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (Allan 1995). Three types of drift have been described in the macroinvertebrate literature. Behavioral drift is a well-studied phenomenon and is demonstrated by diel periodicity for most species, where the abundance of drifting organisms peaks between dusk and dawn in streams where fish are present (Waters 1972; Allan 1995). Pringle and Ramirez (1998) found that naturally fishless streams lack behavioral drift, suggesting nighttime drift is a response to predator avoidance in many BMIs, especially when exposed to fish that depend on visually locating prey. Catastrophic drift occurs during natural or anthropogenic events such as floods, high temperatures, or substrate disturbances, causing large numbers of BMIs to enter stream drift. Lastly, constant drift consists of continuously low numbers of organisms drifting either actively or passively during daylight hours (Waters 1972).

Constant drift may be a good indicator of what is available to visual-feeding fish because fish often require a minimum amount of light for efficiently capturing prey. For example, Wilzbach et al. (1986) reported that the relative growth rate of Cutthroat Trout, a drift-feeding fish, was 10 times greater in an unshaded reach of stream versus a shaded reach. Additionally, they found mean percentage of prey captured, or feeding efficiency, for this visual feeding trout increased linearly as surface light increased.

The amount and type of sunlight able to reach the stream surface is related to the type and density of the riparian canopy. This, in turn, will affect primary production and stream temperatures (Hill et al. 1995). Periphyton, which includes primary producers such as diatoms and green algae, is one important base of the aquatic food web and is affected by light, temperature, current, and substrate (Allan 1995). Kiffney et al. (2004) found that periphyton biomass in a stream increased with light penetration, and that the abundance and biomass of select BMIs were positively related to light, in part due to the increase in primary production. Hawkins et al. (1982) compared opened and closed canopied streams and found that open canopied streams had higher abundances of invertebrates across most functional feeding groups, including collector-gatherers, filter feeders, herbivore shredders and piercers, and predators.

Hauer and Benke (1991) found the daily growth rates of chironomid larvae to be proportional to stream discharge, with a suggested cause being the subsequent increase in seston (e.g., chlorophyll and bacterial biomass) within the water column which are filtered out or gathered by collector chironomids. Common BMI families such as Chironomidae (midge flies), Simuliidae (black flies), Baetidae (mayflies), and Hydropsychidae (caddisflies) are generally filtering or gathering collectors (Merritt and Cummins 1996). In addition, daily growth rates of select BMIs have been reported to increase with an increase in temperature, with the rate of increase dependent on the species (Hauer and Benke 1991; Benke 1993). Smith and Li (1983) showed an increase in daytime invertebrate drift to be associated with an increase in water velocity. These studies suggest greater BMI biomass may result from an increase in stream discharge and water temperature, while an increase in velocity may increase the amount of BMIs entering drift, thus increasing the potential food supply for insect-feeding fish.

A 1956 Memorandum of Agreement (MOA) between the Gavilan Water District (later to be incorporated into the SCVWD) and the California Department of Fish and Wildlife (CDFW) required specific minimum reservoir releases for the operation of Uvas Reservoir, depending upon water storage in the reservoir (SCVWD 2009a). Winter (15 December through 30 April) releases required a minimum of 0.56 m^3/s (20 f^3/s) and summer (01 May through 15 December) releases required a minimum of 0.28 m^3/s (10 f^3/s). The 1956 MOA was active during the study period. However, alternative reservoir operating strategies were being employed by the SCVWD during the study period to release pulse flows in the winter and spring to attract migrating Steelhead adults and to allow for smolt outmigration (SCVWD 2009a). Trial modifications of the operating rules that provided additional water at different times of the year for Steelhead began in 2005 and were formalized in 2012 (SCVWD 2012a).

Turbidity is a measure of suspended particles in a water column and can affect the amount of light able to penetrate to the streambed, as well as visibility for visual-feeding fish. Gilvear and Petts (2006) studied suspended load and turbidity variations downstream from a reservoir and found that fine organic matter dominated the seston (suspended particles) close to the dam, whereas mineral particles dominated farther downstream, presumably from tributary sources. Gippel (1989) proposed that a linear relationship between turbidity and suspended solids concentration in a stream can be expected when using a calibrated turbidity meter as a measure of scattered light, if particles are not physically altered as their concentration varies.

Substrate is defined by Allan (1995) as any object residing on the bottoms or sides of streams including both natural (cobbles, boulders, sands, silts, detritus, and fallen trees) and artificial (concrete, debris, etc.) material. The type and condition of substrate can affect biological conditions for fish and BMIs during a variety of life stages. Fine sediments, in particular, can have a major effect. For example, Kaller and Hartman (2004) found EPT taxa richness decreased when accumulated fine substrate particles, those less than 0.25 mm, exceeded 0.8 to 0.9% of riffle substrate composition. Adding gravels to streams has been proposed as mitigation for the lack of bedload recruitment below dams (Boles 1981). These cleaner gravels could replace sediment laden or highly embedded gravels, which in turn could improve spawning habitat for fish and support a higher abundance of BMIs.

Reservoir-regulated streams, when compared with unregulated streams, are found to exhibit changes in discharge and current, temperature regime, channel morphology, transportation of suspended sediment, and deposition of fine sediments (Allan 1995). These changes can impact fish, aquatic insects, algal growth, and riparian vegetation (Allan 1995; Pardo et al. 1998). For example, compared to a natural system, reservoirs used for flood protection or downstream percolation will often produce lower flood peaks and a less variable flow of water throughout most of the year and among years. Similarly, temperatures directly downstream of a dam may be determined by hypolimnion temperature of a bottom-release reservoir or by reservoir surface temperature during spilling (Allan 1995). Benthic invertebrate communities have been reported to respond to these and other physical and biological changes by having lower taxa richness and greater abundance below a dam (Allan 1995; Jackson et al. 2007).

The effects of dams on downstream reaches of streams vary with regard to the size, purpose, and operation of an individual reservoir (Allan 1995). Jackson et al. (2007) observed that effects need to be assessed on a case-by-case basis in order to determine the best management practice for reservoir operation. Because dams often block the migration of anadromous fishes to upstream spawning and rearing sites, it is important to evaluate downstream conditions in order to maximize fish production in the remaining accessible habitats. Opinions may differ as to what makes a habitat suitable for fishes and other stream organisms, and this affects the types of methods used for assessing environmental factors such as benthic macroinvertebrate conditions, canopy cover, temperature, algal production, sediment, and substrate, as well as what ecological associations are studied.

This study was undertaken to: 1) assess seasonal changes in benthic macroinvertebrate taxa richness, abundance, and biomass in a longitudinal comparison between reaches; 2) assess drifting macroinvertebrate taxa richness, density, and biomass as an index of Steelhead food availability in a longitudinal comparison between reaches; and 3) assess environmental factors such as water temperature, turbidity, riparian canopy closure, stream flow, and substrate, as they may affect benthic macroinvertebrate abundance and Steelhead habitat quality. This study was conducted in 2008 during the juvenile Steelhead rearing period from May through October.

STUDY AREA

Uvas Creek is a reservoir-regulated, 4th order stream within the Pajaro River Watershed in South Santa Clara County, California. Other major tributaries of the Pajaro River include Llagas Creek and the San Benito River (Figure 1). Uvas Creek drains an 83 km^2 subwatershed on the eastern side of the Santa Cruz Mountains. Uvas Dam, completed in 1957 to create Uvas Reservoir (SCVWD 2010), is located on Uvas Creek approximately 27.5 river kilometers upstream of the Pajaro River confluence. The study area is comprised of 14.5 river kilometers of Uvas Creek from the Uvas Reservoir outlet to approximately 0.1 km downstream of the Miller Avenue crossing of Uvas Creek in Gilroy, California.

Uvas Reservoir is a 1.2×10^7 m^3 (9,835 acre-feet) capacity bottom-release reservoir managed by the SCVWD for groundwater recharge and flood control (SCVWD 2010). When at maximum capacity, Uvas Reservoir extends approximately 3.5 km up a narrow canyon and has an average surface area of 1.2×10^6 m^2 (288 acres). The reservoir is oriented in a northwest to southeast direction with the deepest portion near Uvas Dam. Uvas Dam is 32 m tall from the streambed to the Uvas Dam crest, with a concrete spillway to drain surface water from the reservoir to Uvas Creek at a location approximately 125 m downstream of the Uvas Dam outlet.

From the outlet of Uvas Reservoir, Uvas Creek generally flows southeasterly to its confluence with the Pajaro River. At that point, the Pajaro River flows in a westerly direction until it empties into Monterey Bay just southwest of the city of Watsonville. Two major tributaries, Little Arthur Creek and Bodfish Creek, enter Uvas Creek within the study area (Figure 1). Both tributaries generally become disconnected from Uvas Creek in late spring or early summer due to stream dryback in the lower reaches, but tend to provide perennial flow in their upper reaches. An approximately 16.5 km stretch of Uvas Creek is located on the unconfined portion of the Llagas Groundwater Subbasin, from just downstream of the Uvas Road crossing of Uvas Creek to 1.0 km upstream of Highway 101 (Figure 2) (SCVWD 2012b). The unconfined portion of the Llagas Groundwater Subbasin is the “recharge zone,” where Uvas Creek generally loses water via percolation into the aquifer. Uvas Creek and Llagas Creek are important components in the recharge of this aquifer for domestic, industrial, and agricultural use in South Santa Clara County.

Upstream of Uvas Reservoir, the surrounding landscape consists of steeply sloped topography covered with oak and conifer woodlands. Land uses above the reservoir are mostly open space and rural residential. From Uvas Reservoir to just downstream of Watsonville Road (Figure 3), upland habitats are primarily oak woodland and coastal scrub dominated by valley oak (*Quercus lobata*), coast live oak (*Quercus agrifolia*), California sagebrush (*Artemesia californica*), sticky monkeyflower (*Mimulus aurantiacus*), poison oak (*Toxicodendron diversilobum*), and coyote brush (*Baccharus pilularis*). The riparian zone is dominated by a dense canopy of white alder (*Alnus rhombifolia*.), willow (*Salix* spp.), California sycamore (*Platanus racemosa*), black cottonwood (*Populus trichocarpa*), and Oregon ash (*Fraxinus latifolia*), with evergreens such as coast live oak and California bay (*Umbellularia californica*) on the upper banks. Understory and aquatic vegetation include California blackberry (*Rubus ursinus*), watercress (*Nasturtium officinale*), nutsedges (*Cyperus* sp.), and sedges (*Carex* sp.). Invasive, non-native species include green wattle (*Acacia decurrens*), Himalayan blackberry (*Rubus armeniacus*), and broom (*Cytisus* spp. or *Genista* spp.). The stream channel in this reach of Uvas Creek has an average slope of 0.6% as calculated from streambed elevations measured by the SCVWD as part of a groundwater recharge analysis study (SCVWD 2008b). Surrounding land uses include rural residential, agriculture (primarily vineyards), open space, and trailer parks.

From downstream of Watsonville Road to W. Luchessa Avenue (Figure 4), Uvas Creek has an average slope of 0.3% (SCVWD 2008b) and a riparian zone dominated by willows, sycamore, black cottonwood, and mulefat (*Baccharis salicifolia*) that is progressively more open downstream. Invasive, non-native species include Himalayan blackberry, giant reed (*Arundo donax*), and blue gum eucalyptus (*Eucalyptus globulus*). Uvas Creek in the vicinity of W. Luchessa Avenue generally does not maintain surface flow in late summer/early fall during most years due to percolation losses in the stream channel. Surrounding land uses are more urban and include low- to medium-density residential developments, commercial nurseries, golf courses, agriculture, open space, and an amusement park.

Downstream of W. Luchessa Avenue, Uvas Creek flows through a narrow, densely vegetated channel to its confluence with the Pajaro River. Surrounding land use is almost exclusively agriculture. Uvas Creek downstream of Highway 101 is renamed Carnadero Creek, and the entire drainage is sometimes referred to as Uvas/Carnadero Creek. However, for the purposes of this study, only the Uvas Creek designation will be used.

Four sites were selected for sampling and are denoted by familiar landmarks such as road names or adjacent residential developments. Two of the sites, designated Uvas Road and Watsonville Road, are located in the closed-canopied reach within 6.5 km downstream of the Uvas Reservoir outlet, and for this study will be referred to as the upstream reach (Figure 3). The other two sites, designated Eagle Ridge and Miller

Avenue, are located in the more open-canopied reach downstream of Watsonville Road, which will be referred to as the downstream reach (Figure 4).

The site designated as Uvas Road consisted of two riffles located approximately 1.0 km downstream of the Uvas Reservoir outlet and 600 m upstream of the Uvas Road Bridge. The Uvas Road site was bordered by Uvas Road to the southwest and Uvas Pines R.V. Park to the northeast. The trailer park maintains a buffer of oak woodland habitat between the creek channel and the paved trailer spaces. However, a set of regularly maintained dirt trails run through the oak woodland with some trails extending to the waterline of the creek. The site designated as Watsonville Road was located approximately 6.3 km downstream of the Uvas Reservoir outlet near the Watsonville Road crossing of Uvas Creek and consisted of three riffles; one was located approximately 100 m upstream of the Little Arthur Creek confluence and upstream of Watsonville Road, and two were located downstream of Little Arthur Creek, approximately 30 m upstream and 30 m downstream of the Watsonville Road Bridge. The site designated as Eagle Ridge consisted of three riffles located adjacent to the Eagle Ridge Residential Community approximately 10.8 km downstream of the Uvas Reservoir outlet and 800 m downstream of the Highway 152 crossing of Uvas Creek. The site designated as Miller Avenue was located approximately 14.4 km downstream of the Uvas Reservoir outlet and consisted of four riffles in the vicinity of the Miller Avenue crossing of Uvas Creek within the city of Gilroy. Two riffles were located approximately 70 m and 150 m downstream of Miller Avenue. Two riffles were located approximately 375 m and 650 m upstream of the Miller Avenue crossing. The two riffles located upstream of

Miller Avenue were not accessible during the May sampling event due to the adjacent park being used as a firefighting base camp for the 4,270 acre Summit Fire, which was burning in the Santa Cruz Mountains approximately 8.0 km west of Uvas Reservoir. The two riffles located downstream of Miller Avenue were not sampled during the July and October sampling events due to low stream flows at the riffles.

METHODS

Uvas Reservoir Conditions and Stream Flow

I analyzed April through October 2008 reservoir water quality data, which were collected at monthly intervals by the SCVWD. Reservoir water quality profiles were taken at the approximate deepest portion of Uvas Reservoir, located at 275 m upstream of Uvas Dam. The intake structure of the reservoir is presumably in close proximity to this sampling site. A Hydrolab multiparameter sonde was lowered at 0.25 m to 1.0 m increments and recorded depth, dissolved oxygen, and temperature. Secchi depth measurements were taken once per sampling event from the shady side of the boat and recorded between 09:00 PST and 12:00 PST during all sampling events.

I analyzed 2007 and 2008 mean daily reservoir storage and release data acquired from the SCVWD (SCVWD 2008a). Additional data were gathered from the SCVWD ALERT System streamflow gauge SF 84 (SCVWD 2009b), which measured stream flow approximately 30 m downstream of the Uvas Reservoir outlet throughout the study period (Figure 5). Since Uvas Reservoir is a bottom-release reservoir and did not spill during this sample period, the SCVWD flow gauge is a measurement of the stream flow in Uvas Creek immediately downstream of Uvas Reservoir.

Additionally, a streamflow study was conducted on Uvas Creek from Uvas Dam to W. Luchessa Avenue by the SCVWD in November of 2008 to assess percolation rates in the Uvas Creek channel for instream groundwater recharge (SCVWD 2008b). Similar studies were conducted by the SCVWD in 1968, 2005, and 2006. Elevations of the Uvas Creek channel were measured by the SCVWD as part of the groundwater recharge analysis study (Figure 6). All SCVWD data were considered preliminary as the SCVWD does not guarantee that the data presented accurately reflect conditions at any particular site or time.

During the May 2008 sampling event, flow velocity and water depth were measured with a Marsh McBirney Flo-Mate flow meter at transects within sampled riffles. Measurements were taken by setting the flow meter sensor at 60% of the depth to provide the mean velocity (Buchanan and Somers 1969). Mean velocity and mean water depth were calculated based on these measurements. The width of the stream (waterline to waterline) was measured at the riffle transects. Mean velocity, mean depth, and width were then multiplied together to estimate stream flow for the select riffles. These results were compared to estimates from the November 2008 SCVWD streamflow study.

Air and Water Temperature

To measure air and water temperature conditions along Uvas Creek, HOBO Water Temp Pro v2 data loggers were deployed by the SCVWD in approximately 0.8 km increments from 100 m downstream of the Uvas Dam outlet to 100 m upstream of W.

Luchessa Avenue. The loggers recorded data at one hour logging intervals for the entire study period. The loggers had an operation range of -40º to 70ºC in air and a maximum sustained temperature of 50ºC in water, with a manufacturer accuracy of 0.2ºC over 0º to 50ºC (Onset Computer Corporation 2010). To measure air temperature, data loggers were deployed at each station hanging freely in a shaded position. To measure water temperature, loggers were located in deep areas of riffles, runs, and pool tailouts to ensure the sensors remained submerged. Water loggers were housed in metal casings with 1.5 cm holes drilled along all sides to allow for adequate water circulation. Following retrieval, loggers were calibrated to correct for minor instrument discrepancies. Data from loggers determined to be out-of-tolerance were discarded.

I analyzed corrected mean, minimum, and maximum hourly temperatures from May through October 2008 and reported monthly averages for 5 temperature stations located in closest proximity to the study sites (Figure 5). The Uvas Reservoir Outflow temperature station was located approximately 100 m downstream of the Uvas Reservoir outlet at the location of SCVWD streamflow gauging station SF 84. The Uvas Road temperature station was located approximately 10 m upstream of the Uvas Road Bridge. The Watsonville Road temperature station was located approximately 15 m downstream of the Watsonville Road Bridge and 90 m downstream of the Little Arthur Creek confluence. The Eagle Ridge temperature station was located approximately 835 m downstream of the Highway 152 Bridge adjacent to the Creekside Homes within the Eagle Ridge residential development. The Miller Avenue temperature station was located approximately 335 m upstream of the Miller Avenue crossing (Figure 5). Actual mean water temperatures in the vicinity of the Miller Avenue temperature station may be slightly higher than reported due to the location of the data loggers being placed in a deep pool.

Turbidity

I periodically measured stream turbidity at six sites on various dates during spring, summer, and fall of 2008 using a portable HACH 2100P turbidimeter reported in nephelometric turbidity units (NTU). Three samples were taken in an undisturbed area of stream at each site and the mean NTU was reported. Turbidity measurements were taken at sample sites during sampling events, and additional measurements were taken 100 m downstream of the outlet in August, September, and November and at the Old Creek Road crossing of Uvas Creek (located between the Uvas Road and Watsonville Road sites) in most months from April through November, 2008.

Canopy Closure and Solar Radiation Availability

I measured average percent canopy closure and the average percent as evergreen in late May of 2008 using a spherical densiometer from the middle of each sample riffle. Two to three riffles per sample site were measured and averaged together to report canopy closure per site.

The exposure of solar radiation to the stream surface affects both water temperature and primary productivity, with shade-producing features decreasing the amount of sunlight reaching the stream. I periodically measured the percent of available solar radiation at various sites from August through October 2008 using a Solar

Pathfinder™. This instrument consists of a transparent dome which provides a panoramic reflection of all shade producing features of an entire site, taking into account canopy cover, stream aspect, and surrounding topography. The Solar Pathfinder™ was placed mid-channel, leveled, and oriented to the south. I traced all shade producing features onto a sunpath diagram, recording deciduous versus evergreen foliage. Two to three riffles per site were measured and averaged together to report percent solar availability per site.

The Solar Pathfinder™ was designed to estimate solar radiation data for the entire year from one sampling event by giving percentage approximations of the amount of each month's average daily radiation for a given six-degree latitude band. I estimated mean monthly solar energy availability for the months of April through October for each reach following guidelines provided by Solar Pathfinder™ (Solar Pathfinder 2008). I used the estimates to compare available solar radiation between months and between study sites.

Algae Cover

Percent algal cover for filamentous algae was assessed during each benthic macroinvertebrate sampling event with a Hess benthic sampler. Once the 33 cm diameter Hess Sampler was placed on the streambed for benthic macroinvertebrate sampling and prior to disturbing the area inside, I estimated the percent cover of algae within the area of the Hess Sampler based on four ranked classifications: 0-5%, 5-20%, 20-50%, and >50%. I compared the mean results between seasons and between sites.

Substrate and Visual Silt Score

General substrate size was assessed during the October benthic macroinvertebrate sampling events. I randomly selected 5 coarse substrate particles from each Hess sample. Rocks selected for substrate sampling tended to be cobbles (64-256 mm) and large pebbles (32-64 mm) found at the substrate surface, rather than smaller pebbles (16-32 mm), gravels (2-16 mm), and sand (< 2 mm). Sediment size classifications follow the Wentworth Scale as presented in Allan (1995). I measured the two longest lengths (A-axis and B-axis) and compared the mean of the two axes between sites. At the Uvas Road site, the riffles contained numerous boulders up to 610 mm (2 ft) in diameter, many of which were unable to fit in the 33 cm diameter Hess Sampler. Therefore, samples had to be taken in the spaces between large boulders. The Miller Avenue substrate samples were obtained from the two riffles located approximately 375 m and 650 m upstream of the Miller Avenue crossing. Coarse substrate particles from each sample were collected in a tray and any accumulated silt on the surface of the particles was rinsed into the tray using clean water. The water in the tray was then stirred up by hand, and a rough visual assessment of the abundance of silt (visual silt score) was documented as high, medium, or low.

Macroinvertebrate Assessment

Benthic Macroinvertebrate Taxa Richness, Abundance, and Biomass.— Macroinvertebrates on the streambed were sampled at the four sites (Uvas Road, Watsonville Road, Eagle Ridge, and Miller Avenue) once monthly in May, July, and October, 2008 (Table 1). I excluded Watsonville Road in July due to difficulties accessing the property. Benthic samples were taken using a 33 cm diameter (0.08 m^2), 363µm mesh size Hess Sampler (Hauer and Resh 2006) at 4 to 5 random locations within each riffle for each sample period. Since the same area was sampled for each benthic sample, sample total was used in reporting, rather than density. I began sampling at the downstream end of the riffle and proceeded upstream for subsequent samples. I set the Hess Sampler at a randomly selected spot in the riffle, and pushed it down into the substrate as far as it would go, making sure there were no gaps around the bottom edges where organisms could get in or out. If a proper seal could not be obtained, another random sample site was selected.

Once the Hess Sampler was in place, I removed the first 5 coarse substrate particles encountered and immediately placed the rocks in a tray of clean water. I flushed organisms off of the rocks and into the tray. The organisms in the tray were filtered through a sieve and included in the sample. The rocks were set aside for measurement. Once the coarse substrate particles were removed from the Hess Sampler, I dug through the upper substrate and underlying material as much as possible, mixing the substrate and water for at least one minute. In this way, organisms on the substrate were washed into the collection net. I flushed all collected organisms down to the collection jar, and picked off any organisms that remained clinging to the inside of the net. All of these organisms were included in the sample. For samples with a high amount of filamentous algae, I collected the algae from the surface and placed it in the tray of clean water. I then rinsed the algae of organisms as much as possible into the tray. These organisms were filtered in a sieve and included with the sample. Organisms that could not be seen with the naked eye were left clinging to the algae. Therefore, samples with high amounts of algae present likely underestimated macroinvertebrate abundance.

Collected samples were preserved in the field with a 70% ethanol solution. Of the 4 to 5 samples collected from each riffle, I randomly selected 3 of those samples for macroinvertebrate identification and analysis. In the lab, macroinvertebrates were sorted from the entire benthic sample by eye (Carter and Resh 2001) and were identified to family level using standard keys (Merritt and Cummins 1996). Organisms were sorted by family into 1 mm size classes using a dissecting microscope and length-mass relationships were determined using length-mass equations (Benke et al. 1999) where total body length is converted to dry mass. Taxa richness, as well as abundance and biomass of each family, were reported.

Benthic samples with a large volume of benthic organisms to be sorted were subsampled. I used a fixed-count approach to subsampling. I spread the sample evenly across a mesh-bottomed tray supported by a metal frame of a 6 x 4 square grid with each grid square approximately 6 cm x 6 cm. Using a random number table, I selected 4 pairs of numbers corresponding to the squares within the gridded tray. For any organism located on a line separating two squares, I considered it to be in the grid which contained most of its body. I removed all organisms from the 4 selected squares and transferred them to a sorting tray to be identified and counted. The subsampled number of macroinvertebrates was then multiplied by 6 to estimate the total number of organisms.

Drifting Macroinvertebrate Taxa Richness, Density, and Biomass.—I sampled drifting macroinvertebrates at the four sites in May of 2008 (Table 2). Miller Avenue drift samples were taken at the two riffles located downstream of Miller Avenue since the riffles located upstream of Miller Avenue were not accessible during the May sampling event.

At each site, I positioned two 363 μm mesh drift nets side-by-side at the downstream end of each riffle. I conducted drift sampling at a site at least one day prior to conducting benthic sampling at the same site, and care was taken to ensure the riffle substrate was not disturbed. Each net was positioned at least 5 cm above the streambed to exclude benthic macroinvertebrates from the sample. The volume of water passing through each drift net was estimated by measuring the area of the net submerged in the water column and the flow velocity at the time of deployment. Mean flow velocity was measured with a Marsh McBirney Flo-Mate flow meter at the mouth of each net by setting the flow meter sensor at 60% of the depth (Buchanan and Somers 1969). Nets were deployed at each site for 1 hr periods at 2 hrs prior to sunset over a five day sampling period. Sunset times were obtained for Gilroy, California from the Astronomical Applications Department within the U. S. Naval Observatory (USNO 2008). The nets were rinsed into a tray, and organisms were filtered into a sieve. I visually inspected the inside of the nets and picked off any organisms that remained clinging to the inside of the net. All of these organisms were included in the sample. Collected samples were preserved in the field with a 70% ethanol solution.

In the lab, macroinvertebrates were sorted from the entire drift sample by eye and were identified to family level using standard keys (Merritt and Cummins 1996). Organisms were sorted by family into 1 mm size classes using a dissecting microscope and length-mass relationships were determined using Benke et al. (1999) length-mass equations for aquatic larvae and Sabo et al. (2002) length-mass equations for terrestrial and aquatic adults. Taxa richness, as well as drift density and biomass of each family, were reported. For biomass, sample total was used in reporting, rather than density.

Drift density was expressed as numbers of invertebrates drifting per 100 m^3 of water per taxon (#/100 m^3), using the following equation shown below (Allan 1995; Smock 2006):

$$Drift\ Density = \frac{[(N)(100)]}{\left[(t)(W)(H)(V)\left(\frac{3600s}{h}\right)\right]}$$

Where:

N = number of invertebrates in a sample

t = length of time the net was in the stream (h)

W = net width (m)

H = mean height of the water column in the net mouth (m)

V = mean water velocity at the net mouth (m/s)

RESULTS

Uvas Reservoir Conditions and Stream Flow

Reservoir Conditions.—Uvas Reservoir drained down to approximately 4.0×10^5 m^3 (323 acre-feet) on 09 February 2007, which was 3.3% of total capacity (Figure 7). The maximum storage in Uvas Reservoir in 2007 occurred in March and was 3.3×10^6 m^3 (2,706 acre-feet), which was 28% of total capacity. Uvas Reservoir drained down to approximately 3.9×10^5 m^3 (316 acre-feet) by 03 January 2008, which was 3.2% of total capacity. A series of particularly late storm events in January and February of 2008 increased reservoir storage to 1.1×10^7 m^3 (9,140.5 acre-feet) by 04 March 2008, which was 93% of total capacity (Figure 7). The region received no precipitation between May and September 2008, resulting in a gradual decline in reservoir storage and depths throughout the study period (Figure 7). By 31 October 2008, Uvas Reservoir had drained down to approximately 2.3×10^6 m^3 (1,865 acre-feet), which was 19.0% of total capacity. Uvas Reservoir did not spill during 2007 and 2008.

By 21 April 2008, Uvas Reservoir surface to bottom profiles for water temperature and dissolved oxygen showed that the water column had begun to stratify, with a thermocline within the water column, where temperature decreased at least 1°C per meter of depth (Figure 8). Above the thermocline was a warmer, mixed epilimnion and below the thermocline was a cooler, stagnant hypolimnion. Water temperature and dissolved oxygen measurements on 21 April ranged from 16.2°C and 9.6 mg/L at the reservoir surface to 10.8°C and 1.7 mg/L at the bottom. The water column depth at the April sampling point was 21.2 m, and Secchi depth was 2.8 m from the surface.

Uvas Reservoir remained stratified through mid-August, but reservoir bottom temperature gradually increased from 10.8°C to 18.2°C due to the release of cooler bottom water and the gradual wind-driven downward mixing of surface heat (Figure 8A). Water column depth decreased from 21.2 m to 15.6 m by mid-August. By the 15 September reservoir sampling event, Uvas Reservoir had been destratified due to declining depth (13.5 m), wind mixing, and surface cooling, and water temperatures were approximately 22°C from surface to bottom (Figure 8A). However, dissolved oxygen levels were still depressed (1.4 mg/L) at the reservoir bottom (Figure 8B). Secchi depth was 1.6 m from the surface. By the 06 October reservoir sampling event, mean temperatures throughout the water column had decreased to 20.5°C, and dissolved oxygen was nearly mixed and ranged from 8.8 mg/L at the surface to 5.6 mg/L at the bottom. The water column depth at the October sampling point was 12.0 m, and Secchi depth was 1.1 m from the surface.

2007 Stream Flow.—Limited storage required below normal reservoir releases throughout 2007 in order to keep a portion of Uvas Creek perennial. Daily mean stream flow releases from Uvas Reservoir ranged from 0.07 m^3/s (2.3 f^3/s) to 0.12 m^3/s (4.1 f^3/s) from late April throughout the remainder of 2007. With the exception of isolated pools, Uvas Creek did not maintain surface flow during the summer and fall of 2007 from approximately 1.5 km downstream of Watsonville Road to the boundary of the unconfined aquifer, which is located approximately 1.0 km upstream of Highway 101 (Figure 2). This dry stretch of channel comprised a total of approximately 10.0 river kilometers, and included the Eagle Ridge and Miller Avenue sample sites.

2008 Stream Flow.—Five ramped pulse flows were released from Uvas Reservoir in the winter and spring of 2008 to attract adult Steelhead to Uvas Creek and to encourage smolt outmigration. The first pulse flow occurred in early February and consisted of flows with two consecutive days at 2.66 m^3/s (94 f^3/s). The second pulse flow occurred in late March and consisted of two consecutive days at 2.18 m^3/s (77 f^3/s). The last three pulse flows, for smolt outmigration, occurred in April and early May approximately 10 days apart and each consisted of two consecutive days at 0.74 m^3/s (26 f^3/s) to 0.76 m^3/s (27 f^3/s) (Figure 9).

Stream flow releases from Uvas Reservoir ranged from approximately 0.34 m^3/s (12 f^3/s) to 0.42 m^3/s (15 f^3/s) from mid-May through the end of October, during this study (Figure 9). At the sample sites during the May benthic sampling events, mean stream flow was calculated to be 0.43 m^3/s (15 f^3/s) at Uvas Road, 0.41 m^3/s (14 f^3/s) at Watsonville Road, 0.20 m^3/s (7 f^3/s) at Eagle Ridge, and 0.12 m^3/s (5 f^3/s) at Miller Avenue (downstream of the road crossing) (Figure 10). Riffle sample site velocities recorded during the May benthic sampling events were similar: 0.43 m/s (1.4 f/s) at Uvas Road, 0.46 m/s (1.5 f/s) at Watsonville Road, 0.47 m/s (1.5 f/s) at Eagle Ridge, and 0.48 m/s (1.6 f/s) at Miller Avenue (downstream of the road crossing). Riffle sample site depths were also similar: 0.23 m at Uvas Road, 0.16 m at Watsonville Road, 0.15 m at Eagle Ridge, and 0.17 m at Miller Avenue. Stream flow was maintained beyond the Miller Avenue crossing during the study period, but flows declined downstream of Miller Avenue and were less than 0.05 m^3/s during the July and October sample periods.

On 18 November 2008, the SCVWD conducted a recharge analysis at seven sites downstream of Uvas Dam to determine percolation rates into the unconfined Llagas Subbasin aquifer (Figure 10). Sample sites included the Uvas Dam outlet, Uvas Road, Old Creek Road, Highway 152, Santa Teresa Boulevard, Miller Avenue, and W. Luchessa Avenue. Stream flow at the Uvas Dam outlet was measured at 0.28 m^3/s (9.9 f^3/s), which was lower than the streamflow estimate from SCVWD's SF 84 gauge which recorded 0.33 m^3/s (11.6 f^3/s) on 18 November. Stream flow remained fairly constant from below Uvas Reservoir to the Highway 152 crossing located approximately 9.9 river kilometers downstream, where stream flow ranged between 0.28 m^3/s (9.9 f^3/s) and 0.31 m^3/s (11.0 f^3/s). Stream flow decreased to 0.17 m^3/s (6.0 f^3/s) at Santa Teresa Boulevard and to 0.07 m^3/s (2.5 f^3/s) at Miller Avenue. The W. Luchessa Avenue site was dry during the 18 November recharge analysis. Results were similar to earlier SCVWD recharge analyses conducted in 1968, 2005, and 2006 (Figure 10).

Air and Water Temperature

Air Temperature.—In general, monthly average daily maximum (MAX) air temperatures increased from upstream to downstream, with the exception that Watsonville Road was generally cooler than Uvas Road from May through September (Figure 11). Monthly average daily mean (MEAN) temperatures varied <3.0°C between sites during each month. However, MAX air temperatures were substantially greater at Eagle Ridge and Miller Avenue in all months and reached 43°C at Miller Avenue in July and Eagle Ridge in August (Figure 11). The lowest monthly average daily minimum (MIN) temperatures were at Miller Avenue during all months. Eagle Ridge and Miller Avenue experienced the greatest ranges of temperatures (difference between MAX and MIN values during each month) as compared to the sites located farther upstream.

Water Temperature.—MAX, MEAN, and MIN water temperatures increased with distance downstream in May through July, with the highest MAX water temperature (23.9°C) occurring at Miller Avenue in July (Figure 12). Uvas Reservoir Outflow values reflected the water temperatures within the bottom of the reservoir at the time of release. During the months of May, June, and July, MEAN water temperatures at the Uvas

Reservoir Outflow were lower than MEAN air temperatures downstream of Uvas Dam (Figures 11, 12). By August, the MEAN water temperature (19.4°C) at the Uvas Reservoir Outflow had increased and was within 2.6 degrees of MEAN air temperatures measured at all sites. Between the 13 August and 15 September reservoir profile sampling events, the reservoir became well mixed from top to bottom, and bottom release temperatures increased by 3.7 degrees to 21.9 degrees (Figure 12). In September and October, MEAN, MIN, and most MAX water temperatures cooled downstream (Figure 12).

Turbidity

Turbidity levels generally decreased with distance downstream of Uvas Dam, with the Miller Avenue sites measuring less than 6 NTU during all sampling events (Figure 13). In April, May, and July, turbidity levels at Uvas Road ranged from 14.1 NTU to 18.9 NTU, but increased to 33.1 NTU by 25 August, 37.4 NTU by 01 September, and 43.9 NTU by 18 October as temperature stratification ended in the reservoir. October turbidity levels were constantly higher (33.3 to 43.9 NTU) from Uvas Road to Watsonville Road, and were more than 4 times higher than at Eagle Ridge and more than 12 times higher than at Miller Avenue.

Riparian Canopy Closure and Percent Solar Radiation

Mean riparian canopy closure in May of 2008 was highest at Watsonville Road (84%) and second highest at Uvas Road (73%) (Figure 14). The Eagle Ridge (28%) and Miller Avenue (18%) sites had considerably less canopy closure than the two upstream sites. Many of the large, overhanging willows in the Eagle Ridge reach appeared dead in May and did not leaf out until after the July sampling period. Riparian canopy closure information at the Miller Avenue sample site was collected from 100 m downstream of Miller Avenue because of the inaccessibility of the creek upstream of Miller Avenue due to the Summit Fire base camp. The percent canopy cover as evergreen was at least two times higher in the upstream reach at Uvas Road (15%) and Watsonville Road (18%), than in the downstream reach at Eagle Ridge (7%) and Miller Avenue (3%).

The estimated percent solar radiation, based on Solar Pathfinder™, at the Uvas Road site was approximately 25% in May and increased to 40% by the July sampling event (Figure 15). The percent solar radiation at Uvas Road then declined to 18% by the September sampling event and 5% by the October sampling event. Percent solar radiation at the Watsonville Road site remained low throughout the study period, ranging from 5% to 25% (Figure 15). Percent solar radiation at the Eagle Ridge site was estimated to be 60% to 75% during April through August, but declined to 40% by the October sampling event (Figure 15). Solar radiation at the Miller Avenue site (recorded 0.1 km downstream of Miller Avenue) was estimated to be approximately 90% during the entire study period.

Algae Cover

During the May benthic sampling events, mean algal cover was estimated to be 20-50% at Uvas Road, 0-5% at Watsonville Road, 20-50% at Eagle Ridge, and >50% at Miller Avenue. During the July benthic sampling events, mean algal cover substantially declined at Uvas Road (0-5%), remained 20-50% at Eagle Ridge, and declined at Miller

Avenue (20-50%). During the October benthic sampling events, mean algal cover was generally low at all sites and estimated to be 5-20% at Uvas Road, 0-5% at Watsonville Road, 5-20% at Miller Avenue, and 0-5% at Eagle Ridge.

Substrate and Visual Silt Score

Mean particle size of coarse substrate was highest at Uvas Road (113.6 mm), followed by Eagle Ridge (78.0 mm), Miller Avenue (63.9 mm), and Watsonville Road (59.0 mm). Uvas Road was the only sample site in which the riffle substrate contained large boulders ranging from 250 mm to 610 mm in diameter, which were not included in the particle size assessment. During the May sampling events, the visual silt score was medium at Uvas Road and Watsonville Road and low at Eagle Ridge and Miller Avenue. During the July sampling events, the visual silt score was high at Uvas Road and low at Eagle Ridge and Miller Avenue. During the October sampling events, the visual silt score was high at Uvas Road and Watsonville Road, medium at Eagle Ridge, and low at Miller Avenue.

Benthic Macroinvertebrate Taxa Richness, Abundance, and Biomass

May Benthic Macroinvertebrates.—Mean total sample biomass at Uvas Road (331.4 mg) and Eagle Ridge (308.0 mg) was more than twice that at Watsonville Road (153.7 mg) and nearly four times that at Miller Avenue (79.9 mg) (Figure 16 and Table 3). Family taxa richness was highest at Watsonville Road (19 taxa), followed by Eagle Ridge (16 taxa), Uvas Road (12 taxa), and Miller Avenue (11 taxa) (Table 3).

The mean total biomass and mean length at Uvas Road was greatest for Hydropsychidae (233.6 mg, 7.7 mm, and 70.5% of site biomass), Perlodidae (44.7 mg, 4.6 mm), and Baetidae (36.9 mg, 2.7 mm) (Figure 16 and Table 3). Small Baetidae were the most abundant (288.8), followed by the much larger Hydropsychidae (52.3) and Perlodidae (23.8) (Table 3). Mean length of Hydropsychidae in May at Uvas Road (7.7 mm) was more than 1.5 times longer than at Watsonville Road (4.4 mm), more than 2 times longer than at Eagle Ridge (3.6 mm), and 3 times longer than at Miller Avenue (2.0 mm).

Mean total biomass and mean length at Watsonville Road was also greatest for Hydropsychidae (66.6 mg, 4.4 mm), Perlodidae (58.4 mg, 5.2 mm), and Baetidae (21.5 mg, 2.8 mm) (Figure 16 and Table 3). As at Uvas Road, small Baetidae were the most abundant (139.9), followed by Hydropsychidae (27.0), small Simuliidae (28.6, 3.1 mm), and Perlodidae (20.4).

Mean total biomass and mean length at Eagle Ridge was considerably different from the two upstream sites and was greatest for Simuliidae (142.3 mg, 3.6 mm), Baetidae (79.0 mg, 2.6 mm), and Chironomidae (57.9 mg, 3.7 mm) (Figure 16 and Table 3). Small and thin Simuliidae (1037.7) and Chironomidae (875.8) were the most abundant, followed by Baetidae (603.5).

Mean total biomass and mean length at Miller Avenue was greatest for small Chironomidae (36.0 mg, 1.6 mm), Baetidae (26.5 mg, 1.9 mm), Simuliidae (8.1 mg, 1.6 mm), and Tipulidae (4.3 mg, 8.2 mm) (Figure 16 and Table 3). Chironomidae were the most abundant (3899.8), followed by Simuliidae (618.5), Baetidae (431.2), and Hydroptilidae (15.2) (Table 3).

July Benthic Macroinvertebrates.—By July, mean total biomass was greatest at the two downstream sites, Eagle Ridge (197.6 mg) and Miller Avenue (271.6 mg), and biomass at the upstream Uvas Road site had declined by nearly two-thirds to 119.2 mg (Figure 16 and Table 4). Family taxa richness was highest at Eagle Ridge (20 taxa), followed by Uvas Road (17 taxa), and Miller Avenue (16 taxa).

The mean total biomass and mean length at Uvas Road consisted primarily of Hydropsychidae (94.5 mg, 5.4 mm) and much smaller Baetidae (10.2 mg, 3.0 mm) (Figure 16 and Table 4). Small Baetidae were the most abundant (62.0), followed by Hydropsychidae (47.2).

Mean total biomass and mean length at Eagle Ridge was greatest for Baetidae (101.2 mg, 3.1 mm), Chironomidae (35.7 mg, 3.4 mm), Hydropsychidae (32.6 mg, 6.0 mm), and Hydroptilidae (14.3 mg, 3.0 mm) (Figure 16 and Table 4). Chironomidae were the most abundant (615.9), followed by Baetidae (615.9), Hydroptilidae (135.4), and the much larger Hydropsychidae (15.4).

Biomass more than tripled from May to July at Miller Avenue and mean total biomass and mean length was greatest for Baetidae (115.7 mg, 4.0 mm), Crangonyctidae (56.9 mg, 3.0 mm), Chironomidae (54.4 mg, 3.9 mm), and Hydroptilidae (25.2 mg, 3.5 mm) (Figure 16 and Table 4). Chironomidae was the most abundant (658.8), followed by Baetidae (337.2), Crangonyctidae (201.8), and Hydroptilidae (148.2).

October Benthic Macroinvertebrates.—Mean total biomass of the benthic macroinvertebrate samples at Eagle Ridge (673.8 mg) was at least 4 times greater than the other 3 sites and more than twice any of the May or July samples (Figure 16 and Table 5). Miller Avenue had the next greatest biomass (152.6 mg) and twice that of the upstream reach sites (67.2 to 76.3 mg). Family taxa richness was highest at Uvas Road (14 taxa), followed by Miller Avenue (12 taxa), Eagle Ridge (11 taxa), and Watsonville Road (10 taxa) (Table 5).

Mean total biomass and mean length at Uvas Road was greatest for Hydropsychidae (56.1 mg, 5.8 mm) and Simuliidae (13.8 mg, 3.5 mm) (Figure 16 and Table 5). The smaller Simuliidae (95.0) and Chironomidae (57.0) were the most abundant, followed by Hydropsychidae (33.3).

Mean total biomass and mean length at Watsonville Road was greatest for Hydropsychidae (56.1 mg, 6.1 mm), Elmidae (3.7 mg, 4.0 mm), and Baetidae (3.1 mg, 3.1 mm) (Figure 16 and Table 5). Hydropsychidae was the most abundant (36.3), followed by Baetidae (25.8), Simuliidae (9.5), and Elmidae (9.0).

Mean total biomass and mean length at Eagle Ridge was greatest for Hydropsychidae (559.4 mg, 6.1 mm), followed by Baetidae (65.5 mg, 3.5 mm) and Elmidae (32.7 mg, 3.9 mm) (Figure 16 and Table 5). Hydropsychidae was the most abundant (315.0), followed by small Baetidae (249.7) and Elmidae (74.7).

Mean total biomass and mean length at Miller Avenue was greatest for Baetidae (98.3 mg, 3.9 mm), Crangonyctidae (25.0 mg, 4.1 mm), and Tricorythidae (10.2 mg, 1.5

mm) (Figure 16 and Table 5). Baetidae was the most abundant (321.0), followed by Crangonyctidae (57.8) and Tricorythidae (23.0).

Drifting Macroinvertebrate Taxa Richness, Density, and Biomass

May Drifting Macroinvertebrates.—Mean total biomass of drifting macroinvertebrates in May was much greater at Eagle Ridge (317.8 mg) and Miller Avenue (212.4 mg) than at Watsonville Road (141.4 mg) and Uvas Road (77.1 mg) (Figure 17 and Table 6). Water velocities recorded at the net at the time of deployment were 0.74 m/s (2.4 f/s) at Uvas Road, 0.49 m/s (1.6 f/s) at Watsonville Road, 0.62 m/s (2.1 f/s) at Eagle Ridge, and 0.36 m/s (1.2 f/s) at Miller Avenue.

At Uvas Road, Baetidae had the highest mean total biomass (28.1 mg), followed by Simuliidae (9.3 mg), and Chironomidae (7.5 mg) among aquatic species. Mean total biomass of terrestrial macroinvertebrates (23.9 mg) made up 31% of the total drift at Uvas Road (Figure 17 and Table 6). Terrestrial invertebrate biomass at all sites was comprised mainly of large Formicidae (ants), other Hymenoptera (bees and wasps), Hemiptera (true bugs), and Coleoptera (beetles). Simuliidae had the highest drift density (111.9 #/100 m^3), followed by Chironomidae (77.0 #/100 m^3), Baetidae (56.0 #/100 m^3), and generally larger terrestrial invertebrates (18.4 #/100 m^3) (Table 6).

At Watsonville Road, Chironomidae had the highest mean total biomass (138.0 mg), followed by Simuliidae (22.2 mg), Baetidae (14.8 mg), and Corixidae (8.5 mg) among aquatic species (Figure 17 and Table 6). Total mean biomass of terrestrial macroinvertebrates (27.4 mg) made up 54% of the total drift at Watsonville Road.

Chironomidae had the highest drift density (138.0 #/100 m^3), followed by terrestrial invertebrates (27.4 #/100 m^3), Simuliidae (22.2 #/100 m^3), and Baetidae (14.8 #/100 m^3).

At Eagle Ridge, Simuliidae had the highest mean total biomass (127.1 mg), followed by Chironomidae (113.9 mg), and Baetidae (34.2 mg) among aquatic species (Figure 17 and Table 6). Total mean biomass of terrestrial macroinvertebrates (38.5 mg) made up 12% of the total drift at Eagle Ridge. Chironomidae had the highest drift density (810.2 #/100 m^3), followed by Simuliidae (563.5 #/100 m^3), Baetidae (76.4 #/100 m^3), and terrestrial macroinvertebrates (30.1 #/100 m^3).

At Miller Avenue, Simuliidae had the highest total mean biomass (80.9 mg), followed by Chironomidae (77.1 mg) and Baetidae (33.9 mg) among aquatic species (Figure 17 and Table 6). Total mean biomass of terrestrial macroinvertebrates (17.4 mg) made up 8% of the total drift at Miller Avenue. Simuliidae had the highest drift density (1023.3 #/100 m^3), followed by Chironomidae (808.8 #/100 m^3), Baetidae (206.4 #/100 m^3), and terrestrial macroinvertebrates (13.6 #/100 m^3).

DISCUSSION

The overwhelming majority of the mean total biomass of drifting organisms (84% to 99%) at all four Uvas Creek sample sites in May 2008 was comprised of Ephemeroptera (primarily Baetidae), Simuliidae, Chironomidae, and terrestrial invertebrates, indicating that these organisms may be the most important for drift feeding fish in spring. Even though the two downstream sites had been dry the previous summer, mean total drift biomass of Ephemeroptera, Simuliidae, Chironomidae, and terrestrial invertebrates was much higher at the downstream sites, Eagle Ridge (313.7 mg) and Miller Avenue (209.3 mg), than at the upstream sites, Uvas Road (69.0 mg) and Watsonville Road (112.8 mg).

Benthic samples had greater mean total biomass at the Uvas Road site in May 2008 as compared to downstream sites, primarily due to the presence of large hydropsychid larvae; these likely overwintered (Steve Fend, USGS, pers comm.). Additionally, Hydropsychidae has been found to be more abundant closer to lake outfalls due to the steady supply of high nutrient seston (e.g., lake-derived plankton) available to filter-feeding macroinvertebrates (Oswood 1979). Despite Hydropsychidae making up 70.5% of the total biomass found in Uvas Road benthic samples in May, it comprised only 2.6% of the mean total biomass found in Uvas Road drift during the same month. However, Smith and Li (1983) and Casagrande (2010) found Hydrosychidae common in fall drift samples. These larger organisms may have been less likely to drift in May, possibly because hydropsychid larvae inhabit “fixed-retreats” attached to boulder or cobble substrate (Wiggins 1996). In addition, the large mean size of Hydropsychidae larvae (7.7 mm length) at Uvas Road in May would have excluded them from the available food supply of small young of the year (YOY) juvenile Steelhead in spring.

As the year progressed, mean total biomass of benthic macroinvertebrates at the downstream sites increased and greatly exceeded that of the upstream sites. This was likely due to the gradual increase in BMI productivity at the previously dry sites, and also to the more favorable growth conditions for BMIs (warmer water, cleaner substrate, and more sunlight) at Eagle Ridge and Miller Avenue.

2007 Stream Dryback Effects

The drought conditions and subsequent reduced reservoir summer releases in 2007 resulted in drying of the two lower sites sampled in 2008. Due to the dryback, rearing juvenile Steelhead and BMIs were restricted to the wet portions of the stream during most of 2007. This may partially explain the presence of large overwintering Hydropsychidae larvae only in the perennial upstream reach in May 2008. At the two downstream sites, BMIs, including hydrosychids, had to colonize and grow. Additionally, the dryback killed the upper trunks of willows, particularly at the Eagle Ridge sample site, reducing and delaying the amount of canopy. This opened up the canopy, especially in early summer 2008, which in turn increased sunlight and primary productivity during that time. Simuliidae, Chironomidae, and grazing Baetidae were quick to colonize following the 2007 dryback and were most abundant at downstream sites in May 2008.

2008 Stream Flow

During the May through October study period, releases from the reservoir made up almost all of the stream flow and were at least 0.34 m^3/s (12 f^3/s). However, stream flow gradually decreased by as much as 0.28 m^3/s (10 f^3/s) from upstream to downstream primarily due to stream bed percolation.

The higher biomass and density of drifting organisms at Eagle Ridge and Miller Avenue occurred despite the substantially lower overall stream flow and velocity relative to the upstream sites, reflecting much higher densities and possible tendency to drift because of the high densities (Hildebrand 1974; Allan 1995).

Water Temperature and Macroinvertebrates

Since Ephemeroptera, Simuliidae, and Chironomidae drift rates in May mirrored benthic biomass (r^2=0.564, Figure 18), they are also likely to be key components of drift in July and October. Analyzing benthic abundance and biomass of these organisms may give a useful comparison of food availability for drift feeding fish (Weber et al. 2014). Total mean abundance and mean biomass of benthic Ephemeroptera, Simuliidae, and Chironomidae in July, when water temperatures at the downstream sites were highest, were much greater at Eagle Ridge (1259.5, 142.4 mg) and Miller Avenue (1007.5, 174.9 mg) than at Uvas Road (135.4, 19.2 mg). Hydropsychidae benthic abundance was not reflected in the May drift results.

Upstream temperatures increased in late August and September due to reservoir destratification, and remained higher than the downstream sites through October. However, total mean abundance and mean biomass of benthic Ephemeroptera, Simuliidae, and Chironomidae in October remained relatively low at upstream sites, Uvas Road (170.7, 17.6 mg) and Watsonville Road (36.7, 4.2 mg), as compared to downstream sites, Eagle Ridge (337.4, 73.4 mg) and Miller Avenue (385.0, 112.6 mg). This condition may present a challenge to Steelhead residing in the upstream reach during reservoir destratification if water temperatures quickly increase food demands while food supply remains low (Weber et al. 2014).

Sediment and Turbidity

The Miller Avenue sites had low turbidity levels (<6 NTU) during the entire study period. Conversely, the upstream sites responded more to changes in reservoir conditions, with higher turbidity levels (>30 NTU) occurring in response to reservoir destratification and mixing. Increased turbidity levels can indicate increased fine sediment deposition on the streambed, which reduces habitat value for most BMIs (Kaller and Hartman 2004).

Uvas Reservoir is a bottom-release reservoir, and turbidity levels are high immediately downstream of Uvas Dam in winter and early spring due to suspended sediments in the storm flows that fill the reservoir. This situation is exacerbated during drought years when reservoir levels are low and bottom sediments are easily mixed into the water column. During the study period, the increase in Uvas Creek turbidity levels in late August corresponded with increased mixing of the water column in Uvas Reservoir due to reservoir draw down and seasonal destratification. In addition, sediment was also input into Uvas Creek from homesite development and vineyards along Uvas Creek and in the Little Arthur Creek watershed, which discharges immediately upstream of Watsonville Road (Smith 2007). The streambed was quite silty from Uvas Dam downstream to about midway between Watsonville Road and Highway 152. By the time flows reached the Eagle Ridge and Miller Avenue sample sites, much of the sediment had settled out and turbidity levels at those locations were much lower and substrate appeared much cleaner.

Canopy Closure

Canopy closure reduces stream heating, but open canopy reaches can provide sunlight to fuel primary productivity (Myrick and Cech 2005). Algae can provide food and cover for growing BMIs, which then become food for drift feeding fish such as

Steelhead. The BMIs that were most abundant in Uvas Creek, Hydropsychidae, Baetidae, Simuliidae, and Chironomidae, are collector-gatherers, collector-filterers, and grazing scrapers, which depend upon algae and FPOM from algae as food (Waters 1972; Merritt and Cummins 1996). In general, during the May and July 2008 sampling events, higher levels of algal coverage in the downstream sites as compared to upstream sites (particularly Watsonville Road) was likely due to the more open canopy.

Terrestrial Macroinvertebrate Contribution to Drift

Terrestrial drift as a percent of mean total drift biomass was strongly correlated ($r^2 = 0.945$) with canopy closure (Figure 19). This would seem to make sense as terrestrial invertebrates (ants, wasps, beetles) falling from vegetation should increase with more vegetation. However, the absolute amount of terrestrial drift was similar (24.0 to 38.5 mg) among shaded Uvas Road and sunnier Eagle Ridge and Miller Avenue. All three had less terrestrial drift than the very shaded Watsonville Road (76.7 mg; Figure 20). The big difference in relative contribution of terrestrial drift was because of the much greater drift as aquatic invertebrates at the sunnier sites; total drift biomass was 212.4 to 317.8 mg at the sunny downstream sites compared to 77.1 to 141.4 mg at the shaded upstream sites. At the less shaded downstream sites, there was still a bushy border of willows and shrubs that apparently supported abundant terrestrial invertebrates.

Uvas Creek Steelhead

This study was designed to complement a study conducted by Joel Casagrande in Uvas Creek during fall of 2005 to 2008 to document juvenile Steelhead distribution, densities, growth, and habitat use (Casagrande 2009; Casagrande 2010). The Casagrande study included sample sites in the vicinity of Uvas Road, Old Creek Road, Watsonville Road, Highway 152, and Miller Avenue. Similar to previous years (Smith and Li 1983), Casagrande (2009) found that 99% of the Steelhead captured in 2008 were young of the year (YOY) fish. Fish densities (number of fish per 30.5 meters of stream sampled) and mean standard lengths of YOY Steelhead were lower at the upstream sites of Uvas Road (7.6, 69 mm), Old Creek Road (7.9, 70 mm), and Watsonville Road (5.2, 58 mm) as compared to the downstream sites of Highway 152 (67.4, 90 mm) and Miller Avenue (23.5, 98 mm) (Table 7; Casagrande 2009). Downstream sites experienced higher mean water temperatures than upstream sites from May through August 2008. Myrick and Cech (2005) documented increased Steelhead growth rates in warmer water when food was abundant. However, Casagrande (2009) indicated that the increased densities observed in 2008 may have been the result of a reduction in warm water predators and a more open canopy caused by the 2007 dryback, which likely increased food production. Additionally, Casagrande (2009) concluded that the high shade, silty substrate, and seasonal turbidity conditions observed at the upstream sites limited the growth and survival of Steelhead. Turbidity is also an issue for feeding efficiency of Steelhead (Sigler et al. 1984; Barret et al. 1992), and the downstream sites provided both clearer water and less shading to interfere with drift feeding.

The results of this macroinvertebrate study support the findings of the Casagrande study in that mean total biomass of benthic macroinvertebrates collected in October 2008, when Steelhead sampling was also conducted (Casagrande 2009), was more than 4 times greater at Eagle Ridge (located approximately 0.6 km downstream of Highway 152) and more than 2 times greater at Miller Avenue than at the upstream sites. Similarly, the May 2008 drift results showed that mean total biomass of drifting BMIs (excluding terrestrial organisms) was more than 4 times higher at Eagle Ridge and more than 3 times higher at Miller Avenue than at the upstream sites. Even with terrestrial drift included, downstream mean total biomass (212.4 mg to 317.8 mg) was much greater than upstream mean total biomass (77.1 mg to 141.4 mg). Overall, these results indicate that substantially more food was available for rearing juvenile Steelhead in the warmer, less turbid and silty, more open canopied reaches. Despite the warmer water and higher metabolic rates, conditions for Steelhead growth were better due to the presence of higher visibility conditions and abundant food (Myrick and Cech 2005; Weber et al. 2014).

Management Implications

Since open canopy was associated with higher food availability and with potentially more efficient feeding (see also Sigler et al. 1984; Barret et al. 1992), reduction in canopy could be beneficial for drift-feeding Steelhead. Although higher water temperatures in less shaded habitat also raises metabolism and increases food demands, the increase in food availability and digestion rate improve fish growth (Smith and Li 1983; Myrick and Cech 2005). This will increase the likelihood that Steelhead will be big enough to smolt as yearlings and successfully make it to the ocean (Sogard et al. 2012). These conditions often contrast with goals and mitigation measures of resource agencies, which desire dense canopy cover to reduce water temperatures. In natural stream conditions, a stream is subject to both flooding and drought, both of which thin riparian vegetation and partially open the canopy in certain locations. Since Uvas Creek is a reservoir-regulated stream system, flood flows are attenuated and, during non-drought years, flows are generally constant from Uvas Dam downstream to Gilroy. Casagrande (2010) documented the historic changes in riparian canopy conditions at the upstream sites, where canopy cover increased substantially from 1970 to 2008 between Uvas Dam and Highway 152. Therefore, removing riparian trees and opening up portions of the canopy in select locations, such as over riffles, can actually produce both a more natural condition and a condition more suitable for insect production and fish growth. Selective openings would also have relatively minor effects on stream temperature (Sullivan 2002) and could be directed first at removal of invasive, non-native *Acacia*.

Managing Uvas reservoir during non-drought years to extend flow beyond the Miller Avenue crossing would increase the length of the productive feeding area and the stream flow for rearing juvenile Steelhead within that area. The periodic drybacks during droughts can also have unexpected benefits by reducing riparian encroachment.

Reservoir spilling produces greater flows and velocities downstream of a dam, which may rinse out fine sediment and collapse or destroy vegetation (Kim and Choi 2013). Uvas Reservoir had not spilled for two years prior to the study period and substantial spills have been rare because of winter releases to prevent large spills. However, increasing reservoir spilling during non-drought years could be used to reduce siltiness and substrate embeddedness in the stream channel and to thin vegetation, which in turn could increase insect productivity and water clarity. Similarly, an aggressive vineyard erosion and sediment control program along Uvas Creek and in the Little Arthur Creek watershed should be pursued in Santa Clara County to reduce excessive sediment input into sensitive aquatic habitats. A program could be modeled after established Vineyard Erosion and Sediment Control (VESCO) programs in Marin and Sonoma counties, which require best management practices for vineyards to reduce impacts to stream water quality (County of Marin 2014; County of Sonoma 2014).

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FIGURES

FIGURE 1.—Vicinity map showing the Pajaro River watershed, including the Uvas Creek sub-watershed (in bold) and other major tributaries.

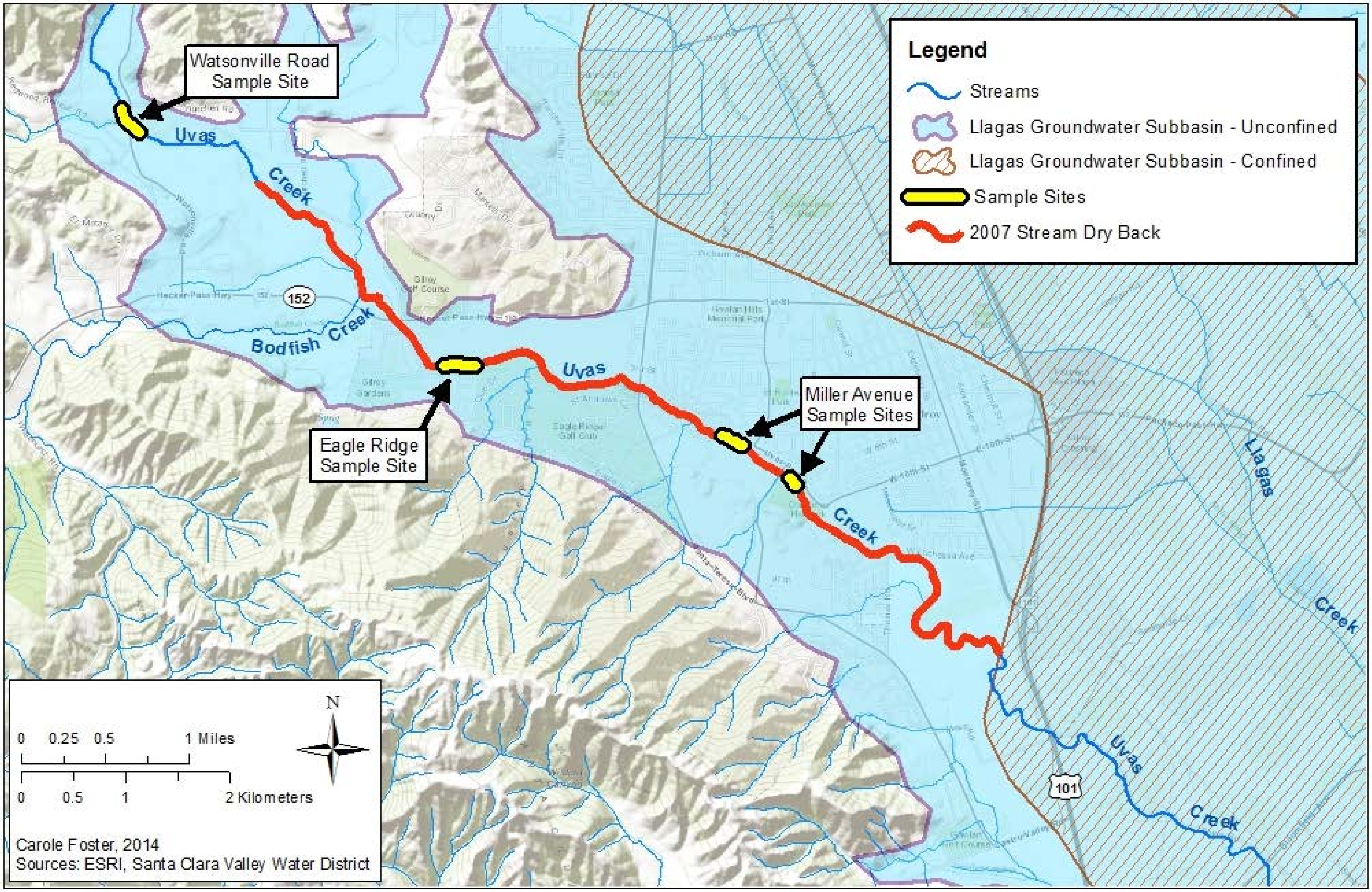

FIGURE 2.—Confined and unconfined Llagas groundwater subbasins, including location of 2007 dryback zone.

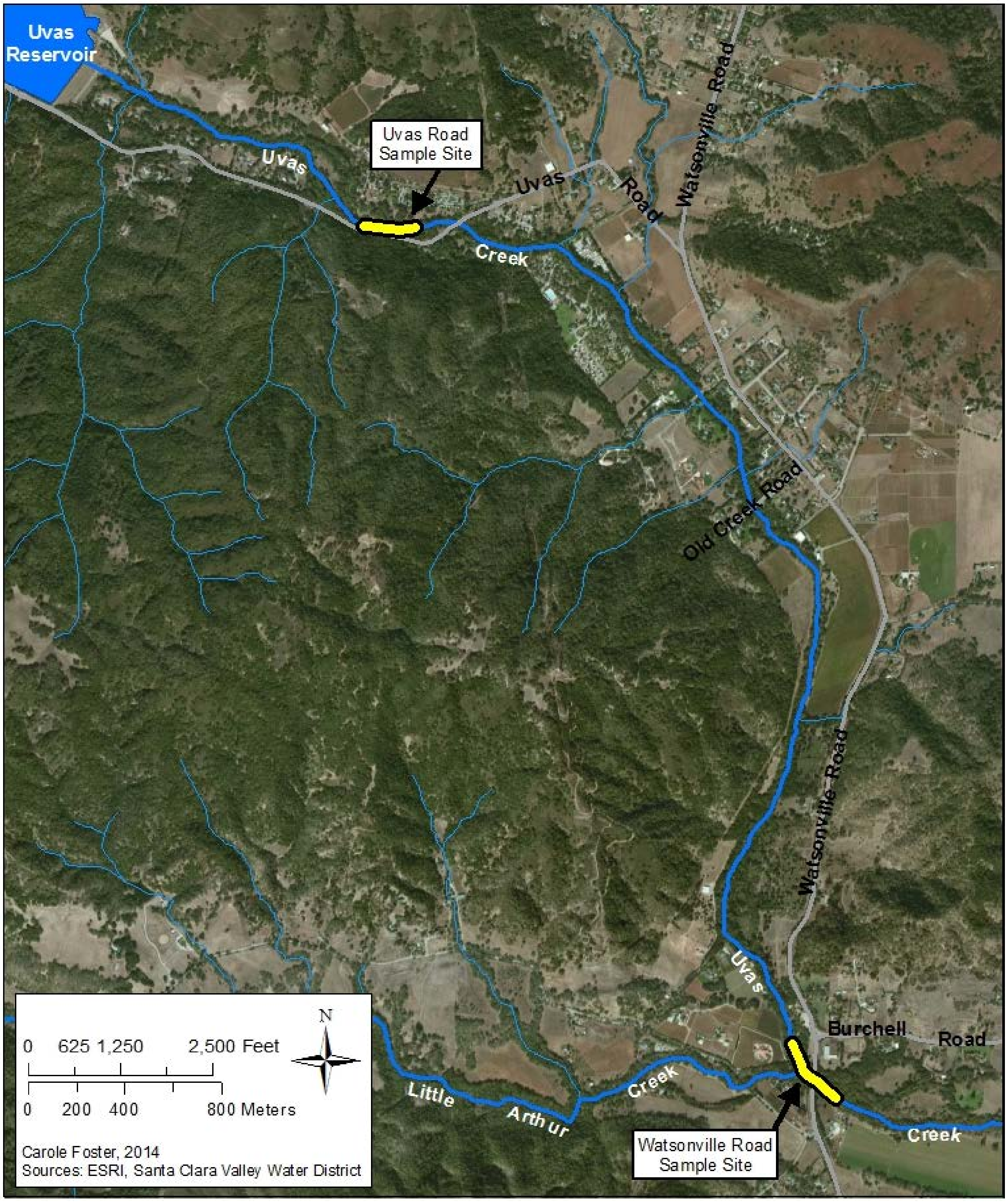

FIGURE 3.—Uvas Road and Watsonville Road macroinvertebrate sample sites in the designated "upstream" reach, which is characterized by higher flows and a dense riparian canopy.

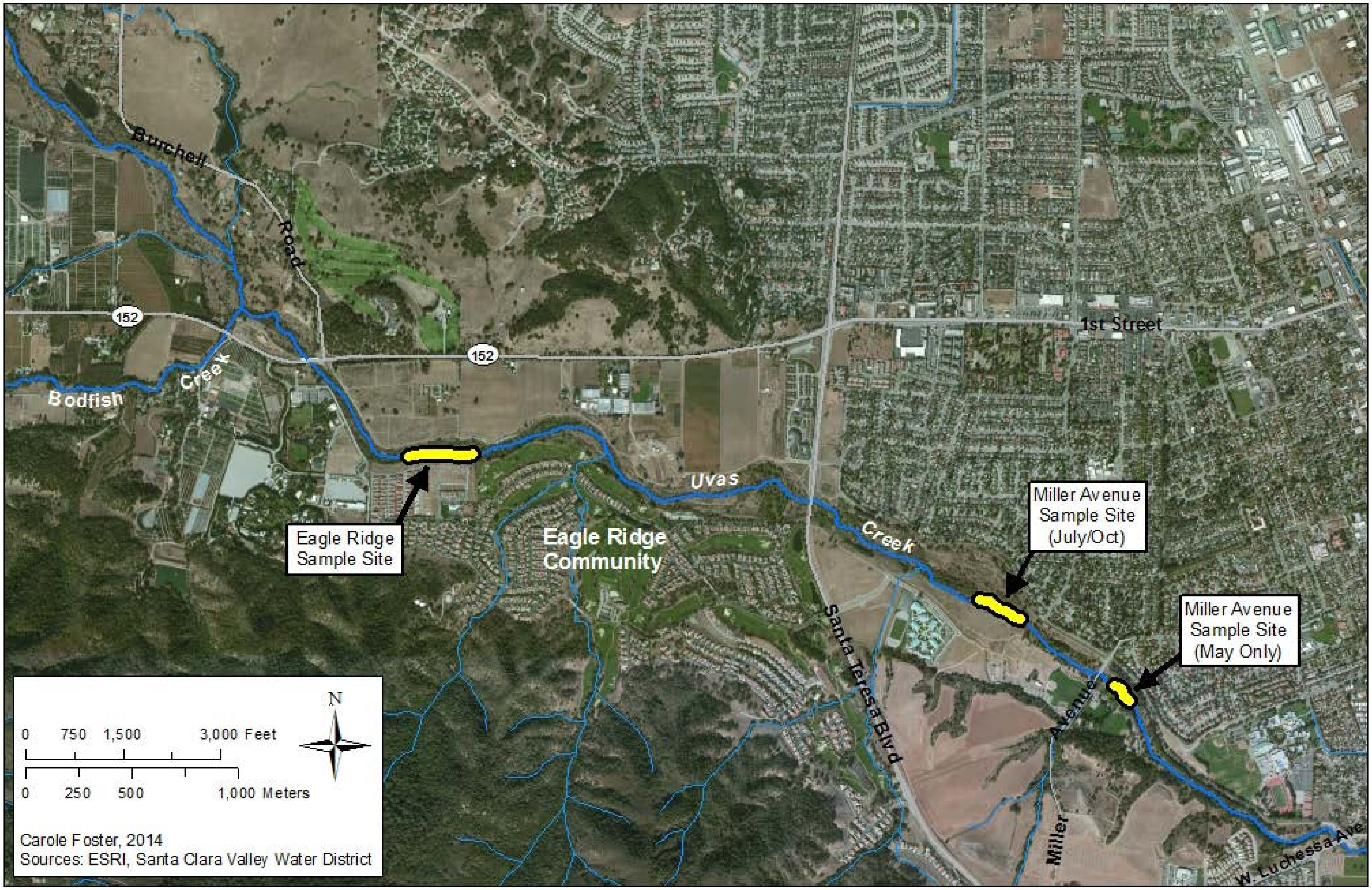

FIGURE 4.—Eagle Ridge and Miller Avenue sample sites in the designated "downstream" reach, which is characterized by lower flows and more open riparian canopy.

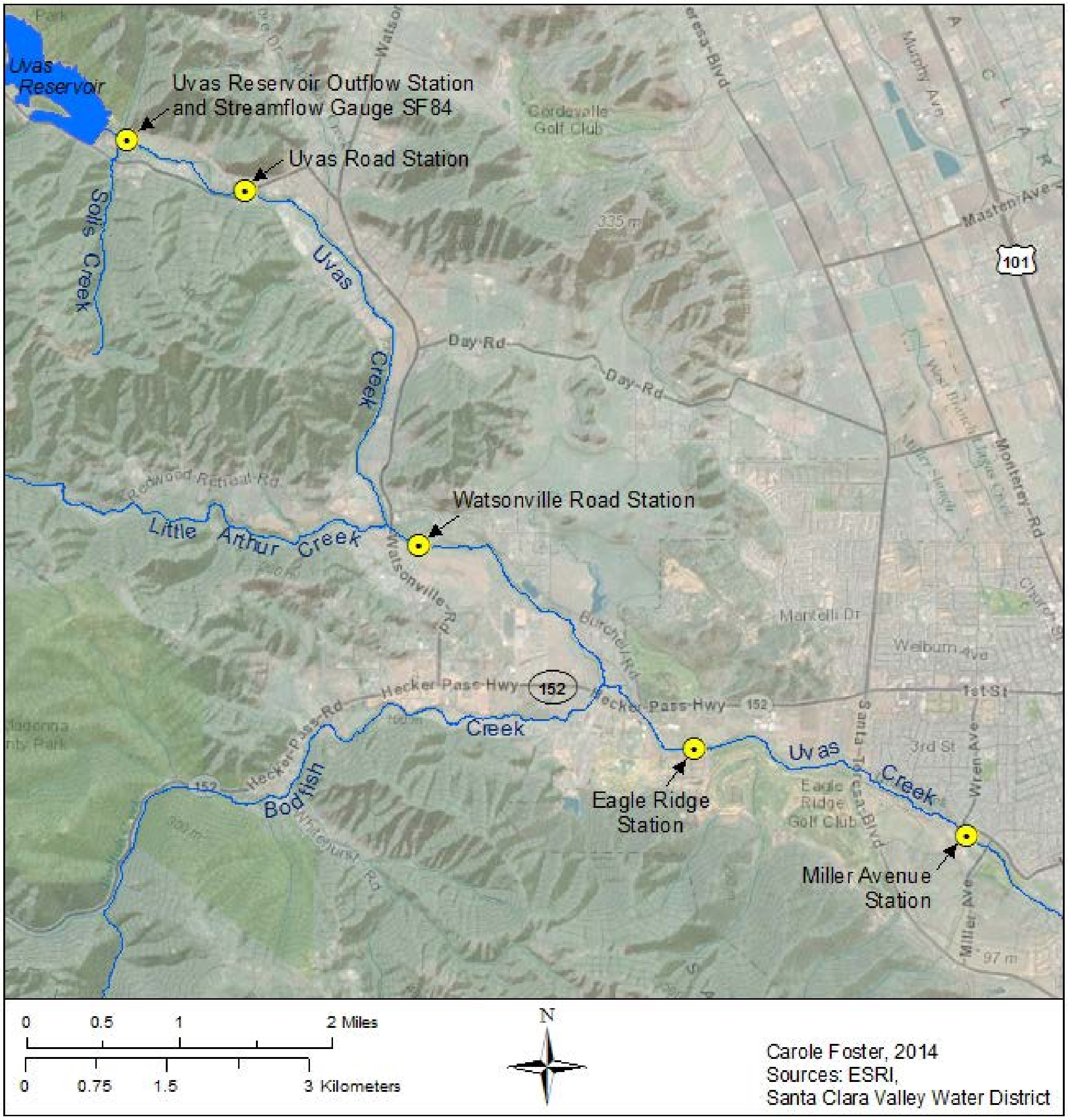

FIGURE 5.—Air/water temperature stations, including location of SCVWD streamflow gauging station SF 84.

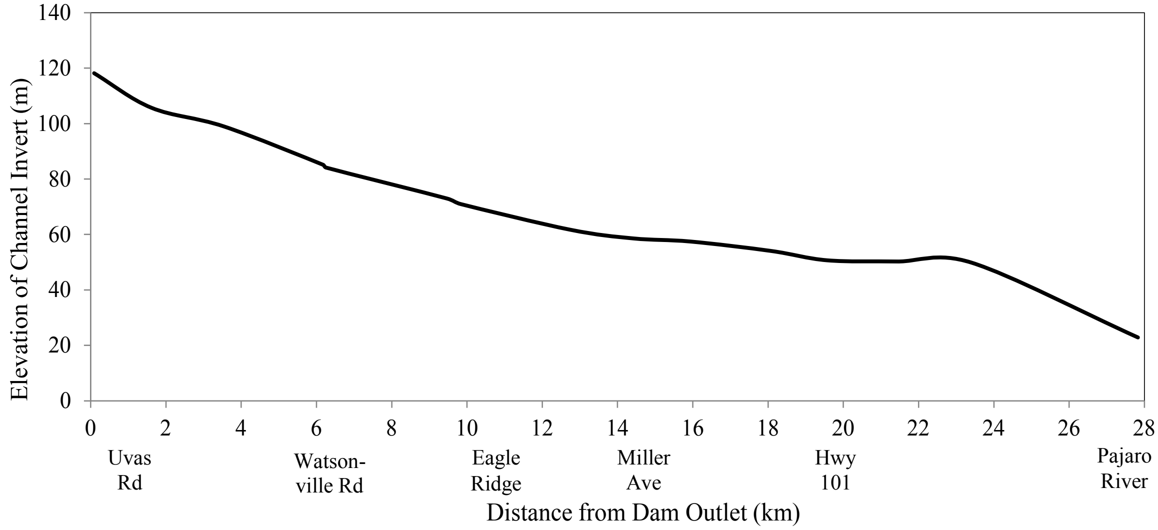

FIGURE 6.—Longitudinal profile from upstream (left) to downstream (right) of the Uvas Creek channel elevation in meters in stream kilometers from Uvas Dam (0 km) to the Pajaro River confluence (28 km), as recorded by the SCVWD (SCVWD 2008b).

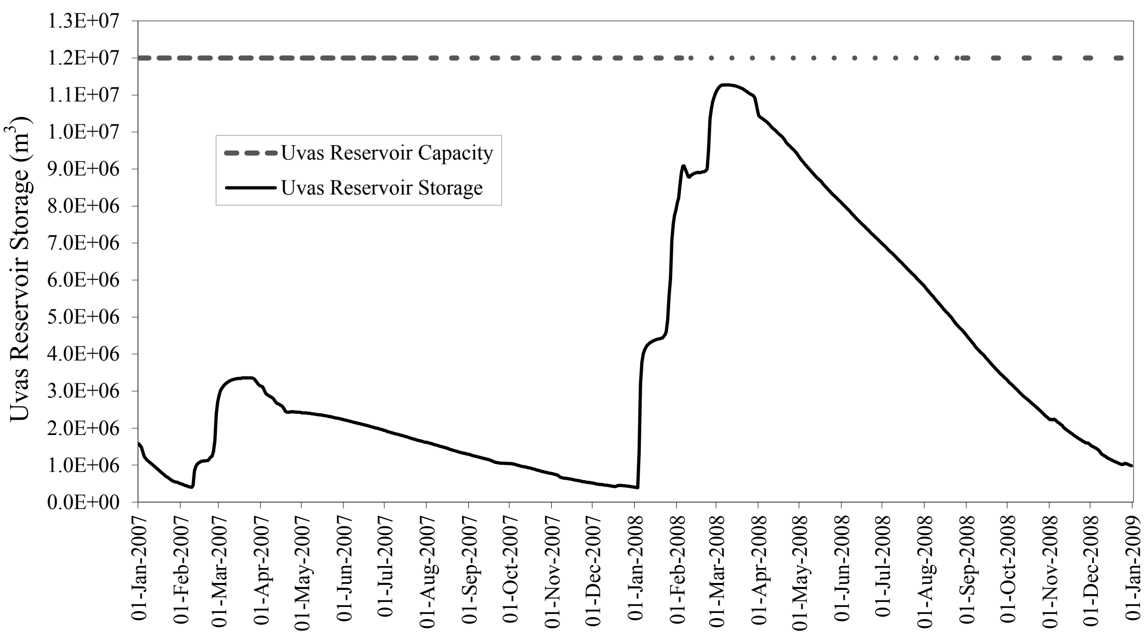

FIGURE 7.—Uvas Reservoir storage during 2007 and 2008 (SCVWD 2008a). Uvas Reservoir storage at maximum capacity is 1.2E+07 m³ = 9,835 acre-feet.

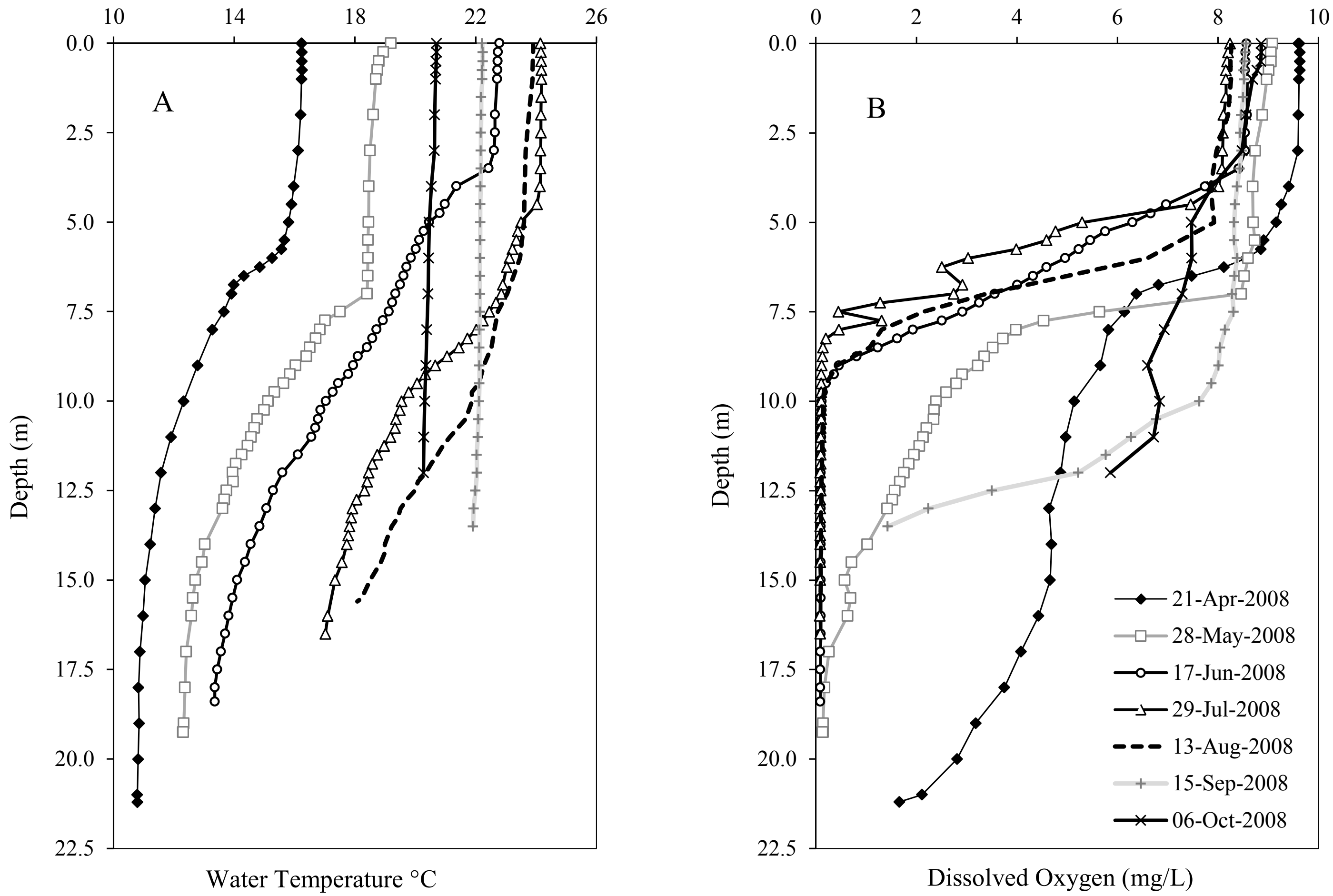

FIGURE 8.—Surface to bottom (A) water temperature and (B) dissolved oxygen concentrations collected in Uvas Reservoir near Uvas Dam, April through October, 2008.

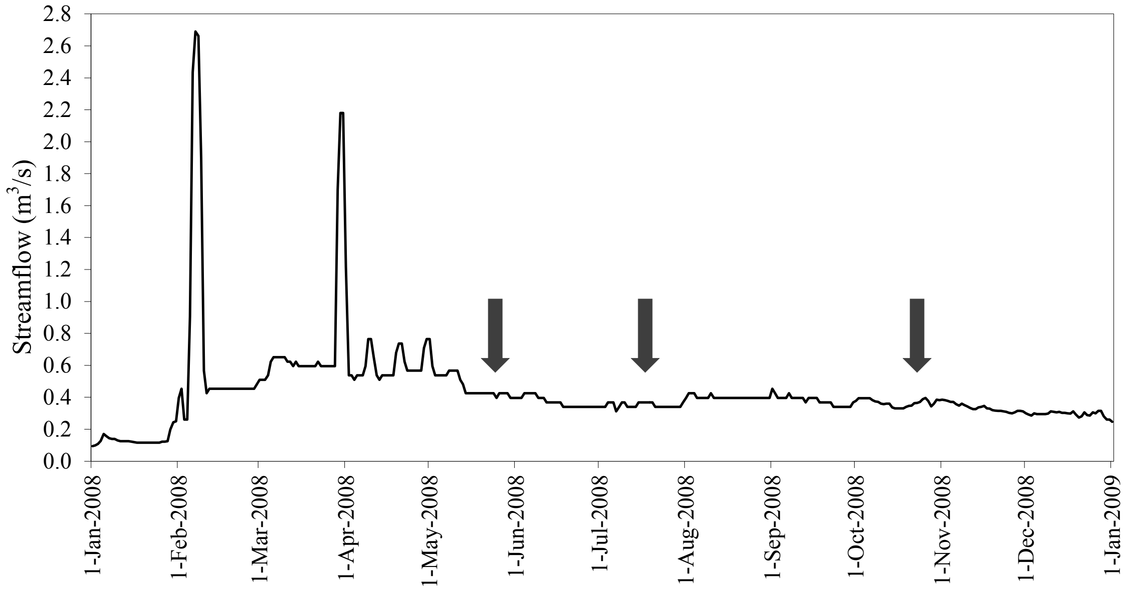

FIGURE 9.—Daily mean stream flow released from Uvas Dam recorded by SCVWD Alert System Gage SF 84, located approximately 100 m downstream of the Uvas Dam outlet (01 Jan 2008 - 01 Jan 2009). Note: four pulse flows released during March and April for Steelhead adult access and smolt outmigration (0.74 to 2.66 m^3/s). Stream flow fluctuated between 0.3 and 0.6 m^3/s during the study period. Arrows indicate sampling events.

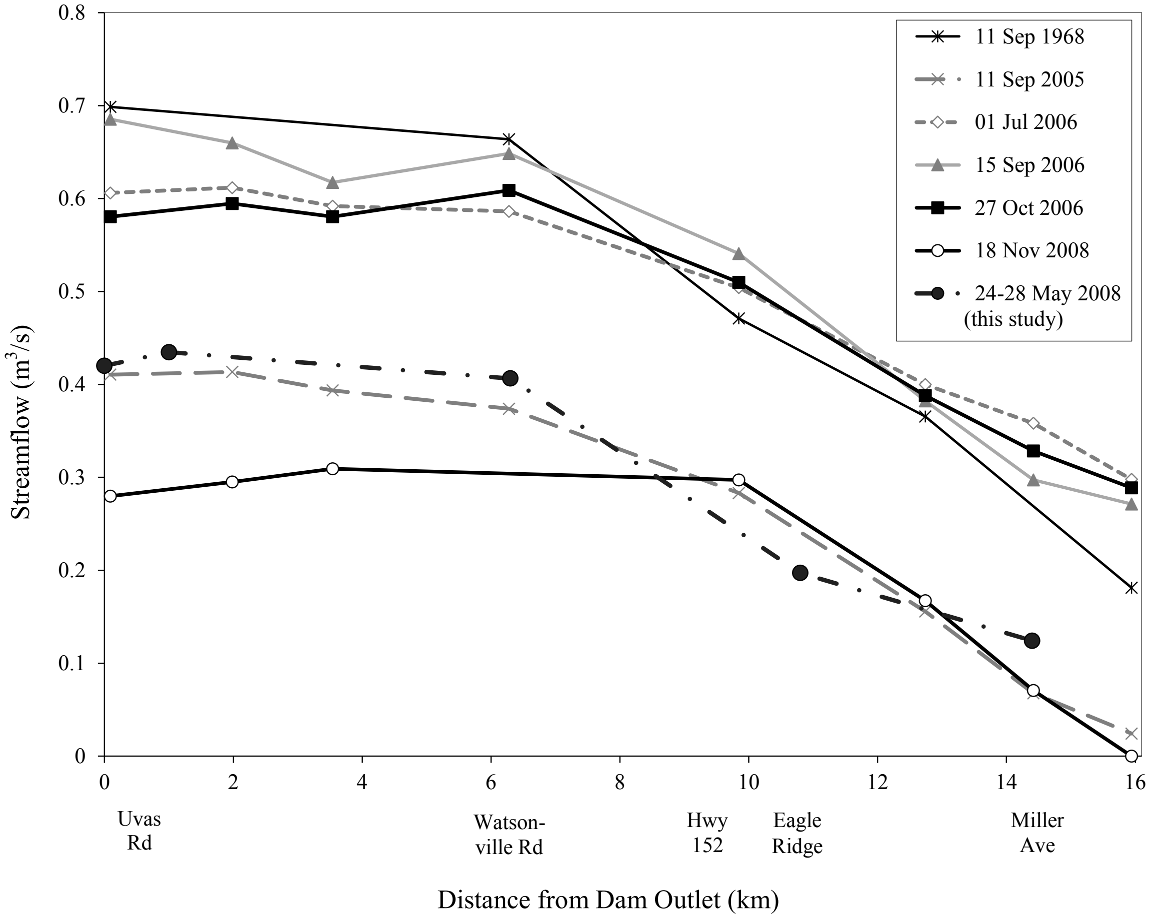

FIGURE 10.—Stream discharge measured at the four sample sites from 24-28 May 2008 during benthic macroinvertebrate sampling events on Uvas Creek from Uvas Dam to Miller Avenue in Gilroy, California. All other stream discharge measurements were recorded by SCVWD (SCVWD 2008b) during percolation tests on Uvas Creek from Uvas Dam to W. Luchessa Avenue.

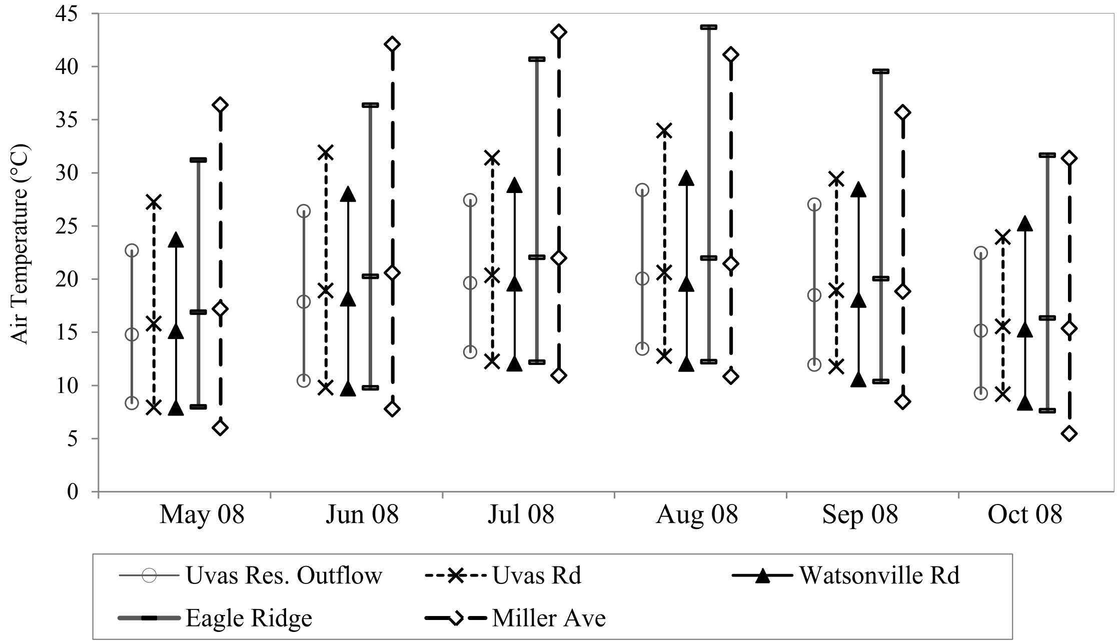

FIGURE 11.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) air temperatures at five sites along Uvas Creek May – October, 2008. Sites in order from upstream (left) to downstream (right) (Figure adapted from Casagrande 2010).

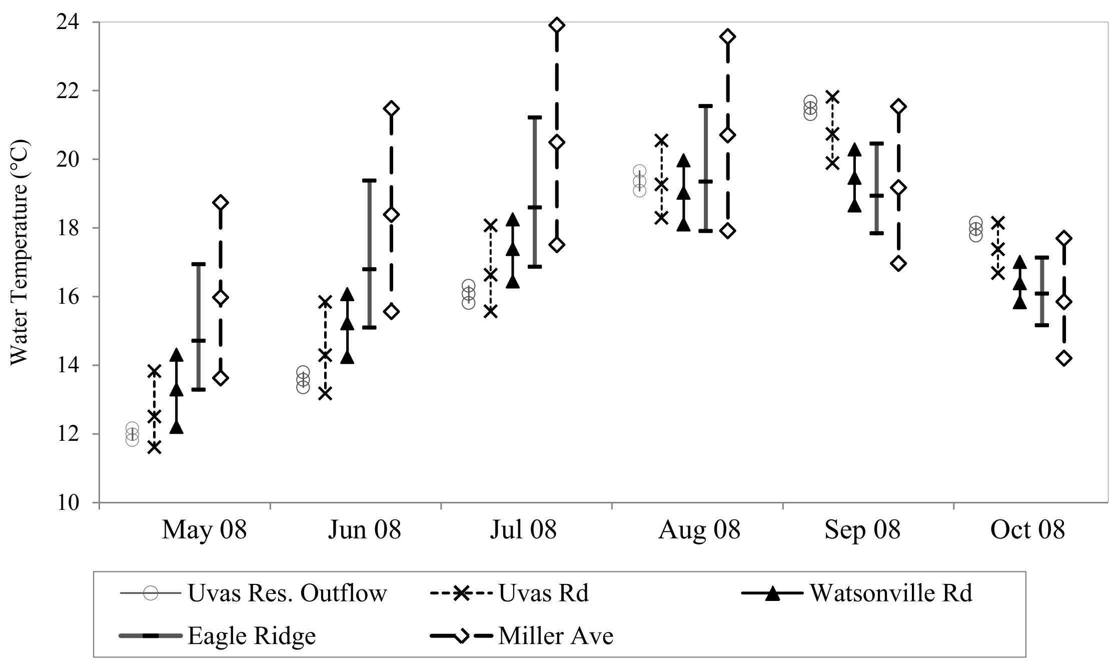

FIGURE 12.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) water temperatures at five sites along Uvas Creek May – October, 2008. Sites in order from upstream (left) to downstream (right) (Figure adapted from Casagrande 2010).

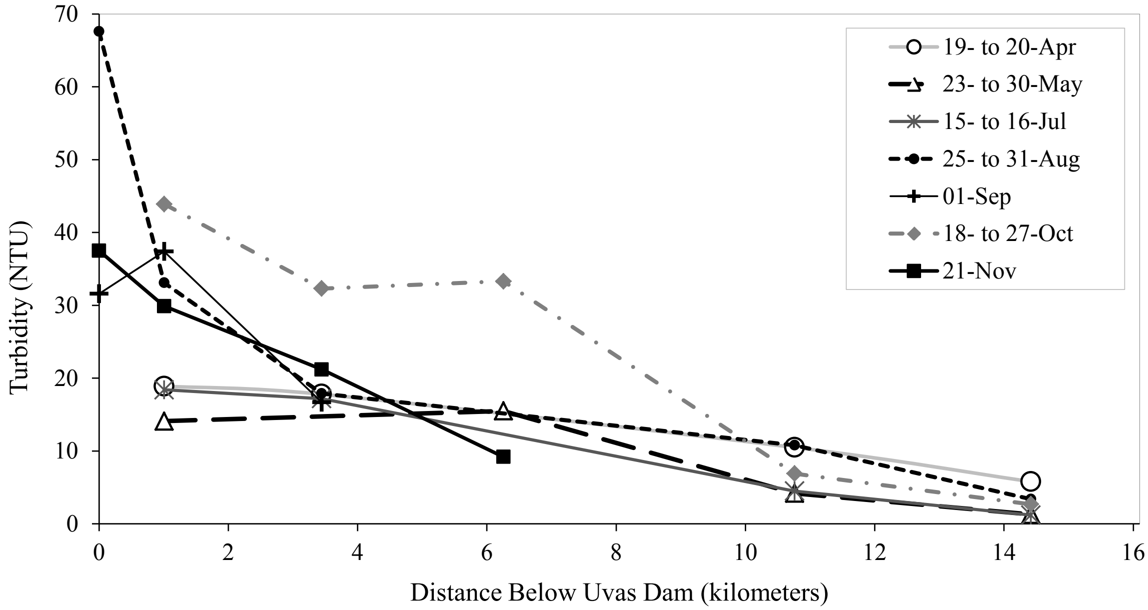

FIGURE 13.—Turbidity in Uvas Creek by river kilometer downstream of Uvas Dam for various dates in 2008 (river kilometer 0 is at Uvas Dam and river kilometer 14.3 is at Miller Avenue).

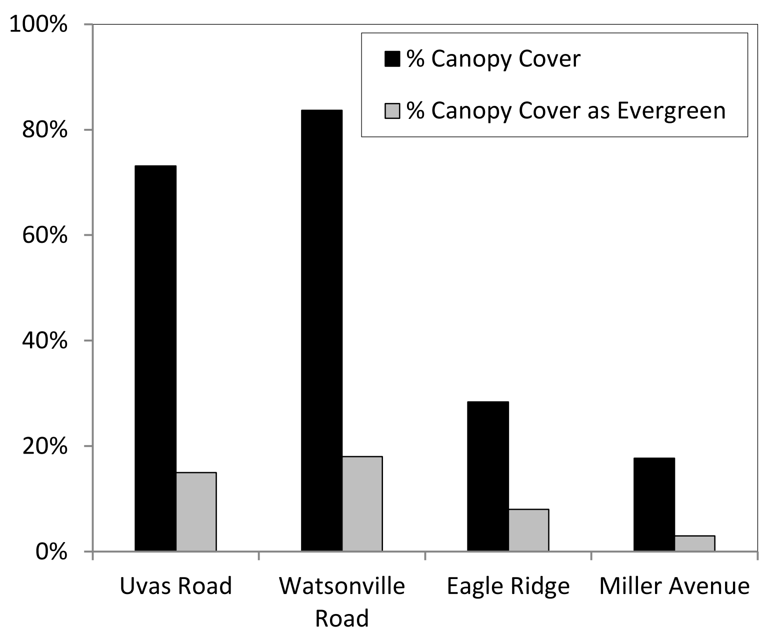

FIGURE 14.—Percent canopy cover and percent canopy cover as evergreen in May 2008 at the four Uvas Creek invertebrate sampling sites (upstream to downstream, left to right).

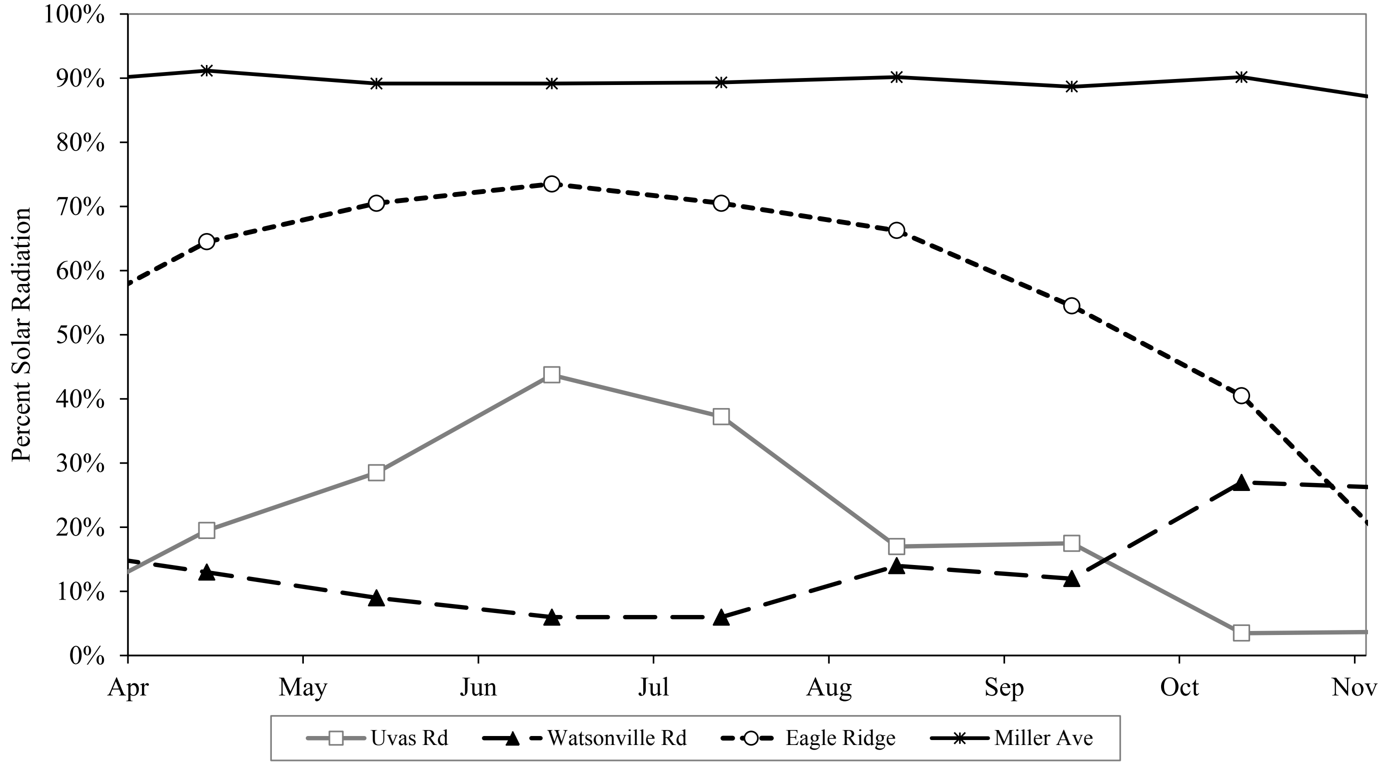

FIGURE 15.—Estimated percent solar radiation based on Solar Pathfinder™ data recorded at four sample sites (Uvas Road, Watsonville Road, Eagle Ridge, and 100 m downstream of Miller Avenue) between August and October 2008.

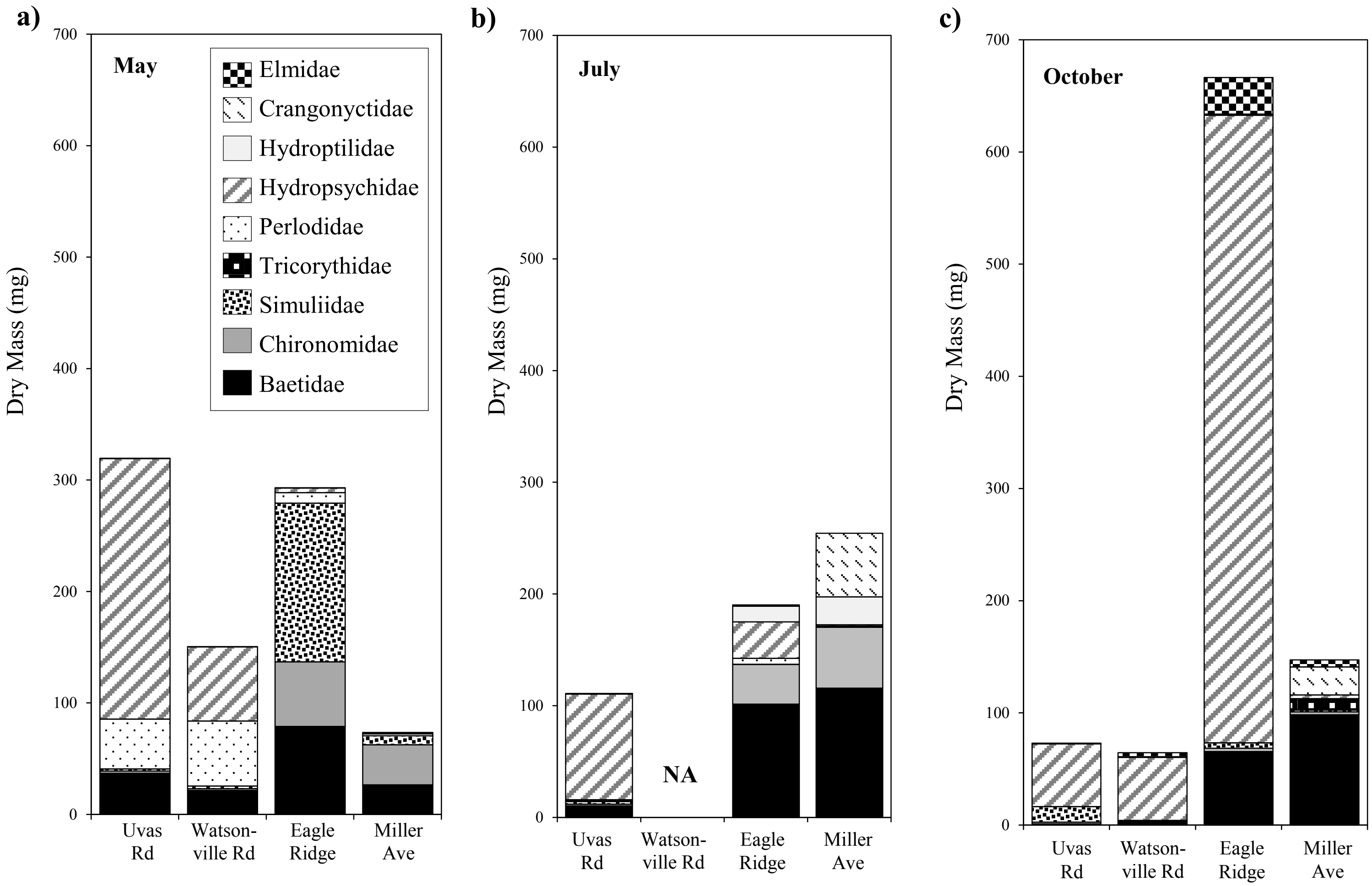

FIGURE 16.—Benthic macroinvertebrate mean total sample dry mass (mg) of dominant insect families which comprised 5% or more of the total percent dry mass per site per sampling period at the four Uvas Creek invertebrate sampling sites from upstream (left) to downstream (right) in (a) May, (b) July, and (c) October, 2008.

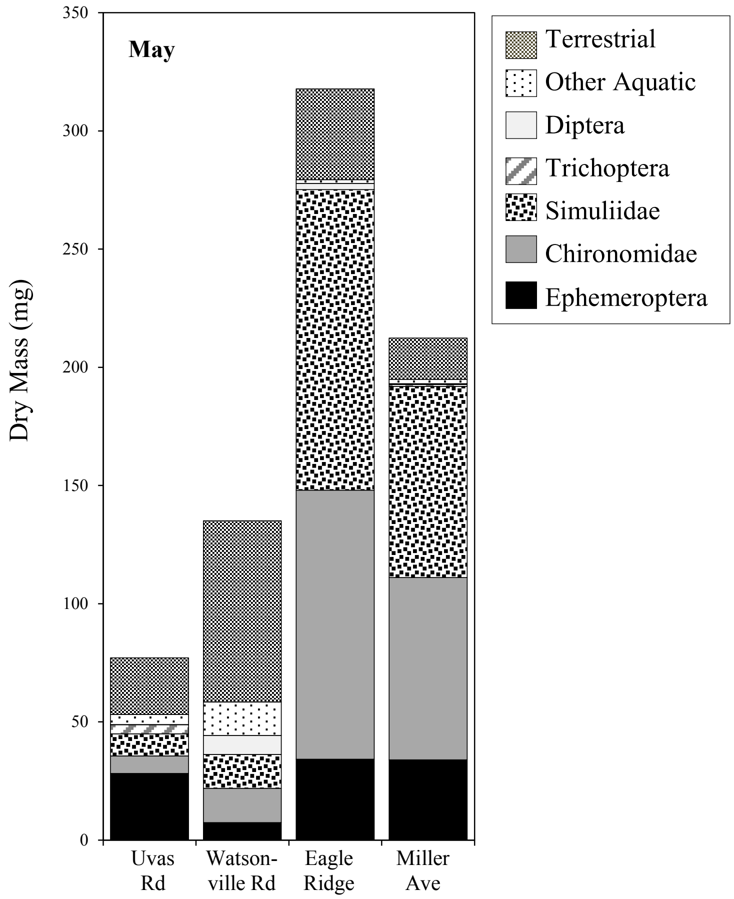

FIGURE 17.—Drifting macroinvertebrate mean total sample dry mass (mg) at the four Uvas Creek invertebrate sampling sites from upstream (left) to downstream (right) collected in May 2008.

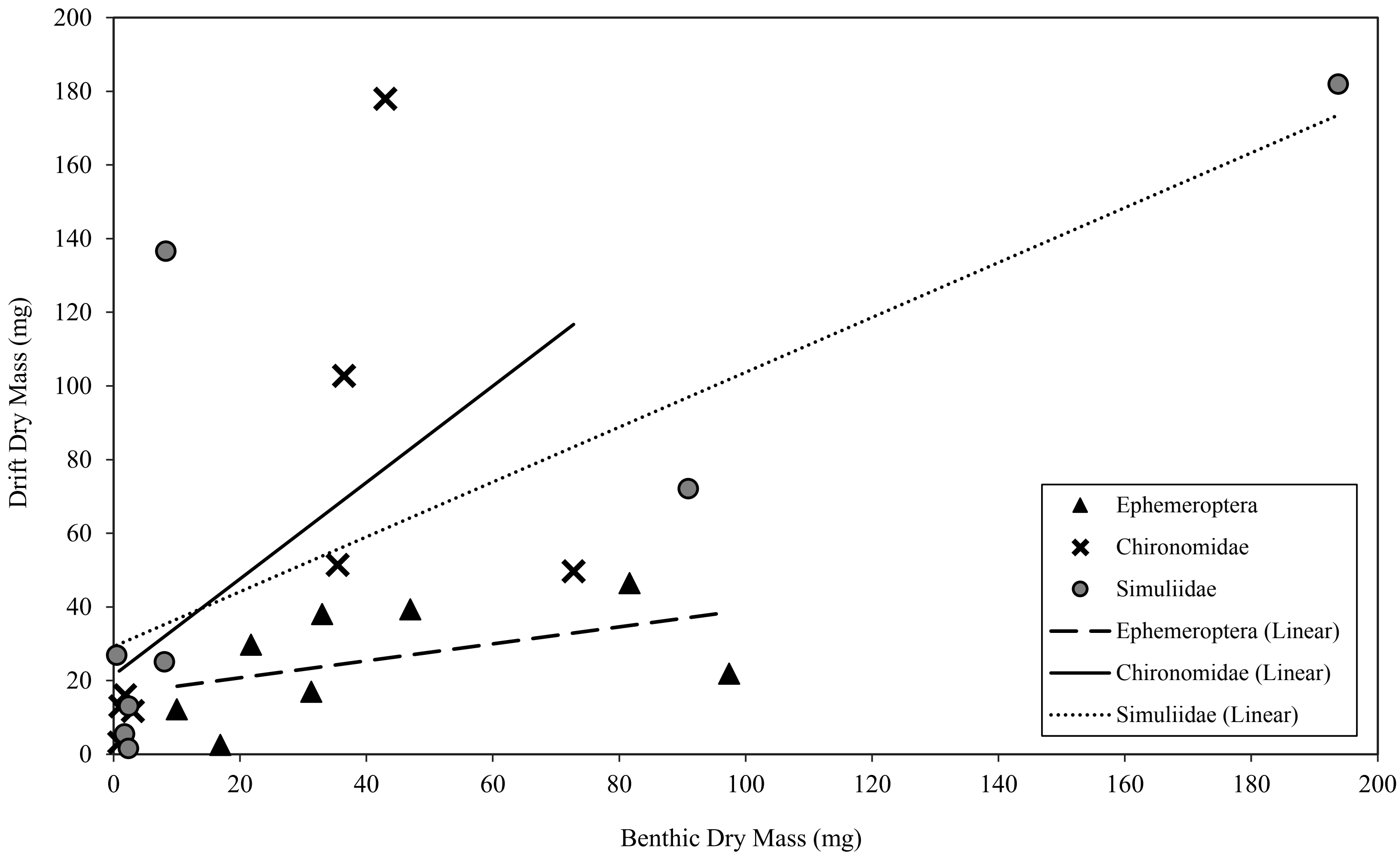

FIGURE 18.—Benthic invertebrate mean total dry mass (mg) and drifting invertebrate mean total dry mass (mg) of Ephemeroptera (r^2=0.229), Chironomidae (r^2=0.341), and Simuliidae (r^2=0.595) at two riffles at each of four sites on Uvas Creek in May 2008.

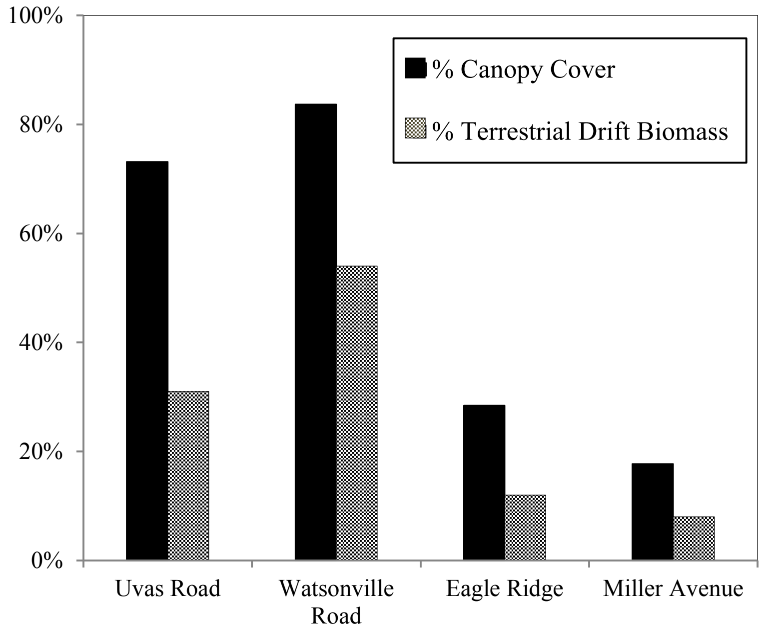

FIGURE 19.—Percent canopy cover and percent of invertebrate biomass as terrestrial drift.

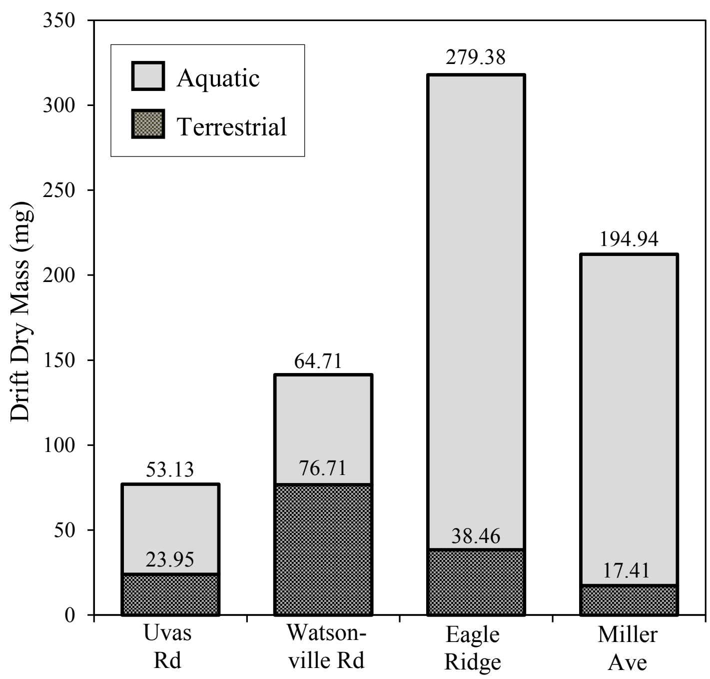

FIGURE 20.— Drifting aquatic and terrestrial macroinvertebrate mean total dry mass (mg) at the four Uvas Creek invertebrate sampling sites from upstream (left) to downstream (right) collected in May 2008.

TABLES

TABLE 1.— List of dates benthic samples were collected at each site. Times are recorded in Pacific Standard Time and correspond to the time at which sampling commenced at each sample site.

Upstream Sample Sites		Downstream Sample Sites		
Uvas Road	Watsonville Road	Eagle Ridge	Miller Avenue	Notes
24 May 08 14:05	26 May 08 15:45	26 May 08 12:55	28 May 08 13:45	Miller Avenue samples were taken downstream of Miller Avenue due to inability to access upstream site because of Summit Fire Basecamp.
16 Jul 08 13:25	Not collected	15 July 08 11:15	16 Jul 08 11:05	Watsonville Road site was not sampled in July due inaccessibility of site. Miller Avenue samples were taken upstream of Miller Avenue due to low flows at riffles downstream of Miller Avenue.
18 Oct 08 09:45	27 Oct 08 09:00	19 Oct 08 10:00	19 Oct 08 12:05	Watsonville Road site was sampled later in the month due to inaccessibility of site. Miller Avenue samples were taken upstream of Miller Avenue due to low flows at riffles downstream of Miller Avenue.

TABLE 2.— List of dates and times drift samples were collected at each site. Times are recorded in Pacific Standard Time and correspond to the time at which drift nets were placed in the stream. All nets were left in the stream for approximately 1 hr. Sunset times during the sample period ranged from 19:14 to 19:17 PST.

Upstream Sample Sites		Downstream Sample Sites		
Uvas Road	Watsonville Road	Eagle Ridge	Miller Avenue	Notes
23 May 08 16:53 23 May 08 17:11	24 May 08 16:25 24 May 08 16:45	25 May 08 16:24 25 May 08 16:41	27 May 08 16:40 27 May 08 16:56	Miller Avenue samples were taken downstream of Miller Avenue due to inability to access upstream site because of Summit Fire Basecamp.

TABLE 3.—Benthic macroinvertebrate taxa, abundance, length, total mass, and percent mass collected in 0.08 m^2 Hess samples at four sites in Uvas Creek, May 2008 (excluding Physidae and Planaridae). All insects are larvae except Elmidae and Crangonyctidae.

Site	Order	Family	Mean Abundance	Mean Length (mm)	Mean Total Mass (mg)	Percent of Total Mass
Uvas Road	Trichoptera	Hydropsychidae	52.3	7.7	233.6	70%
	Plecoptera	Perlodidae	23.8	4.6	44.7	13%
	Ephemeroptera	Baetidae	288.8	2.7	36.9	11%
	Plecoptera	Perlidae	6.5	5.8	5.5	2%
	Ephemeroptera	Leptophlibiidae	10.7	2.3	2.3	1%
	Diptera	Simuliidae	30.5	2.8	2.1	1%
	Megaloptera	Sialidae	1.2	4.0	2.0	1%
	Diptera	Chironomidae	33.0	3.4	2.0	1%
	Plecoptera	Nemouridae	5.3	3.3	1.2	0%
	Odonata	Coenagrionidae	1.0	6.0	0.7	0%
	Diptera	Tipulidae	5.7	2.8	0.4	0%
	Trichoptera	Hydroptilidae	1.8	2.7	0.2	0%
		Total Number of Taxa 12		**Total**	**331.4**	**100%**
Watsonville Road	Trichoptera	Hydropsychidae	27.0	4.4	66.6	43%
	Plecoptera	Perlodidae	20.4	5.2	58.4	38%
	Ephemeroptera	Baetidae	139.9	2.8	21.5	14%
	Diptera	Simuliidae	28.6	3.1	2.4	2%
	Diptera	Chironomidae	21.1	3.7	1.5	1%
	Diptera	Tipulidae	3.7	4.6	0.7	0%
	Plecoptera	Nemouridae	5.1	2.5	0.6	0%
	Coleoptera	Elmidae	1.6	2.6	0.3	0%
	Plecoptera	Perlidae	1.4	0.9	0.3	0%
	Diptera	Empididae	0.1	3.7	0.3	0%
	Ephemeroptera	Leptophlibiidae	3.1	1.9	0.3	0%
	Odonata	Coenagrionidae	0.1	3.0	0.3	0%
	Ephemeroptera	Ephemerellidae	0.4	1.5	0.2	0%
	Trichoptera	Limnephilidae	0.4	3.2	0.2	0%
	Diptera	Muscidae	0.6	2.6	0.1	0%
	Ephemeroptera	Tricorythidae	0.2	1.0	0.0	0%
	Trichoptera	Hydroptilidae	0.1	1.3	0.0	0%
	Amphipoda	Crangonyctidae	0.4	0.7	0.0	0%
	Ephemeroptera	Heptageniidae	0.1	0.0	0.0	0%
		Total Number of Taxa 19		**Total**	**153.7**	**100%**

TABLE 3.—Cont.

Site	Order	Family	Mean Abundance	Mean Length (mm)	Mean Total Mass (mg)	Percent of Total Mass
Eagle Ridge	Diptera	Simuliidae	1037.7	3.6	142.3	46%
	Ephemeroptera	Baetidae	603.5	2.6	79.0	26%
	Diptera	Chironomidae	875.8	3.7	57.9	19%
	Plecoptera	Perlodidae	2.0	7.1	9.4	3%
	Ephemeroptera	Leptophlibiidae	6.8	6.8	5.9	2%
	Trichoptera	Hydropsychidae	4.8	3.6	4.3	1%
	Ephemeroptera	Heptageniidae	1.0	7.3	2.8	1%
	Ephemeroptera	Ephemerellidae	0.7	6.8	1.7	1%
	Plecoptera	Perlidae	1.5	1.8	1.1	0%
	Coleoptera	Elmidae	2.8	3.0	1.0	0%
	Diptera	Muscidae	3.3	3.9	0.9	0%
	Diptera	Empididae	0.7	3.5	0.8	0%
	Plecoptera	Nemouridae	1.7	4.2	0.7	0%
	Ephemeroptera	Tricorythidae	0.2	2.5	0.2	0%
	Diptera	Tipulidae	0.3	1.8	0.0	0%
	Trichoptera	Hydroptilidae	0.2	1.0	0.0	0%
		Total Number of Taxa 16		**Total**	**308.0**	**100%**
Miller Avenue	Diptera	Chironomidae	3899.8	1.6	36.0	45%
	Ephemeroptera	Baetidae	431.2	1.9	26.5	33%
	Diptera	Simuliidae	618.5	1.6	8.1	10%
	Diptera	Tipulidae	0.7	8.2	4.3	5%
	Plecoptera	Perlodidae	3.0	3.3	1.7	2%
	Trichoptera	Hydroptilidae	15.2	2.6	1.0	1%
	Ephemeroptera	Ephemerellidae	0.8	5.5	0.9	1%
	Plecoptera	Perlidae	2.3	2.4	0.8	1%
	Coleoptera	Elmidae	4.5	2.0	0.2	0%
	Trichoptera	Hydropsychidae	4.7	2.0	0.2	0%
	Diptera	Muscidae	5.5	2.2	0.1	0%
		Total Number of Taxa 11		**Total**	**79.9**	**100%**

TABLE 4.—Benthic macroinvertebrate taxa, abundance, length, total mass, and percent mass collected in 0.08 m^2 Hess samples at three sites in Uvas Creek, July 2008 (Watsonville Road site was inaccessible in July 2008) (excluding Physidae and Planaridae).

Site	Order	Family	Mean Abundance	Mean Length (mm)	Mean Total Mass (mg)	Percent of Total Mass
Uvas Road	Trichoptera	Hydropsychidae	47.2	5.4	94.5	79%
	Ephemeroptera	Baetidae	62.0	3.0	10.2	9%
	Ephemeroptera	Leptophlibiidae	21.4	3.5	4.2	3%
	Diptera	Simuliidae	22.1	3.1	2.3	2%
	Diptera	Chironomidae	26.6	3.5	1.5	1%
	Diptera	Tipulidae	5.8	4.7	1.4	1%
	Plecoptera	Nemouridae	7.9	2.9	1.1	1%
	Ephemeroptera	Tricorythidae	3.3	2.3	1.0	1%
	Diptera	Ephydridae	2.3	6.3	1.0	1%
	Plecoptera	Perlodidae	0.2	2.0	0.6	1%
	Odonata	Coenagrionidae	0.3	4.3	0.5	0%
	Coleoptera	Elmidae	0.6	1.4	0.3	0%
	Amphipoda	Crangonyctidae	2.0	2.1	0.2	0%
	Trichoptera	Hydroptilidae	2.6	2.5	0.2	0%
	Trichoptera	Limnephilidae	0.8	1.9	0.1	0%
	Megaloptera	Sialidae	0.3	2.8	0.1	0%
	Trichoptera	Brachycentridae	0.2	0.7	0.0	0%
		Total Number of Taxa	**17**	**Total**	**119.2**	**100%**

TABLE 4.—Cont.

Site	Order	Family	Mean Abundance	Mean Length (mm)	Mean Total Mass (mg)	Percent of Total Mass
Eagle Ridge	Ephemeroptera	Baetidae	615.9	3.1	101.2	51%
	Diptera	Chironomidae	625.8	3.4	35.7	18%
	Trichoptera	Hydropsychidae	15.4	6.0	32.6	16%
	Trichoptera	Hydroptilidae	135.4	3.0	14.3	7%
	Ephemeroptera	Tricorythidae	14.6	3.2	5.3	3%
	Diptera	Muscidae	7.6	6.1	3.0	2%
	Trichoptera	Limnephilidae	2.3	5.4	1.5	1%
	Coleoptera	Elmidae	3.6	3.3	0.9	0%
	Diptera	Dolichopodidae	0.6	3.4	0.9	0%
	Diptera	Stratiomyidae	1.2	4.0	0.4	0%
	Plecoptera	Perlidae	2.3	0.8	0.4	0%
	Diptera	Ephydridae	0.1	4.3	0.3	0%
	Plecoptera	Nemouridae	5.9	2.1	0.3	0%
	Coleoptera	Hydrophilidae	0.1	2.3	0.2	0%
	Ephemeroptera	Leptophlibiidae	0.3	1.7	0.1	0%
	Diptera	Simuliidae	2.7	1.7	0.1	0%
	Odonata	Coenagrionidae	0.1	2.3	0.1	0%
	Diptera	Tipulidae	0.6	3.3	0.1	0%
	Ephemeroptera	Caenidae	0.2	1.2	0.0	0%
	Amphipoda	Crangonyctidae	0.1	1.0	0.0	0%
		Total Number of Taxa 20		**Total**	**197.6**	**100%**
Miller Avenue	Ephemeroptera	Baetidae	337.2	4.0	115.7	43%
	Amphipoda	Crangonyctidae	201.8	3.0	56.9	21%
	Diptera	Chironomidae	658.8	3.9	54.4	20%
	Trichoptera	Hydroptilidae	148.2	3.5	25.2	9%
	Diptera	Muscidae	18.3	4.8	10.0	4%
	Ephemeroptera	Caenidae	9.7	4.5	3.6	1%
	Diptera	Dolichopodidae	2.7	3.1	1.5	1%
	Coleoptera	Hydrophilidae	1.2	1.5	1.1	0%
	Trichoptera	Hydropsychidae	0.2	6.0	1.1	0%
	Ephemeroptera	Tricorythidae	0.8	4.8	1.0	0%
	Diptera	Stratiomyidae	1.3	5.8	0.5	0%
	Diptera	Empididae	4.7	1.1	0.4	0%
	Diptera	Simuliidae	1.0	1.7	0.2	0%
	Diptera	Ephydridae	0.3	2.3	0.1	0%
	Diptera	Tipulidae	0.3	2.0	0.0	0%
	Plecoptera	Nemouridae	0.2	1.5	0.0	0%
		Total Number of Taxa 16		**Total**	**271.6**	**100%**

TABLE 5.—Benthic macroinvertebrate taxa, abundance, length, total mass, and percent mass collected in 0.08 m^2 Hess samples at four sites in Uvas Creek, October 2008 (excluding Physidae and Planaridae).

Site	Order	Family	Mean Abundance	Mean Length (mm)	Mean Total Mass (mg)	Percent of Total Mass
Uvas Road	Trichoptera	Hydropsychidae	33.3	5.8	56.1	73%
	Diptera	Simuliidae	95.0	3.5	13.8	18%
	Diptera	Chironomidae	57.0	2.4	1.6	2%
	Plecoptera	Nemouridae	7.8	3.3	1.6	2%
	Ephemeroptera	Leptophlibiidae	2.5	5.3	1.2	2%
	Ephemeroptera	Baetidae	16.2	2.2	1.0	1%
	Megaloptera	Sialidae	0.2	5.0	0.3	0%
	Amphipoda	Crangonyctidae	1.5	1.8	0.3	0%
	Trichoptera	Lepidostomatidae	1.0	1.5	0.1	0%
	Odonata	Coenagrionidae	0.3	2.3	0.1	0%
	Diptera	Tipulidae	0.2	3.0	0.1	0%
	Diptera	Muscidae	1.0	1.5	0.1	0%
	Coleoptera	Elmidae	0.2	1.5	0.0	0%
	Trichoptera	Hydroptilidae	1.0	1.0	0.0	0%
		Total Number of Taxa 14		**Total**	**76.3**	**100%**
Watsonville Road	Trichoptera	Hydropsychidae	36.3	6.1	56.1	84%
	Coleoptera	Elmidae	9.0	4.0	3.7	5%
	Ephemeroptera	Baetidae	25.8	3.1	3.1	5%
	Diptera	Tipulidae	0.2	11.5	2.2	3%
	Diptera	Simuliidae	9.5	3.6	1.1	2%
	Plecoptera	Nemouridae	2.0	3.7	0.5	1%
	Amphipoda	Crangonyctidae	1.8	1.6	0.4	1%
	Megaloptera	Sialidae	0.3	2.3	0.1	0%
	Ephemeroptera	Tricorythidae	0.2	1.0	0.0	0%
	Diptera	Chironomidae	1.2	2.0	0.0	0%
		Total Number of Taxa 10		**Total**	**67.2**	**100%**

TABLE 5.—Cont.

Site	Order	Family	Mean Abundance	Mean Length (mm)	Mean Total Mass (mg)	Percent of Total Mass
Eagle Ridge	Trichoptera	Hydropsychidae	315.0	6.1	559.4	83%
	Ephemeroptera	Baetidae	249.7	3.5	65.5	10%
	Coleoptera	Elmidae	74.7	3.9	32.7	5%
	Plecoptera	Nemouridae	25.5	3.8	6.6	1%
	Diptera	Simuliidae	22.3	4.8	4.9	1%
	Diptera	Chironomidae	63.2	3.3	3.0	0%
	Diptera	Tipulidae	3.0	2.2	0.5	0%
	Amphipoda	Crangonyctidae	0.5	3.1	0.7	0%
	Diptera	Empididae	3.2	1.3	0.2	0%
	Trichoptera	Hydroptilidae	1.5	1.7	0.2	0%
	Ephemeroptera	Tricorythidae	2.2	0.8	0.0	0%
		Total Number of Taxa 11		**Total**	**673.8**	**100%**
Miller Avenue	Ephemeroptera	Baetidae	321.0	3.9	98.3	64%
	Amphipoda	Crangonyctidae	57.8	4.1	25.0	16%
	Ephemeroptera	Tricorythidae	23.0	1.5	10.2	7%
	Coleoptera	Elmidae	10.8	4.4	6.1	4%
	Trichoptera	Hydropsychidae	1.7	8.5	3.4	2%
	Diptera	Chironomidae	31.5	4.2	2.6	2%
	Odonata	Libellulidae	0.3	11.5	2.4	2%
	Diptera	Stratiomyidae	12.2	3.9	1.8	1%
	Diptera	Simuliidae	9.5	4.1	1.5	1%
	Plecoptera	Perlidae	1.0	2.5	1.0	1%
	Diptera	Empididae	1.0	1.5	0.1	0%
	Plecoptera	Nemouridae	0.2	2.5	0.1	0%
		Total Number of Taxa 12		**Total**	**152.6**	**100%**

TABLE 6.— Mean drifting macroinvertebrate taxa, density (#/100 m^3), length, sample mass, and percent mass collected at four sites in Uvas Creek, May 2008 (all insects are larvae unless otherwise noted).

Site	Order	Family	Drift Density (#/100 m^3)	Mean Length (mm)	Mean Mass (mg)	Percent of Mass
Uvas Road	Terrestrial Adult		18.4	2.9	24.0	31%
	Ephemeroptera	Baetidae (Adult)	37.4	5.2	23.9	31%
	Diptera	Simuliidae	107.8	2.9	5.9	8%
	Unidentified Aquatic Adult		1.5	1.8	4.3	6%
	Ephemeroptera	Baetidae	18.5	3.5	4.2	5%
	Diptera	Chironomidae (Adult)	23.8	3.3	3.6	5%
	Diptera	Simuliidae (Adult)	4.0	3.9	3.5	4%
	Diptera	Chironomidae	46.2	3.8	3.2	4%
	Trichoptera	Hydropsychidae	2.4	2.5	2.0	3%
	Trichoptera	Unidentified (Adult)	0.3	4.5	1.8	2%
	Diptera	Chironomidae (Pupae)	7.0	2.6	0.7	1%
	Ephemeroptera	Leptophlibiidae	0.3	2.0	0.1	0%
	Diptera	Muscidae	0.8	2.5	0.0	0%
	Diptera	Unidentified Larvae	1.3	1.3	0.0	0%
	Total Number of Identified Aquatic Taxa	**7**		**Total**	**77.1**	**100%**
Watsonville Road	Terrestrial Adult		27.4	3.7	76.7	54%
	Diptera	Simuliidae (Adult)	11.3	4.0	13.6	10%
	Diptera	Chironomidae	122.0	3.9	9.6	7%
	Hemiptera	Corixidae	20.4	5.0	8.5	6%
	Diptera	Dixidae	10.0	4.9	6.2	4%
	Unidentified Aquatic Adult		0.7	3.0	5.2	4%
	Ephemeroptera	Baetidae (Adult)	3.6	6.0	5.1	4%
	Plecoptera	Perlodidae	0.6	4.5	5.0	3%
	Diptera	Chironomidae (Pupae)	6.3	4.4	2.7	2%
	Ephemeroptera	Baetidae	11.2	3.2	2.2	2%
	Diptera	Chironomidae (Adult)	9.7	3.3	2.2	1%
	Diptera	Unidentified Larvae	5.2	2.3	1.4	1%
	Plecoptera	Nemouridae	4.3	3.8	1.3	1%
	Diptera	Simuliidae	10.9	3.1	0.7	1%
	Coleoptera	Elmidae	1.9	3.5	0.5	0%
	Diptera	Muscidae	1.4	4.0	0.2	0%
	Diptera	Empididae	1.3	2.0	0.2	0%
	Ephemeroptera	Leptophlibiidae	0.6	1.0	0.0	0%
	Total Number of Identified Aquatic Taxa	**11**		**Total**	**141.4**	**100%**

TABLE 6.—Cont.

Site	Order	Family	Drift Density (#/100 m^3)	Mean Length (mm)	Mean Mass (mg)	Percent of Mass
Eagle Ridge	Diptera	Simuliidae	492.0	4.0	71.6	22%
	Diptera	Chironomidae (Adult)	239.4	3.9	56.5	18%
	Diptera	Simuliidae (Adult)	65.0	3.9	53.8	17%
	Diptera	Chironomidae	517.8	4.3	46.9	15%
	Terrestrial Adult		30.1	2.1	38.5	12%
	Ephemeroptera	Baetidae (Adult)	33.0	5.2	20.9	6%
	Ephemeroptera	Baetidae	43.4	3.8	13.3	4%
	Diptera	Chironomidae (Pupae)	53.0	3.5	10.5	3%
	Diptera	Simuliidae (Pupae)	6.5	1.9	1.7	1%
	Diptera	Unidentified Larvae	12.0	4.0	1.6	1%
	Amphipoda	Crangonyctidae	34.4	1.0	1.6	1%
	Diptera	Dixidae	2.6	2.3	0.6	0%
	Diptera	Muscidae	2.9	3.9	0.4	0%
	Plecoptera	Nemouridae	0.5	1.0	0.0	0%
	Trichoptera	Limnephilidae	0.3	1.0	0.0	0%
	Total Number of Identified Aquatic Taxa 7			**Total**	**317.8**	**100%**
Miller Avenue	Diptera	Simuliidae	1011.6	2.9	72.0	34%
	Diptera	Chironomidae (Adult)	263.8	3.0	40.3	19%
	Ephemeroptera	Baetidae	201.7	2.9	30.5	14%
	Diptera	Chironomidae	475.9	3.3	22.5	11%
	Terrestrial Adult		13.6	2.1	17.4	8%
	Diptera	Chironomidae (Pupae)	69.0	3.2	14.3	7%
	Diptera	Simuliidae (Adult)	10.8	3.7	8.8	4%
	Ephemeroptera	Baetidae (Adult)	4.7	5.7	3.4	2%
	Hemiptera	Corixidae	5.5	2.4	1.8	1%
	Trichoptera	Unidentified (Adult)	1.0	2.0	0.5	0%
	Diptera	Muscidae	1.2	3.0	0.4	0%
	Trichoptera	Hydroptilidae	1.0	2.0	0.2	0%
	Diptera	Simuliidae (Pupae)	0.9	1.5	0.1	0%
	Total Number of Identified Aquatic Taxa 6			**Total**	**212.4**	**100%**

TABLE 7.—October densities (# / 30.5 m) of Age 0 / Age 1 and Age 2 Steelhead and mean Age 0 standard length ( ) in mm at five sites on Uvas Creek in 2005-2008. Data source (modified from): 2005 and 2006 (Casagrande 2010), 2007 (Casagrande unpublished), and 2008 (Casagrande 2009).

Site	2005	2006	2007	2008
Uvas Road	13.8 / 0.8 (79)	10.0 / 0.8 (80)	2.1 / 0.4 (68)	7.6 / 0.1 (69)
Old Creek Road	9.4 / 0.7 (82)	5.1 / 0.8 (81)	0.5 / 0.0 (73)	7.9 / 0.2 (70)
Watsonville Road	4.8 / 0.3 (89)	3.7 / 0.6 (75)	1.8 / 0.3 (58)	5.2 / 0.2 (58)
Highway 152	3.3 / 0.3 (101)	0.9 / 0.2 (94)	Dry	67.4 / 0.1 (90)
Miller Avenue	7.1 / 0.0 (147)	2.4 / 0.5 (169)	Dry	23.5 / 0.0 (98)

APPENDICES

Appendix A: Photos taken at each site where macroinvertebrate sampling was conducted.

a. Uvas Reservoir Outlet into Uvas Creek.

b. SCVWD Streamflow Gauge SF84 located approximately 30 m downstream of Uvas Reservoir Outlet.

c. Uvas Road Sample Site.

FIGURE A-20.—Photos taken at various macroinvertebrate and water quality sample sites in Uvas Creek.


d. Uvas Road Sample Site.


e. Uvas Pines R.V. Park at Uvas Road Sample Site. Note the clearance of understory vegetation.


f. Watsonville Road Sample Site.

FIGURE A-20.—Cont.

g. Eagle Ridge Sample Site.

h. Eagle Ridge Sample Site.

i. Miller Avenue Sample Site – Upstream of Miller Avenue.

FIGURE A-20.—Cont.


j. Miller Avenue Sample Site – Upstream of Miller Avenue.


k. Miller Avenue Sample Site – Downstream of Miller Avenue.


l. Miller Avenue Sample Site – Downstream of Miller Avenue.

FIGURE A-20.—Cont.