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Distribution, Abundance, Growth, and Habitat Use of Steelhead in Uvas Creek, CA

Joel Malone Casagrande
San Jose State University

DISTRIBUTION, ABUNDANCE, GROWTH, AND HABITAT USE OF STEELHEAD IN UVAS CREEK, CA

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Joel M. Casagrande

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Dr. Jerry J. Smith, Department of Biological Sciences

Dr. Paula Messina, Department of Geology

Dr. Sean A. Hayes, National Marine Fisheries Service

ABSTRACT

DISTRIBUTION, ABUNDANCE, GROWTH AND HABITAT USE OF STEELHEAD IN UVAS CREEK, CA

by Joel M. Casagrande

Distribution, abundance, growth, and habitat use of juvenile steelhead (*Onorhynchus mykiss*) were studied in a central California stream under two increased summer flow reservoir release strategies. The effect of habitat quality (including longitudinal changes in flow, water temperature, canopy closure, substrate quality, and turbidity) on abundance and growth of steelhead among sites was determined. Increased stream flow extended rearing habitat and steelhead distribution downstream to reaches that previously would have been dry. Yearling or older steelhead were relatively scarce at all Uvas Creek sites. Steelhead were most abundant, but small, in the upstream half of the study reach, despite higher flows and cooler water for most of the summer. Insects were scarce at upstream sites due to dense shade, silty substrate, and high turbidity in late summer and fall. Steelhead grew much larger at warmer downstream sites, and reached smolt size by their first winter. Downstream sites were productive due to less shade, better substrate quality, and low turbidity. Steelhead abundance in the downstream reach was limited by the scarcity of fast-water feeding habitat. These results show that, where food is sufficient, steelhead can rear and reach smolt size in their first year in warm, augmented stream flows. Management strategies that improve stream productivity would improve steelhead production in Uvas Creek below the reservoir.

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Table of Contents

Page #

List of Figures

List of Tables

Introduction

Throughout California and much of the West, water resource managers are challenged with meeting increasing water demands for municipal and agricultural supplies while providing in-stream flows necessary for maintaining healthy aquatic ecosystems (Gillilan and Brown 1997; NMFS 2009). The listing of multiple salmonid populations under the Federal Endangered Species Act (NMFS 2006) has further complicated this challenge because it obligates water resource managers to provide sufficient stream flows needed to maintain suitable habitat conditions for these species (NMFS 2009). In periods of drought, this dilemma often results in intense conflict over the most beneficial use of the water and disagreements over how much water is needed to maintain suitable habitat and for recovery of populations of fish and other aquatic species. Usually watershed or stream-specific data on the distribution and specific habitat uses of salmonids are limited; this is particularly true in the southern extent of their ranges where few populations persist and anthropogenic disturbances are high (Moyle et al. 2008).

Within a watershed, several environmental factors influence the distribution, habitat selection, and growth of juvenile steelhead (*Oncorhynchus mykiss*). These include seasonal and longitudinal changes in water temperature, habitat velocity, productivity, and turbidity: all of these are greatly affected by other variables such as flow volume, riparian canopy cover, and substrate conditions. For regulated streams, the operation of upstream reservoirs greatly affects each of these variables in space and time (Ligon et al. 1995; Collier et al. 1996).

Salmonid growth rates can be used as an indicator of habitat quality and use within a watershed. In most temperate coastal systems, juvenile steelhead typically rear between one and three years before entering the ocean (Shapovalov and Taft 1954; Moyle 2002; Quinn 2005; Sogard et al. 2009). Growth in relatively small coastal streams or low order streams within a larger watershed is generally poor due to low summer flow, dense shade, and low overall stream productivity (Smith 1982; Quinn 2005; Alley and Associates 2007; Hayes et al. 2008). Significant increases in fish growth generally occur after the fish emigrate downstream to more productive stream reaches or estuary habitats (Hayes et al. 2008). Several studies have confirmed that size at ocean entry for juvenile salmonids plays a critical role in determining ocean survival (Ward et al 1989; Holtby et al. 1990; Bond 2006; Hayes et al. 2008), and therefore systems capable of producing greater numbers of relatively large juvenile salmonids each year are likely to have more robust adult populations.

Longitudinal water temperature gradients within a watershed can have significant impacts on fish community partitioning, although with varying degrees of species overlap (Moyle and Vondracek 1985; Baltz et al. 1987; Cech et al. 1990; Marchetti and Moyle 2001; Harvey et al. 2002). In general, overlap of fish species increases as temperature gradients become more gradual (Brown and Moyle 1991; Reese and Harvey 2002).

Water temperature affects the metabolic rate, physiology, and growth of juvenile salmonids (Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005). An increase in water temperature has a positive effect on fish metabolic rates, and therefore water temperature can indirectly influence habitat selection of juvenile salmonids (Chapman and Bjornn 1969; Smith and Li 1983; Vondracek and Longanecker 1993). If available, juvenile steelhead will use riffles and other fast water habitats where food resources, in the form of drifting invertebrates, are more abundant (Chapman and Bjornn 1969). In order to cope with increased metabolic demands associated with rearing in warmer stream environments, juvenile steelhead utilize specific microhabitats where they can maximize food intake while minimizing energetic costs associated with feeding (Smith and Li 1983; Fausch 1984; Hill and Grossman 1993). Smith and Li (1983) found that as water temperatures increased, juvenile steelhead increasingly used focal points with greater water velocities in order to obtain suitable amounts of food to meet metabolic costs. Where food is abundant, high growth rates can be achieved in warmer water (Elliot 1973; Myrick and Cech 2005) and steelhead can reach smolt size in one year (Moore 1980; Smith 1982; Smith and Li 1983; Hayes et al. 2008). However, in situations where food is limited and water temperatures are high, growth is reduced (McCarthy et al. 2009).

In streams, drifting macroinvertebrates comprise the vast majority of the food resources for juvenile salmonids (Chapman and Bjornn 1969; Elliot 1973). Stream primary productivity is regulated largely by light availability, and therefore riparian canopy cover can have a strong influence on invertebrate production and salmonid growth (Behmer and Hawkins 1986; Hill et al. 1995; Quinn et al. 1997; Poole and Berman 2001). Stream substrate condition (size and surface heterogeneity) also has an influence on macroinvertebrate abundance and community structure (Erman and Erman 1984; Gurtz and Wallace 1984), and therefore can influence salmonid production.

Turbidity has been widely studied for its impacts on the behavior, distribution, and growth of juvenile salmonids (Cordone and Kelley 1961; Bisson and Bilby 1982; Sigler 1988; Newcombe and McDonald 1991; Waters 1995; Newcombe and Jensen 1996; Bash et al. 2001). Elevated turbidity levels can produce behavioral effects such as increased coughing (Cordone and Kelley 1961; Berg and Northcote 1985), avoidance behavior or abandonment of territories and cover (Bisson and Bilby 1982; Sigler et al. 1984), and a decrease in predator avoidance response (Newcombe and Jensen 1996). Other sub-lethal effects include: physical impairment of gill surface tissue (Cordone and Kelley 1961), increased stress levels (Redding et al. 1987), reduced growth caused by a reduction in visibility and prey capture success (Sigler et al. 1984; Barret et al. 1992; Sweka and Hartman 2001), and altered prey size-selection caused by impaired visibility (Rowe et al. 2003). Chronic turbidity can force benthic feeding which can result in slow growth (Tippets and Moyle 1978). Also, chronic turbidity can adversely impact stream productivity because of its ability to impair light available for primary production (Kirk 1985; Davies-Colley and Smith 2001).

Reservoirs can have a considerable influence on downstream riparian habitat and biological communities (Power et al. 1996; Poff et al. 1997). Typical impacts to downstream reaches include an alteration of the seasonal hydrograph, a reduction of peak winter flows necessary for channel scouring and complex habitat formation (Ligon et al. 1995; Gordon and Meentemeyer 2006), and a decline in coarse substrate replenishment (Kondolf 1997). Impoundments also impact seasonal water temperature dynamics in downstream reaches, particularly within reaches immediately downstream of the impoundment (Petts 1986; Nilsson and Berggren 2000). Large modifications to water temperature regimes can have significant consequences on biological communities (Marchetti and Moyle 2001; Lessard and Hayes 2003). Finally, because dams provide flood protection, development of downstream floodplain areas for urban and agricultural uses usually follows, which generally leads to more simplified channels designed for flood control objectives that are less suitable for aquatic species (Poff et al. 1997).

Along the Central California Coast, many steelhead populations have declined substantially from historic levels (Good et al. 2005). Factors for decline include dams, overdraft of water resources, habitat loss, and habitat degradation caused by stream flow regulation as well as urban and agricultural development. In Uvas Creek, a tributary of the Pajaro River, the steelhead population has declined considerably due to the construction of Uvas Dam and development within the watershed. Extensive studies on the distribution, relative abundance and habitat use of juvenile steelhead rearing in Uvas Creek were last conducted in the 1970's and early 1980's (Smith 1982; Smith and Li 1983), 15 - 25 years after dam completion. Since then, urban development has increased substantially within the watershed, stream flow regulation has continued for an additional 25 years, and the impacts of these developments on steelhead production and their habitat have largely been unstudied.

The Santa Clara Valley Water District (SCVWD) is responsible for maintaining adequate stream flows in Uvas Creek below Uvas Reservoir to protect steelhead populations and other aquatic resources. In the past, a schedule of stream flow releases, based upon the original memorandum of agreement (MOA) (Anonymous 1956) at the time of the dam's construction, specified a variable set of reservoir releases during winter (December-April) and during the spring through fall period (May-December). In addition, one conditional option for maintaining steelhead populations in this watershed was collecting and trucking returning adults over the dam to spawn upstream of the reservoir. This practice was never conducted and would require out-migrating smolts to pass over the concrete spillway of Uvas Dam or through anoxic bottom waters of the reservoir and through the release port at the base of the dam which would severely limit smolt outmigration. One of SCVWD's current strategies is to prioritize smolt outmigration stream flow releases in April and May and to improve rearing habitat downstream of the dam by increasing base flow releases during summer and fall.

My objectives for this study were to: (1) conduct an inventory of the range of habitat conditions present below Uvas Dam, (2) document the distribution, abundance, growth and habitat use of juvenile steelhead during the increased stream flow release strategies of 2005 and 2006 and (3) monitor the seasonal and longitudinal changes in water temperature, stream flow volume, and turbidity during the increased flow releases to see how these variables were affecting juvenile steelhead distribution, habitat selection, and growth. The data have been used by a technical advisory committee to help the SCVWD develop a stream flow release strategy for Uvas Dam that will ultimately benefit steelhead populations while not compromising municipal water supplies.

Study Area

The primary study area includes much of Uvas Creek downstream of Uvas Reservoir. For comparison, additional steelhead sampling was conducted in Bodfish Creek, a tributary to Uvas Creek, and Blackhawk Canyon Creek, a tributary to Bodfish Creek.

The Uvas Creek watershed drains the eastern side of the Santa Cruz Mountain range in southern Santa Clara County, California and forms one of the major tributaries to the Pajaro River (Figure 1). The Pajaro River flows west and empties into Monterey Bay southwest of the City of Watsonville.

The upper portions of the watershed include steep, densely forested slopes and rolling grazing lands, with sparse rural development. Grazing, low density residential, and vineyard development increase in the foothill areas downstream of the reservoir. Farther downstream, Uvas Creek flows through expanding suburban neighborhoods in the City of Gilroy and then through extensive row crop agriculture on the Santa Clara Valley floor.

Stream flow in the lower watershed is regulated by Uvas Reservoir, which has a capacity of 1.2×10^7 m^3 (9,835 acre-feet) and is managed by the SCVWD for groundwater recharge and flood control. Uvas Dam (built in 1957) captures runoff from 83 km^2 (32 mi^2) and is located approximately 12 km (7.5 mi) upstream of the City of Gilroy and 17 km (10.5 mi) upstream of the Pajaro River confluence. Releases from the reservoir are from the bottom port, and surface spills are generally of brief duration during wet winters. Below Uvas Reservoir, Uvas Creek is a relatively low gradient single thread stream with gradients ranging from 0.1% to 0.7%.

The construction of Uvas Dam has significantly reduced both the frequency and intensity of flood flows in lower Uvas Creek; particularly in reaches immediately below Uvas Reservoir (Kondolf et al. 2001). In their report, Kondolf et al. (2001) stated that the 1.5-year return interval flow below Uvas Reservoir has been reduced from 60 m^3/s (2,118 f^3/s) pre-dam to 27 m^3/s (953 f^3/s) post-dam. Farther downstream, the reservoir has less impact on flood flows due to contributions from unmanaged tributaries, primarily Bodfish and Little Arthur creeks, and also from storm runoff from the City of Gilroy and adjacent agricultural lands.

The original MOA for reservoir operation included specific summer and fall releases, depending upon reservoir storage, of up to 0.28 m^3/s (10 f^3/s), to protect steelhead and other wildlife in Uvas Creek below Uvas Reservoir (Anonymous 1956). During summer and fall, stream flows usually extended to approximately the western edge of the current city limits of Gilroy. In most years, significant volumes of water were also transferred from Uvas Reservoir east to Llagas Creek for groundwater recharge (Smith 2007).

Climate and Rainfall.—Climate in the Uvas Creek watershed is typical of the Mediterranean pattern observed throughout much of Central California, with cool wet winters and warm dry summers. Most precipitation (> 90%) falls between November and April, with an average annual rainfall greater than 1270 mm (50 in) in the Santa Cruz Mountains and approximately 430 mm (17 in) on the valley floor near Gilroy (Figure 2).

During summer, afternoon air temperatures in southern Santa Clara Valley regularly exceed 32ºC (90ºF) on the valley floor. Mean annual maximum air temperatures in the Uvas watershed range from 25ºC (77ºF) at the ridge of the Santa Cruz Mountains to 32ºC (89ºF) on the valley floor near Gilroy (Figure 3)

Vegetation Communities.—The upper elevations of the watershed consist of mixed evergreen forest. Coast redwood (*Sequoia sempervirens*) is the dominant tree species along Blackhawk Canyon Creek with tanoak (*Lithocarpus densiflora*) and California bay (*Umbellularia californica*) in the upland areas. On upper Bodfish Creek, vegetation along the creek is also dominated by coast redwood with some California big-leaf maple (*Acer macrophyllum*) and white alder (*Alnus rhombifolia*), while redwood, tanoak, and California bay are the dominant upland species. Farther downstream on Bodfish Creek, deciduous species such as white alder, big-leaf maple, California sycamore (*Platanous racemosa*), and willow (*Salix spp.*) dominate the streamside, and in the upland the abundance of coast redwood, tanoak and California bay decline, while oaks (*Quercus spp.*) tend to dominate.

Along Uvas Creek below Uvas Reservoir, the riparian canopy is predominantly deciduous consisting of white alder, willow, California sycamore, box elder (*Acer negundo*), and black cottonwood (*Populus trichocarpa*). Coast live oak (*Quercus agrifolia*), valley oak (*Q. lobata*), and California bay are also present but are usually higher up on the stream banks. Acacia, or green wattle (*Acacia decurrens*), a non-native and invasive evergreen, is found between Uvas Reservoir and the confluence of Little

Arthur Creek, and non-native blue gum eucalyptus (*Eucalyptus globulus*), occurs in small patches downstream of the Little Arthur Creek confluence.

Emergent, rooted aquatic species such as bullrush (*Scirpus spp.*), cattails (*Typha latifolia*) and non-native arundo (*Arundo donax*) are occasionally common, especially in downstream reaches where canopy shading is reduced.

Fisheries.—The Pajaro River watershed contains a freshwater fish community similar to, and descendent of, the San Joaquin-Sacramento River system (Smith 1982). Uvas Creek supports a self-sustaining population of steelhead that is part of the Southern Central California Coast Distinct Population Segment (DPS), which is listed as "threatened" under the Federal Endangered Species Act (Good et al. 2005). Other native fish species in the Uvas Creek watershed include Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*), California roach (*Lavinia symmetricus*), riffle sculpin (*Cottus gulosus*), Pacific lamprey (*Lampetra tridentata*), and threespine stickleback (*Gasterosteus aculeatus*). Prickly sculpin (*Cottus asper*) and hitch (*Lavinia exilicauda*) are also present, but are relatively scarce.

Non-native species are relatively uncommon in Uvas Creek. Based on recent sampling, bluegill (*Lepomis macrochirus*) was the most abundant and widespread non-native species, while the common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), goldfish (*Carassius auratus*), largemouth bass (*Micropterus salmoides*), and inland silverside (*Menidia beryllina*) were occasionally captured primarily at sites between Uvas Reservoir and the Little Arthur Creek confluence (Smith 2007).

Methods

Stream Flow

I assessed stream flow using a combination of online data sources and field discharge measurements. The Uvas Dam ALERT gauge hosted on the SCVWD's website provided hourly flow release rates.

Discharge measurements were taken at various sites and times throughout the project period. Most discharge measurements were made by SCVWD staff during percolation tests in both 2005 and 2006. During these tests, stream discharge was measured at eight to ten sites spaced below Uvas Reservoir. I supplemented these data with discharge measurements at various sites throughout the summer of 2005 using a Global Water propeller-style flow probe (Global Water Instrumentation, Inc.).

Discharge data derived from the percolation tests were used to understand seasonal changes in stream flow within different reaches below Uvas Reservoir and how longitudinal changes in flow volume influenced other environmental variables (e.g., water temperature) as well as the distribution, density, habitat selection and growth of juvenile steelhead.

Habitat Assessment

Between July and August of 2005, I conducted an assessment of habitat conditions in Uvas Creek using a modified CDFG Level III Habitat Inventory Method (Flosi et al. 1998). Six stream reaches were selected to represent the longitudinal range of habitat conditions present in Uvas Creek below Uvas Reservoir (Figure 4). Photos of each of these reaches are presented in Figures A-53 (a-l) in Appendix A. A detailed habitat assessment was not conducted in the Bodfish Creek sub-watershed, although stream canopy cover and substrate conditions were estimated at sites during fish sampling.

Within each reach, I collected data at each mesohabitat, or habitat unit (pool, run, riffle, etc.). In general, I classified habitat units following CDFG protocols (Flosi et al. 1998). However, I included a separate habitat unit called "head of pool" to distinguish portions of pools with fast water velocities, from sections of pools with minimal flow velocities. The head of pool habitat type was isolated because of its unique combination of greater depth, high velocity, and often cover from surface turbulence, which presents suitable conditions for drift-feeding juvenile steelhead. I used a velocity threshold of 15 cm/s (0.5 ft/s, measured using a simple float technique) to distinguish between pool and head of pool habitat types.

At each habitat unit I determined the habitat unit length, mean width, mean and maximum depth, percent substrate composition, and percent riparian canopy closure. Mean width and depth were determined after making several measurements throughout the habitat unit. Because the reaches were assessed by a rapid foot traverse with hip chain, I used visual estimates of the channel substrate composition for each habitat type. Walking upstream, two observers estimated the channel substrate composition by visually examining the substrate throughout the habitat unit and then assigning percentages for each substrate class using a modified Wentworth Scale (Wentworth 1922). At the end of the habitat unit the two different estimates were compared and discussed, and final estimates were made for the habitat unit.

I measured percent riparian canopy closure and percent of the canopy as evergreen using a spherical densitometer. For longer (> 30 m) or variable habitat units, I made multiple measurements (beginning, middle, and end) of the canopy and then averaged them for a single habitat unit value.

Water and Air Temperature

I analyzed water temperature data collected by a series of data loggers (Optic StowAway; Onset Computer Corporation) placed at nine sites in Uvas Creek below Uvas Reservoir (Figure 5). The loggers, maintained by the SCVWD, were installed prior to the project's start and collected data throughout the duration of the project period of each year (May-November).

To prevent loss of data from logger failure, two loggers were deployed together at each site in the stream. The loggers were kept in individual metal tubes perforated with several holes approximately 1 cm wide to allow sufficient contact with surrounding water. A single logger (not in a tube) was placed in the riparian canopy adjacent to the in-stream loggers to record air temperature.

The loggers recorded temperatures each hour, and I took the mean of the two in-stream loggers for a single hourly reading. I analyzed the data for the monthly average daily maximum (MAX), monthly average daily mean (MEAN), and monthly average daily minimum (MIN) for selected sites. These data provided me with the general range of temperature conditions present at sites below Uvas Reservoir throughout summer and fall.

In addition, I calculated the percentage of the 24 daily measurements that exceeded different temperature thresholds (16ºC, 18ºC, 20ºC, 21ºC, 22ºC, and 23ºC); these metrics indicated the general timing, frequency, and duration of elevated temperatures to which juvenile steelhead were exposed at various sites.

I also analyzed water temperature depth profiles collected in Uvas Reservoir by SCVWD near Uvas Dam. Stream flow is released from the base of Uvas Dam and therefore changes in water temperature on the bottom of Uvas Reservoir have a substantial impact on the temperature dynamics in Uvas Creek below the dam.

Turbidity

I measured stream turbidity at various sites below Uvas Dam during the summer and fall of 2005 and 2006, although data from 2005 are limited. I used two methods to measure stream turbidity; water samples were analyzed for nephelometric turbidity units (NTU) with a HACH 2100P turbidity meter and water clarity, or visibility, was measured with a 120 cm transparency tube in the field. On some occasions only one method was used. However, I calibrated NTU values and transparency tube readings against each other (R^2=0.90) in order to get estimates for missing values of the other method. Calibrated, the HACH 2100P turbidity meter has an accuracy of ±2% with a resolution of 0.01 NTU. I conducted all transparency tube readings under light conditions representative for that site.

I also analyzed bi-weekly secchi depth measurements and water quality depth profiles taken in Uvas Reservoir by the SCVWD near Uvas Dam. Dissolved oxygen, chlorophyll-*a,* and water temperature were analyzed to determine when the water column in Uvas Reservoir became destratified. I also compared the reservoir profile data and secchi depth measurements with the stream turbidity monitoring that I performed at various sites below Uvas Reservoir to better understand the influence of reservoir water quality conditions on water clarity and temperature observed in Uvas Creek downstream of the reservoir.

Macroinvertebrate Diversity and Drift Rates

I measured macroinvertebrate drift rates at three sites (Uvas Road, Watsonville Road and Miller Avenue) in Uvas Creek in September of 2006. At each site, three drift nets were placed in three different habitat types to compare overall drift volume and rates from different velocities present in each habitat type.

Each drift net had an opening of 760 cm square (20 cm x 38 cm) and was 70 cm in length with a mesh size of 363 µm. I installed the nets approximately 5 cm off the stream bottom to prevent invertebrate predation by riffle sculpin and to limit invertebrates from crawling into the nets. I then used test floats to ensure that upstream nets did not intercept the drift of nets placed downstream. The nets were left in place for approximately one hour duration between 1100 and 1330 hours. At each site, the nets were retrieved in a downstream to upstream order so that invertebrates were not incidentally stirred into downstream nets. Samples were preserved in the field with a 90% ethanol solution, and were then sorted in the lab and identified to Family level using standard keys (Merritt and Cummins 1996).

For comparison, I installed multi-plate samplers (MPS) for one month at the same sites to see if there were differences in relative abundance and taxa (Family) richness among sites. Each sampler consisted of 12 plates (each plate was 7.5 cm x 7.5 cm). The plates were separated by metal washers such that the distance between plates progressively increased slightly (about one washer width) from one end of the sampler to the other, which provided a variety of interstitial spaces utilized by different invertebrate taxa. I anchored the samplers on the stream bottom using steel rods and cable zip ties; samplers were left in place for one month. All invertebrates and accumulated debris were scraped from the plates and placed in jars which were then preserved with a 90% ethanol solution. The samples were sorted and identified to Family level.

I recorded the total number and relative volume of each taxa present from both the drift net and MPS samples. To estimate volume, I utilized a point system where I assigned one point for each 0.5 cm x 0.5 cm of wet mass measured on a 0.5 cm grid. Drift rates were determined by dividing the total volume (excluding Physidae) by the length of time the nets were left in the water.

Steelhead Microhabitat Utilization

I assessed microhabitat habitat use by juvenile steelhead using an underwater camera system (Aqua Vu Z60, Nature Vison Inc.). Water quality concerns associated with urbanized waterways (e.g., fecal coliform), poor visibility due to elevated turbidity and shading at upstream sites, and shallow depths in riffle habitats, made conditions unsuitable for traditional snorkel survey methods. The use of a small camera on a 2 m extendable rod allowed for underwater observation of juvenile steelhead with minimal to no disturbance of the fish's behavior. The camera was tethered to the viewing screen and battery by an 18 m (60 ft) cable.

Walking in an upstream direction, I inspected all mesohabitat types for the presence of juvenile steelhead. Once a fish was located, I observed the fish's behavior for several minutes and noted what type of habitat it was using. I then measured the fish's length (standard length, SL), depth of normal swimming position (focal point), and feeding intercept depth (feeding loci) using a thin calibrated rod (Smith and Li 1983).

I measured focal point velocity, feeding loci velocity (velocity at prey intercept), mean water column velocity (measured at 0.6 of depth from the surface), and surface velocity after each fish was observed for several minutes. In some cases, I did not measure velocities immediately following fish observations. Instead, I placed a weighted marker on the stream bottom at the exact location of the fish and returned later (within hours) to measure all velocities at the appropriate depths (Smith and Li 1983). All velocity measurements were made using a Global Water propeller-style flow probe (Global Water Instrumentation, Inc.). I noted additional environmental data including water temperature, dominant substrate size, and canopy closure. Observations on the fish's behavior, interactions with other fish, and interaction with physical habitat features (use of overhead cover, root wads etc.) were also noted.

Steelhead Distribution, Densities, and Mesohabitat Use

To determine general distribution, site densities, and mesohabitat use, I sampled steelhead using a backpack electrofisher at multiple sites along the mainstem of Uvas Creek and in the Bodfish Creek sub-watershed (Figures 6 and 7). Sampling was conducted during the following dates: 13 October – 8 November 2005, 20 July through 16 August, and 6 - 30 October 2006.

At each site I divided the sampled reach into stations usually consisting of a set of contiguous habitat units (or mesohabitat types). Each station was typically less than 75 meters in total length. Within each station I generally conducted a two-pass depletion method using a Smith-Root LR-24 backpack electrofisher (Smith-Root, Inc.); 3 passes were rarely conducted, when inadequate depletion occurred between the first and second passes.

I placed collected fish in a flow-through live car until all passes were completed within the station. While sampling, the live car was kept in suitable water quality conditions and was covered with a thin cloth to reduce stress on the fish.

I counted and measured all fish (SL), and scales were collected from a sub-sample to determine age-size relationships and relative growth rates. After all fish were measured I measured the length of all habitat units sampled in the station. The fish were then released throughout the station or placed back in the habitat unit from which they were collected.

Although I generally sampled several mesohabitat types during each pass, I determined mesohabitat use by keeping a tally of the number of steelhead collected in each mesohabitat type. All habitat units were sampled except for deeper sections of pools (or those greater than 1 meter deep), which could not be sampled effectively and rarely had steelhead during microhabitat investigations.

I estimated steelhead densities for each site based on population estimates. I calculated population estimates for each station using the Seber and Le Cren two-pass formula (Seber and Le Cren 1967). I then summed the individual population estimates for all stations sampled within each site to obtain a site population estimate. However, I determined the density of juvenile steelhead per mesohabitat type based on actual counts of fish collected in each mesohabitat type instead of using the population estimates.

Steelhead Age–Size Relationship and Growth

I analyzed scales taken from a sub-sample of steelhead of various sizes at each site to determine age, differences in age to size relationships, and relative growth rates. Scales were taken just posterior of the fish's dorsal fin and above its lateral line (Murphy and Willis 1996). In 2006, scales were collected from one side of the fish during the July/August sampling and from the other side during October sampling in order to reduce the chances of collecting regenerated scales. Scales were placed in envelopes labeled with the fish's standard length, date, and site location.

For analysis, I placed multiple scales from each fish between two microscope slides, which were then magnified and analyzed using a Canon Microfiche reader. Annuli were recognized by circuli spacing and by "crossing over" of circuli during winter weight loss (Figure 8). They were confirmed by length-frequency patterns, seasonal patterns of growth from July to October in 2006, and by relative position of growth checks on the scale. I used only scales of relatively symmetrical shape as opposed to regenerated and obliquely shaped scales for final analyses. Age determinations made from scale analyses were compared with size frequency histograms for each site to determine age classes. To determine the size at annulus formation for older fish (Age 1 and Age 2), I used the Frazier-Lee back calculation method (Murphy and Willis 1996).

After determining the age classes, I calculated the mean standard lengths of YOY from each site in order to compare the differences in growth during their first year and how these differences may be related to the range of environmental conditions in Uvas Creek.

For Age 1 and older fish, I compared the size at first annulus formation with YOY fish sizes collected from the same sites. The size at first annulus formation for Age 1 fish collected in October 2005 were compared with sizes of YOY fish collected during October 2005 because sampling was not conducted in 2004. For Age 1 and older fish collected in October 2006, I compared their size at first annulus formation with YOY fish collected in October 2005 from the same sites. For Luchessa Avenue, I compared size at first annulus formation with YOY fish sizes in October 2006, because this site was dry in 2005.

Results

Stream Flow

2005 Stream flow.—Stream flow releases from Uvas Reservoir were maintained at approximately 0.28 m^3/s (10 f^3/s) throughout most of the summer; they increased to approximately 0.35 m^3s (12.5 f^3/s) in late August, and to 0.37 m^3s^{1} (14 f^3/s) for brief periods in September (Figure 9). Stream flow was maintained beyond the Miller Avenue crossing throughout summer and fall of 2005. On 18 July, I measured a stream discharge of approximately 0.17 m^3s (5.9 f^3/s) at Miller Avenue, however by mid September the flows had declined to approximately 0.07 m^3s (2.6 f^3/s) at this site, despite increased releases at the reservoir. Farther downstream at Luchessa Avenue on 14 July, I measured a stream discharge of 0.12 m^3s (4.2 f^3/s), but during a subsequent visit on 19 August the channel was dry. Minimal flows recurred at this site for brief periods throughout September and October, but consistent surface flow did not occur.

On 11 September, the SCVWD collected discharge measurements at nine sites below Uvas Dam as part of a percolation test to determine stream flow loss to streambed percolation downstream of the reservoir at a time when tributaries have no surface flow (Figure 10 and Table 1). The upper 6.4 km (4.0 miles) had minimal stream flow loss of 0.04 m^3/s (1.41 f^3/s) and losses downstream of Luchessa Avenue (15.9 km) were minimal as well. Substantial stream flow loss occurred in the percolating channel between Watsonville Road and Luchessa Avenue (6.4 - 15.9 km), with a total loss of 0.35 m^3s (12.3 f^3/s). The highest rate of stream flow loss was 0.05 $m^3 \cdot s^{-1} \cdot km^{-1}$ (1.72 $f^3 \cdot s^{-1} \cdot mi^{-1}$), which occurred between Santa Teresa Boulevard and Miller Avenue

(12.7 - 14.3 km) and 0.04 $m^3 \cdot s^{-1} \cdot km^{-1}$ (0.80 $f^3 \cdot s^{-1} \cdot mi^{-1}$) between Highway 152 and Santa Teresa Boulevard.

2006 Stream flow.—In summer and fall of 2006, the SCVWD increased stream flow releases from Uvas Reservoir compared to 2005. Early summer releases were kept between 0.34 - 0.5 m^3s (12 - 17.5 f^3/s) which were supplemented with tributary flows, and apparently by some spilling from Uvas Reservoir (Figure 9). By late July, water releases from Uvas Reservoir increased to 0.64 m^3s (22.5 f^3/s) and were maintained near that level into November. The greater stream flow releases in 2006 maintained surface flows throughout summer and fall at both the Miller Avenue and Luchessa Avenue sites, and also downstream beyond the Bolsa Road fish ladder (east of Highway 101).

Staff from the SCVWD performed percolation tests on 21 July, 15 September, and 27 October (Table 1). During each test, stream flow losses were minimal in the 6.4 km (4 mile) reach just below Uvas Dam. During the 15 September and 27 October tests, stream flow increased by 0.03 m^3s (1.0 f^3/s) between Old Creek Road and Watsonville Road (Table 1). Stream flow declined substantially in the 9.5 km (6 mile) reach between Watsonville Road and Luchessa Avenue (Table 1 and Figure 10). During all three tests in 2006, the highest rate of stream flow loss per kilometer occurred in the reach between Highway 152 and Santa Teresa Boulevard (0.04, 0.06, and 0.04 $m^3 \cdot s^{-1} \cdot km^{-1}$) (Table 1). Stream flow loss was somewhat lower between Santa Teresa Boulevard and Miller Avenue (0.03, 0.05, and 0.04 $m^3 \cdot s^{-1} \cdot km^{-1}$).

Downstream of Luchessa Avenue stream flow declined at much lower rates (Table 1), and during the 27 October test, flows actually increased by 0.06 m^3s (2.3 f^3/s)

between Highway 25 and the Uvas-Carnadero Creek Preserve crossing due to agricultural return flows and presumably a full perched aquifer (Figure 10 and Table 1).

1968 Stream flow.—For comparison, I have included results from a percolation test conducted 11 September 1968 by the local water agency. The volume of stream flow released from Uvas Reservoir was the same as in September 2006 (Table 1). Percolation rates were minimal downstream to Watsonville Road (0.01 $m^3 \cdot s^{-1} \cdot km^{-1}$) and increased substantially between Watsonville Road and Santa Teresa Boulevard (0.05 and 0.04 $m^3 \cdot s^{-1} \cdot km^{-1}$), with the highest rates occurring between Watsonville Road and Highway 152 (0.05 $m^3 \cdot s^{-1} \cdot km^{-1}$).

Habitat Assessment

Habitat Types.—Downstream sites (Luchessa Avenue and Miller Avenue) were dominated by pool habitat (65% and 49%, respectively of the total length assessed), while riffle and head of pool habitats were relatively scarce (Figure 11). Pool was the most abundant habitat type at Watsonville Road and Uvas Road, however these sites also had a greater abundance of fast water habitats (riffle, run, and head of pools) relative to downstream sites. Overall, upstream sites (Old Creek Road and Uvas Road) had the highest total abundance of fast water habitats, particularly riffles (10% and 14%) and head of pools (13% and 10%).

Substrate.—Channel substrate conditions, based on surface particle sizes, varied both by site and mesohabitat type (Figures 12 and 13). Gravel was the most abundant substrate size class at all sites. Coarse substrate, such as cobbles and boulders, was more abundant at upstream sites (Old Creek Road and Uvas Road), especially in riffles and run habitats (Figure 13), and became increasingly scarce at most sites downstream of Watsonville Road. Cobble abundance was notably higher at Highway 152 (compared to Watsonville Road and Miller Avenue) due to replenishment from Bodfish Creek which enters just upstream of this site.

Watsonville Road had the highest combined amount of sand and fine sediments/detritus (51%) followed closely by Luchessa Avenue (49%). Overall, substrate conditions at Watsonville Road were notably degraded compared to sites just upstream and downstream. Substrate conditions would have been expected to improve below the Little Arthur Creek confluence due to coarse substrate replenishment from Little Arthur Creek and flushing of fine sediments from unimpaired storm flows. However there were substantial increases in the amount of both fine sediments and sand below the confluence compared to upstream (Figure 12).

Often the fine sediment was a coating of variable thickness over the surface of gravel or even cobbles. Although not quantitatively measured, the depth of very fine sediments in pools and glides was much greater upstream of Little Arthur Creek and immediately downstream of Little Arthur Creek than farther downstream. In addition, high accumulations of fine sediments within the substrate were observed even in fast water habitats (e.g., riffles and runs) at sites upstream of Highway 152. This was readily noticed when the substrate was agitated. Algae on cobbles and root mats along the stream banks were also coated in fine sediments that produced sediment plumes when disturbed.

In the Bodfish Creek watershed, boulders and cobbles were the most common substrate classes at upstream sites (Bodfish Creek below Sprig Lake and Blackhawk Canyon Creek above Sprig Lake), while sand and fine sediments were generally scarce. Downstream at Whitehurst Rd gravel and cobbles were the dominant size classes with greater amounts of sand and fine sediment compared to upstream sites.

Riparian Canopy Closure.—Average riparian canopy closure was greater at upstream sites with the highest occurring at Old Creek Road (80%) followed closely by Watsonville Road (77%) and Uvas Road (76%) (Figure 14). Miller Avenue had the lowest average canopy closure (38%) which was dominated by relatively small willows with few mature trees on the banks and adjacent floodplain.

In Uvas Creek, the percentage of the canopy closure as evergreen was greatest at Luchessa Avenue (48%) followed by Watsonville Road (20%). Near Luchessa Avenue, parts of Uvas Creek are lined with coast live oak and planted eucalyptus trees, and at Watsonville Road coast live oak was common on the upper stream bank terraces.

In the Bodfish Creek watershed, canopy cover ranged from 92 - 97% with the highest occurring at Blackhawk Canyon Creek above Sprig Lake. Conifer and broadleaf evergreens (coast redwood and tanoak) dominated at the upstream two sites (83% and 90%) but deciduous alders and willows dominated at Whitehurst Road.

Water and Air Temperature

Figures 15-18 show the monthly mean daily maximum (MAX), monthly mean daily mean (MEAN) and the monthly mean daily minimum (MIN) air and water temperature for multiple sites in Uvas Creek between May and November of 2005 and

2006. Raw values are presented in Tables B-12 and B-13 (Appendix B). Figures 19-34 show the daily percent exceedance of different water temperature thresholds at each site from May into November in both years. Figures 39 and 40 show the results of the periodic reservoir water quality profile data collected during 2005 and 2006.

Air Temperature.—In 2005, MAX, MEAN, and MIN air temperatures all peaked in July or August (Figure 15 and Table B-12 in Appendix B) with the highest MAX air temperature (33.9ºC) and MEAN (20.5ºC) occurring at Miller Avenue. The MEAN temperatures were similar at all sites, with generally < 2.0ºC difference. The highest MIN temperature occurred upstream at the Uvas Reservoir Outlet site (13.2ºC), while the lowest MIN consistently occurred at the most downstream site, Miller Avenue, which experienced the greatest range of temperatures among all sites.

In 2006 MAX, MEAN, and MIN air temperatures peaked in July with the highest MAX temperatures recorded at Miller Avenue (35.3ºC) (Figure 16). The MEAN temperatures were again similar at all sites (within 1.2ºC), and MIN temperatures were the lowest at Miller Avenue from June to October.

Water Temperature 2005.—From the Uvas Outflow Release site downstream to the Little Arthur Creek confluence site MAX, MEAN, and MIN water temperatures peaked during September (Figure 17). The Bodfish Creek confluence and Highway 152 sites peaked in August, and downstream sites (Santa Teresa Boulevard and Miller Avenue) peaked during July and August with the highest MAX water temperature (22.9ºC) occurring at Miller Avenue. The range of temperatures (difference between the

MAX and MIN) was consistently greater at Miller Avenue, reaching 6.2 degrees in July, while at the Uvas Reservoir Outflow site the average range never exceeded 0.6 degrees.

The Uvas Reservoir Outflow site remained the coolest of all upstream sites during the early part of summer. Stream temperatures increased considerably between August and September as water temperatures increased on the bottom of Uvas Reservoir (Figures 17 and 39). In September through November the warmest MAX, MIN, and MEAN temperatures were those at the dam outlet. Just downstream at the Uvas Road and Old Creek Road sites, water temperature increased slightly with distance downstream in June through August, but showed cooling with distance downstream in September through November (Figure 17). At sites downstream of the Little Arthur Creek confluence, water temperatures increased downstream and within sites from June to August. However, from September through October, the stream cooled between the Little Arthur Creek confluence and the Bodfish Creek confluence sites and MEAN temperatures changed little farther downstream (usually ≤ 1ºC).

Water Temperature Daily Percent Exceedance 2005.—Water temperature at the Uvas Reservoir Outflow site remained below 16ºC consistently until early August, but was the warmest site in September after the reservoir turned over (Figures 19-22). Sites just downstream exceeded 16ºC earlier and more frequently with increasing distance downstream. From the Uvas Reservoir Outlet downstream to the Little Arthur Creek confluence site, temperatures exceeded 16ºC throughout much of August, September and October with extended periods of temperatures greater than 18 and 20ºC. However, temperatures at the Little Arthur Creek confluence site never exceeded 20ºC during 2005 because of cooling effects downstream of the reservoir during warm September releases.

Downstream of the Little Arthur Creek confluence to below Highway 152, water temperatures exceeded 16ºC and 18ºC more frequently than upstream sites between June and August with the duration of these exceedances increasing downstream; however, exceedance duration for 18ºC was actually less than upstream sites in September (Figures 23-24). Water temperatures exceeded 20ºC only briefly in July and August with greater frequency and duration at the downstream site (below Highway 152).

At Santa Teresa Boulevard, and especially at Miller Avenue, water temperatures exceeded 16ºC almost continuously throughout July and August, and daytime temperatures exceeded 18ºC and 20ºC for extended periods on most days (Figures 25-26). Water temperatures exceeded 22ºC and 23ºC for brief periods during July and August, although temperatures usually cooled to within 16ºC - 18ºC during night and early morning hours. The frequency and duration of temperatures above 16ºC decreased into September and October at these sites.

Water Temperature 2006.—In 2006 water temperature patterns were similar to those observed in 2005. From the Uvas Reservoir Outflow downstream to the Little Arthur Creek confluence site, MAX, MEAN, and MIN temperatures again jumped sharply and peaked in September when temperatures of bottom waters in Uvas Reservoir rose (Figures 18 and 40). However, upstream to downstream temperature differences were less than in 2005, and differences among all sites were relatively small in September. The Bodfish Creek confluence and Highway 152 sites also peaked in

September (as opposed to August in 2005) at a time of higher stream flow at all sites compared to 2005 (Figure 18).

At Santa Teresa Boulevard and Miller Avenue, MAX, MEAN, and MIN temperatures peaked in July with the highest temperatures again occurring at Miller Avenue. The MAX and MEAN water temperatures during July and August were cooler (Figure 18) while stream flows were higher at these sites compared to 2005 (Figure 17).

Water Temperature Daily Percent Exceedance 2006.—Water temperatures remained cool and consistently below 16ºC at the Uvas Reservoir outflow site through early August and then abruptly increased in late August as the reservoir turned over (Figure 27). Water temperatures exceeded 21ºC continuously for nearly an entire week in early September which included a brief period where temperatures exceeded 22ºC continuously for a few days (Figure 27). Water temperatures from Uvas Reservoir outflow downstream to Little Arthur Creek confluence exceeded the 16ºC and 18ºC thresholds for extended periods between August and October and exceeded the 20ºC and 21ºC thresholds during daytime hours for brief periods in September (Figures 27-30). Unseasonably warm waters at the Uvas Road site during May and June were likely due to warm surface waters spilling from Uvas Reservoir. These temperatures were not detected at the Uvas Reservoir outflow site, which is upstream from where the dam's spillway enters Uvas Creek (Figures 27 and 28).

Water temperatures at the sites at Bodfish Creek confluence and below Highway 152 exceeded 16ºC continuously throughout much of August, September, and early October with brief periods also exceeding 18ºC continuously in early September (Figures

31-32). In early September, water temperatures also exceeded 20ºC and 21ºC in the afternoon. These sites were warmer than upstream through early August, but were cooler than upstream from mid August through October, at a time when reservoir releases were warm.

Downstream at the Santa Teresa Boulevard and Miller Avenue sites, water temperatures exceeded 20ºC for shorter periods during 2006. Water temperatures exceeded higher thresholds (21ºC and 22ºC) earlier in the summer than in 2005 but did not exceed the 23ºC threshold as had occurred in 2005 (Figures 33-34). These daytime extremes were followed by cooler temperatures (16ºC - 18ºC) during night and early morning hours. In September and October, temperatures remained above 16ºC more often compared to 2005.

Turbidity

Turbidity 2005.—Turbidity samples were collected from sites in Uvas Creek during the habitat assessment data collection period in July and August. Chronic turbidity during late summer and fall was not anticipated for Uvas Creek below Uvas Dam, and therefore a more robust monitoring schedule was not initially planned.

In July and August of 2005, turbidity levels were less than 5 NTU at all sites (Table 2 and Figure 35). However, by early fall (7 October) turbidity levels had increased substantially at upstream sites (27 NTU at Uvas Road) and water column visibility (measured by a transparency tube) was down to 37 cm. Downstream at Watsonville Road turbidity was estimated at ≤ 7 NTU, based on a transparency tube reading of > 120 cm. The following week, (12 October) turbidity increased to 36 NTU at

Uvas Road and an estimated 17 NTU (55 cm transparency tube reading) at Watsonville Road (Figure 35 and Table 2).

At downstream sites, turbidity levels remained lower than upstream sites throughout the summer and fall. At Highway 152, water clarity remained greater than 120 cm through 19 October (≤ 7 NTU), although turbidity levels had doubled from 3 NTU on 2 August to 5 NTU on 19 October. Downstream at Miller Avenue, water clarity was always greater than 120 cm (≤ 7 NTU).

Turbidity 2006.—In 2006, periodic monitoring began in April and extended through October (Table 2). The highest turbidity levels were recorded in October at sites closest to Uvas Dam but declined substantially with distance downstream (Figure 35).

Spring turbidity levels (April and May) were elevated at all sites due to release of unsettled storm runoff from the reservoir. In late June and early July, turbidity levels were at their lowest at all sites ranging from 5 NTU at Uvas Road to 2 NTU at Miller Avenue (Table 2 and Figure 35).

On 1 August turbidity increased to 10 NTU at Uvas Road and by the end of the month it had reached 22 NTU (Table 2 and Figure 35). During October, turbidity levels increased at all sites and remained above 28 NTU at Uvas Road, Old Creek Road, and Watsonville Road sites.

In October, the decline in turbidity downstream was less pronounced than in 2005 when reservoir releases were substantially lower ($0.35\ m^3/s$ vs $0.6\ m^3/s$). At Highway 152, water clarity in September and October of 2005 measured greater than 120 cm and turbidity readings in mid October of that year were low (Table 2). However, during the same period in 2006, water clarity (in cm visibility) was reduced by at least half and turbidity levels (NTUs) more than doubled from those measured in 2005.

Uvas Reservoir Water Quality and Impacts on Downstream Turbidity

Water clarity in Uvas Reservoir declined (secchi depths decreased) from July to October during both 2005 and 2006 with a rapid substantial decline in late August into the first week of September despite only a small decrease in reservoir volume (Figures 36 and 37). A comparison of secchi depths from the reservoir with turbidity levels measured at Uvas Road shows a strong relationship between the two (Figures 36). Turbidity in Uvas Creek below Uvas Reservoir also increased during late August and early September (Figure 38).

A comparison of depth profiles for water temperature, dissolved oxygen, and cholorphyll-*a* concentrations shows that the water column in Uvas Reservoir began to destratify by late August and early September of both years (Figures 39 and 40). By mid-September, the water column was well mixed with warm (>20ºC) oxygenated water in the hypolimnion. In addition, concentrations of chlorophyll-*a* increased on the bottom of the reservoir during the middle of August (Figure 40) as phytoplankton from the epilimnion was also mixed to the bottom.

Macroinvertebrate Site Diversity, Abundance, and Drift Rates

Multi-plate sampler (MPS) macroinvertebrate volumes among the seven samples were more than 2-3 times higher in the head of pool habitat at Miller Avenue (214.5) followed by run habitats at Watsonville Road (143.5) and Miller Avenue (136.6) than other samples (Figure 41 and Table 3). Family taxa richness was highest in run habitat at

Miller Avenue (8 taxa) followed by glide habitat at Miller Avenue and head of pool and run habitats at Watsonville Road (5 taxa) (Table 3), but at all sites most of the biomass was from a few taxa. Hydrosychidae was the most abundant taxon and made up the greatest percent biomass (63 - 83%) in all fast-water mesohabitats (head of pool, riffle-run, and run) at all sites (Table 3). In slower glide habitats, Planariidae (56%) had the highest percent biomass at Miller Avenue, and Chironmidae (57%) had the highest percent biomass at Uvas Road. Of the two glide habitats sampled, Miller Avenue had the highest total biomass (17.0) and 5 taxa, compared to Uvas Road (1.8) represented by 3 taxa.

Invertebrate drift volume and taxa richness were greatest in fast-water habitat types (run and head of pool) at all sites (Table 4). The highest volume and taxa richness were collected in head of pool and run habitats at Miller Avenue.

Insect drift rates (insect volume $hour^{-1}$) were greatest in mesohabitats with higher flow velocities at all sites (Figure 42). However, drift rates were substantially greater at each velocity at Miller Avenue, while the velocity-related rates were much lower (2 - 3 times) at Watsonville Road and Uvas Road.

At Miller Avenue, Baetidae and Hydrosychidae made up 54 - 75% of the drifting insect biomass in run and head of pool habitats, and in the glide habitats Baetidae made up 83% (Table 4). Baetidae (48 - 53%) and Simuliidae (3 - 15%) made up the majority of the drifting insect biomass in two mesohabitats types at Watsonville Road. At Uvas Road Baetidae (54 - 96%) dominated the percent biomass for all habitat types followed by Chironomidae (2 - 6%).

Although the data are temporally and spatially limited, there was a relatively strong positive relationship ($R^2 = 0.90$) between insect drift rate and the volume of insects colonized on the MPS (Figure 43). Drift samples had a wider variety of taxa (Tables 3 and 4).

Steelhead Microhabitat Utilization

I conducted underwater observations of 58 juvenile steelhead during August and September 2005 and July 2006 at multiple sites in Uvas Creek. Most were observed at Miller Avenue (n=9), Highway 152 (n=35), and Watsonville Road (n=11) during summer 2005, with three additional fish from Old Creek Road in July 2006. I attempted to observe fish at Old Creek Road and Uvas Road during fall of 2005 however these attempts were unsuccessful due to elevated turbidity levels.

Although I sampled all habitats, all steelhead observed were in fast-water habitats (runs 53%, head of pool 45%, and riffles 2%). In general, riffle habitats were too shallow to detect and observe steelhead with the underwater camera (or snorkeling). Most (86%) juvenile steelhead were observed feeding in mesohabitats with mean water column velocities (measured at 0.6 depth) greater than 30 cm/s, and 36% were using habitats with mean velocities greater than 50 cm/s.

Steelhead selected focal point depths near the stream bottom, with 95% of the observed fish using depths within 10 cm of the substrate and 66% within 5 cm of the substrate. This resulted in focal point velocities that were substantially slower than mean water column velocities. Although there was wide variation in focal point velocities selected, most fish (55 of 58) were observed at focal point velocities greater than 18 cm/s.

Larger juvenile steelhead generally tended to select focal point depths with faster water velocities (Figure 43).

Juvenile steelhead usually intercepted, or struck at drifting prey in velocities equal to or greater than velocities at their focal point, with a majority occurring at velocities much greater than focal point velocities (Figure 45). Prey was usually intercepted immediately upstream and higher in the water column than the focal point.

Out of 58 juvenile steelhead observed, 36 (62%) were found beneath or directly adjacent to vegetative cover which included overhanging branches, woody debris or emergent aquatic vegetation such as hydrilla (*Hydrilla verticillata*), cattails, or arundo. Others used surface turbulence (i.e., bubble curtains) as cover, particularly in deeper heads of pools.

Juvenile steelhead showed a high affinity for their focal point position, and if they left their focal point, they generally returned within seconds. When different sized fish were present together, larger fish were usually positioned farthest upstream where they could take better advantage of insect drift. Larger fish often exhibited aggression toward smaller fish, including smaller fish of other species (e.g., juvenile pikeminnow), when competing for prey and/or position.

Steelhead Distribution, Densities, Growth, and Mesohabitat Use

October 2005 – Distribution, Densities, and Growth.—Between 13 October and 8 November 2005, I sampled a total of 2,631 m (8,633 ft) of stream at five sites on Uvas Creek and three sites in the Bodfish Creek watershed resulting in a total of 767 juvenile steelhead collected (Table 5). Juvenile steelhead were present at all sites sampled.

Figures C-54-C-61 in Appendix C show the size frequencies and age classes for juvenile steelhead collected at each site. Table 5 shows the number of steelhead collected, length of reach sampled, population estimates, and densities of fish (YOY and older fish) at each site.

In Uvas Creek, juvenile steelhead densities (based on site multiple pass population estimates) ranged from 3.5 - 14.6 fish per 30.5 m (100 ft) with the highest densities (10.1 - 14.6 fish per 30.5 m) occurring at the two upstream most sites and the lowest density (3.5 fish per 30.5 m) occurring at Highway 152 (Figures 46 and 47 and Table 5). At Watsonville Road, fish densities were slightly higher upstream of the confluence of Little Arthur Creek (5.6 fish per 30.5 m) than downstream (4.4 fish per 30.5 m).

Based on analysis of scales, the vast majority (93 - 100 %) of fish collected in Uvas Creek were YOY (Table 5 and Figure 8). Yearlings (Age 1) and older cohorts (Age 2 and Age 3) were rare in Uvas Creek, and densities of older fish ranged from 0 - 0.8 fish per 30.5 m with the highest densities occurring at the two upstream sites (Figure 47). All fish captured at Miller Avenue were YOY.

At two Bodfish Creek sites, steelhead densities were 55.3 and 23.4 fish per 30.5 m and in the Blackhawk Canyon Creek tributary fish density was 19.0 fish per 30.5 m (Figure 48 and Table 5). Most of the fish caught at these sites were YOY (87 - 100%). Densities of yearlings and older cohorts were highest at the upstream site on Bodfish Creek (7.3 fish per 30.5 m), and all fish collected in Blackhawk Canyon Creek were YOY.

In Uvas Creek, size of YOY steelhead increased downstream with a very large increase at Miller Avenue (Figure 49 and Table 6). Mean YOY sizes were 79 - 89 mm SL from Watsonville Road upstream, 101 mm at Highway 152, and 147 mm at Miller Avenue.

In the Bodfish Creek watershed, average YOY sizes (57 - 71 mm SL) were smaller than all Uvas Creek sites, with the largest found at the downstream site on Bodfish Creek (Whitehurst Rd) and the smallest from Blackhawk Canyon Creek.

Mesohabitat Use October 2005.—In October 2005, captured juvenile steelhead in Uvas Creek were most abundant in fast-water habitats (riffle, run, and head of pool) (Table 7). Riffle mesohabitat was relatively scarce at all sites, but riffle depth was greater at the two upstream sites (where flows were higher and substrate was coarser); riffles had higher fish density than other habitats at these sites (Table 7). For example, at Uvas Road, steelhead density in riffles was 39.9 fish per 30.5 m. Although riffles comprised of only 8% of the sampled habitat, they supported 46% of captured fish. Over all sites, head of pool habitat was relatively uncommon (9 - 22%) but accounted for 31% of captured fish (Table 7). At Miller Avenue, head of pool comprised of only 9% of the total sampled reach, however juvenile steelhead densities there were four times as high (32.5 fish per 30.5 m) as in run (7.1 fish per 30.5 m) and substantially greater than in glide (3.6 fish per 30.5 m) and in pool (2.3 fish per 30.5 m) habitats. The limited available riffle habitat at Miller Avenue was shallow, and no steelhead were captured. Run habitat was more common (12 - 34%) at all sites, and the moderate densities (2.2 - 14.9 fish per 30.5 m) accounted for 32% of the captured fish. Over all sites, fish densities in glides ranged from 1.9 - 6.9 fish per 30.5 m, and in pools (exclusive of head of pool) densities ranged from 0 - 4.6 fish per 30.5 m. Pool and glide habitat ranged from 40 - 60% of sampled habitat but accounted for only 25% of captured fish.

Size at Annulus Formation 2005.—In Uvas Creek the size at first annulus formation for yearlings and older fish ranged from 77 - 137 mm SL and were mostly within the upper half of the range of YOY fish from each site (Table 8). Figures D-62 - D-67 in Appendix D show a comparison of size at first annulus formation from yearlings and older fish compared with YOY fish sizes collected at each site during October 2005. In Bodfish Creek, fish size at first annulus formation ranged from 72 - 97 mm SL and, as in Uvas Creek, was within the upper half of the range of YOY fish sizes collected at these sites (Table 8).

July/August 2006 – Distribution, Densities, and Growth.—Between 20 July and 16 August 2006, I sampled 1,653 m (5,424 ft) of stream at eight sites in the Uvas Creek watershed, resulting in 611 captured juvenile steelhead (Figure 7 and Tables 9 and 10). Due to the greater stream flow releases, I included an additional sampling site in Uvas Creek at Luchessa Avenue, approximately 1.6 km (1 mile) downstream of Miller Avenue. This site is typically dry by mid-summer under normal stream flow releases and was dry by late August 2005 under slightly higher than normal stream flow releases.

Juvenile steelhead were present at all sites sampled. Table 9 shows the number of steelhead collected, length of reach sampled, population estimates, and densities of fish (YOY and older fish) at each site in Uvas Creek during both the July/August and October sampling periods of 2006. Figures E-68-E-76 in Appendix E show size frequencies and age classes for juvenile steelhead at all sites.

In Uvas Creek, juvenile steelhead densities ranged from 5.4 - 19.5 fish per 30.5 m with the highest densities occurring at the upstream site, Uvas Road, and the lowest densities occurring at Watsonville Road (Figures 46 and 47 and Table 9). Densities at Watsonville Road, as in 2005, were slightly greater above the Little Arthur Creek confluence (5.6 fish per 30.5 m) compared to downstream of the confluence (4.9 fish per 30.5 m). The densities of yearlings and older cohorts ranged from 0.5 - 2.4 fish per 30.5 m in Uvas Creek with the greatest occurring at Uvas Road and the lowest occurring at Luchessa Avenue and Highway 152 (Figure 47). Most (88 - 94%) fish collected at all sites in Uvas Creek were YOY.

In the Bodfish Creek watershed, fish densities were greater than at all sites in Uvas Creek, and ranged from 25.0 - 79.5 fish per 30.5 m (Table 10). The highest densities occurred at the upstream site on Bodfish Creek below Sprig Lake and the lowest densities at the downstream site (Whitehurst Rd, Table 10). Densities of yearlings and older cohorts ranged from 2.4 - 17.0 fish per 30.5 m with the highest occurring at the upstream site on Bodfish Creek below Sprig Lake (Table 10).

In Uvas Creek, mean SL for YOY fish was greatest at downstream sites (Figure 49 and Table 6) with the largest size occurring at Luchessa Avenue (118 mm). Sizes of YOY declined considerably between Miller Avenue (112 mm) and Highway 152 (81 mm) and again between Highway 152 and Watsonville Road (66 mm). Mean sizes at the two upstream sites, Old Creek Road and Uvas Road, were the same (72 mm).

Mean YOY fish size in the Bodfish Creek sub-watershed were smaller than most sites in Uvas Creek (48 - 66 mm SL) and increased with distance downstream (Figure 49 and Table 6).

Mesohabitat Use July/August 2006.—In late July and early August, juvenile steelhead densities were greatest in fast-water mesohabitats (run, head of pool and riffles, Table 7). Run habitat was the most abundant habitat at nearly all sites (30 - 52% of sampled reaches) and accounted for 44% of the collected juvenile steelhead. All fish collected at Luchessa Avenue were found in a single run habitat. Although riffle habitat was again limited at all sites (≤ 13% of sample reaches), fish densities were again highest in this habitat type at Uvas Road and Old Creek Road (96.1 and 96.4 fish per 30.5 m, respectively, Table 7). Overall, head of pool habitat was relatively uncommon (10 - 24% of sampled reaches) and accounted for 18% of the total collected steelhead. However, at Miller Avenue where head of pool habitat comprised only 20% of the sampled reach, steelhead densities (16.3 fish per 30.5 m) were nearly four times greater in head of pool than in run habitat (4.3 fish per 30.5 m), which comprised 47% of the sampled reach, and nearly five times that of glide habitat (3.6 fish per 30.5 m) which was 27% of the sampled reach. Despite higher flows in 2006, riffles were still shallow, and no steelhead were collected in this habitat type at Miller Avenue. For all sites, glide and pool habitat (exclusive of head of pool) made up 20 - 39% of the sampled habitat but only accounted for 9% of the fish collected. In glide habitats, fish densities ranged from 0 - 9.4 fish per 30.5 m and in pool habitats densities ranged from 0 - 6.1 fish per 30.5 m. The highest fish densities for both of these habitat types occurred at the most upstream site, Uvas Road (Table 7).

October 2006 – Distribution, Densities, and Growth.—Between 6 - 31 October, I sampled 2,718 m (8,916 ft) of stream at eight sites on Uvas Creek and three sites in the Bodfish Creek sub-watershed (Figure 7) which resulted in a total of 706 juvenile steelhead collected (Tables 9 and 10). Limited sampling was also conducted at two additional sites on Uvas Creek downstream of Luchessa Avenue (Highway 101 and Bloomfield Rd). Under normal flow releases, these sites typically went dry by early- to mid-summer. During this survey, I sampled greater reach lengths at most sites compared to the July/August survey, and at most sites I re-sampled the same habitat units covered during the July/August survey for comparison.

Juvenile steelhead were present at all sites sampled, including the two additional downstream sites on Uvas Creek. Figures F-77-F-86 in Appendix F show size frequency and age classes for juvenile steelhead at all sites during the October 2006 survey.

In Uvas Creek, densities ranged from 0.8 - 12.0 fish per 30.5 m with the highest density at Luchessa Avenue, followed by Uvas Road (10.8 fish per 30.5 m), and the lowest density at Bloomfield Road (Figures 46 and 47). YOY fish comprised most (82 - 100%) of the total catch at each site, except for Bloomfield Rd where only two yearling fish were captured (Table 9). Densities for yearlings and older cohorts were low at all sites with the highest density at Luchessa Avenue (1.0 fish per 30.5 m) followed by the Old Creek and Uvas Road sites (0.8 fish per 30.5 m) (Figure 47 and Table 9).

Steelhead densities in the Bodfish Creek watershed (19.0, 54.2, and 43.8 fish per 30.5 m) were again greater than at sites on Uvas Creek (Figure 48 and Table 10). The highest densities occurred at the upstream site on Bodfish Creek (below Sprig Lake) and the lowest density at the downstream site, Whitehurst Rd (Table 10). The densities of yearlings and older fish were substantially greater at the two Bodfish Creek sites (8.0 and 10.7 fish per 30.5 m) than sites on Uvas Creek, with the highest density occurring at the upstream site on Bodfish Creek (Table 10). No yearling or older fish were collected in Blackhawk Canyon Creek.

Densities declined at all sites sampled on Uvas Creek between the July/August and October surveys with the exception of Luchessa Avenue (Tables 9 and 10). Density declines during this period were most pronounced at Highway 152 (7.4 to 1.1 fish per 30.5 m, or -85 %) and Miller Avenue (6.8 to 2.9 fish per 30.5 m, or -57 %) while the lowest decline occurred at Watsonville Road (5.4 to 4.2 fish per 30.5 m, or -22 %). Highway 152 had the lowest densities among all sites sampled in October of both 2005 and 2006. At Luchessa Avenue densities actually increased by 46 % (6.5 to 12.0 fish per 30.5m), with all of the fish in both months collected in one run habitat.

In the Bodfish Creek watershed, declines in fish density were similar at the two upstream sites (-34 and -32 %) and somewhat lower at the downstream site (-24 %). Overall, the fish density decline was generally much lower than in Uvas Creek.

I also compared fish densities at each site from habitat units sampled only during both the July/August and October surveys to see if the greater length of sampled habitat in October substantially altered density (see “Resampled Habitats” column in Tables 9 and 10). There was no significant difference between the re-sampled densities and those of the expanded sample.

In Uvas Creek, mean standard lengths for YOY steelhead in October 2006 were, as in July, greatest at downstream sites, Miller Avenue (169 mm) and Luchessa Avenue (145 mm). Sizes at Uvas Road, Old Creek Road, and Watsonville Road were similar and notably smaller than at downstream sites, with mean sizes having a range of 75 - 81 mm (Figure 49 and Table 6). There was a substantial decline in mean YOY fish size between Miller Avenue and Highway 152 (169 mm and 94 mm). For Uvas Creek, the greatest growth rates between the July and October surveys occurred at Miller Avenue where mean sizes increased by 34% (Table 6). At Luchessa Avenue, YOY fish grew faster earlier in the year than at other sites, but between sampling periods the change in size was less pronounced (19%). At sites farther upstream (Highway 152 upstream to Uvas Road), late summer increases in mean YOY fish size were much lower (10 - 14%).

At Miller Avenue, mean YOY steelhead sizes were 20 mm greater in October 2006 than October 2005 (Figure 49 and Table 6). However, at the Highway 152 and Watsonville Road sites, mean YOY sizes were somewhat lower in 2006, while at Old Creek Road and Uvas Road, there were similar between years.

At sites in the Bodfish Creek watershed, mean October YOY fish sizes were similar in both 2005 and 2006. July to October change in fish size was only 6 -14 %, with most of the change by growth of smaller fish (Figure 49 and Table 6).

Mesohabitat Use October 2006.—Juvenile steelhead continued to show a preference for fast-water mesohabitats at all sites (Table 7). Over all sites, run habitat made up 28 - 52% of sampled habitat and accounted for 60% of the collected fish. Fish densities in run habitats ranged from 1.5 - 19.1 fish per 30.5 m with the highest at Luchessa Avenue where all fish were collected in run habitat. Riffle habitat was again rare (≤18% of sampled reaches) and accounted for only 11% of the collected steelhead at all sites. However, Uvas Road, with deeper riffles, had the highest fish densities in riffle habitat (33.7 fish per 30.5 m). Head of pool habitat ranged from 10 - 29% of sampled reaches and accounted for 20% of the collected fish at all sites (Table 7). However, at Miller Avenue head of pool made up just 18% of the sampled habitat but accounted for 45% of the collected fish and the highest fish densities (6.9 fish per 30.5 m) at that site. Overall, fish in glide and pool habitats were rare (<10 % of the total catch). In glide habitats, densities ranged from 0 - 3.1 fish per 30.5 m, and in pool habitats (exclusive of head of pool) densities ranged from 0 - 2.8 fish per 30.5 m, with the highest occurring at upstream sites (Old Creek Road and Uvas Road).

Size at Annulus Formation October 2006.—For the October 2006 collections, I compared size at first annulus formation of yearlings and older fish with YOY fish sizes collected at the same site during October 2005, with the exception of Luchessa Avenue which was dry in 2005 (Table 8 and Figures G-87-G-94 in Appendix G). For sites in Uvas Creek, size at first annulus formation ranged from 67 - 142 mm SL, with most being greater than 77 mm SL and in the upper half of YOY sizes collected at each site (Table 8). At Miller Avenue and Luchessa Avenue sizes at first annulus formation were mostly much smaller than the YOY present at these sites in 2005 and were similar to YOY fish sizes from Bodfish Creek in 2005. The presence of yearlings at Luchessa

Avenue, which had dried in 2005, indicates that these fish migrated in from upstream sites.

In Bodfish Creek the size at first annulus formation ranged from 50 - 105 mm SL, with most being in the upper half of the 2005 YOY fish sizes; the largest sizes were from fish collected at the downstream site at Whitehurst Rd (Table 8 and Figures G-93-G-94).

Discussion

The results of this study show that there are significant longitudinal differences in juvenile steelhead abundance, growth rates, and habitat use below Uvas Dam that are influenced by multiple environmental factors including water temperature, riparian canopy closure, substrate quality, and turbidity. The results also indicate that habitat conditions and steelhead growth have declined considerably since the last extensive studies were conducted in the late 1970's and early 1980's (Smith 1982; Smith pers comm. 2008).

Steelhead Distribution and Densities

The increased stream flow releases from Uvas Reservoir during the summer and fall of 2005 and 2006 extended and maintained surface flows in Uvas Creek downstream to reaches that have usually been dry by the middle of summer under previous release volumes. In 2005, an estimated 4.5 km of rearing habitat was gained by the increased flow releases, and in 2006, an estimated 12 km of habitat was gained. In both years juvenile steelhead were collected at the downstream extent of surface flow indicating that suitable rearing habitat was extended due to the greater flow releases, although the quality of the increased rearing habitat varied. Also, the extended rearing habitat in 2006 produced a greater combined density of large YOY fish at the Miller Avenue and Luchessa Avenue sites, and summer stream flow, and presumably habitat quality, was greatly improved at Highway 152.

In Uvas Creek, steelhead densities were typically greatest at the two upstream sites (Uvas Road and Old Creek Road). This is largely attributed to a combination of factors. First, the greater stream flow volumes provided a greater abundance of fast-water habitats (e.g., riffles, run, head of pool) which were more heavily used relative to slow-water pools and glides. Second, fish growth was slower at these sites (discussed below), and therefore the smaller fish required less living space. The higher flow volumes and increased abundance of larger substrate provided deeper and more complex riffle habitats for the smaller fish to use. At downstream sites, steelhead densities were limited by the increasing scarcity of fast-water habitats with depths suitable for rearing the relatively large steelhead. This was due to lower gradient and to progressive stream flow loss downstream due to percolation.

Yearlings and older fish were generally scarce in Uvas Creek, and most (85 - 100%) juvenile steelhead collected in both years were YOY. By October a majority of YOY steelhead grew enough (≥80 mm SL) to smolt after a brief period of growth during the following spring. At Miller Avenue and Luchessa Avenue most YOY were especially large (Miller Avenue YOY mean size = 147 mm in October 2005 and 169 mm in October 2006) and were capable of smolting as yearlings in early spring. Large, deep, and complex pools for overwintering are common in Uvas Creek, and peak flows are attenuated by Uvas Dam. Therefore, the scarcity of yearlings is likely because they smolted and emigrated, rather than poor overwintering survival. At Miller Avenue and Luchessa Avenue, sizes at first annulus formation for the few yearlings present were much smaller than the YOY steelhead sizes collected at these sites in October 2005 and

2006. This suggests that the few yearlings present at these sites were derived from smaller fish that moved downstream from either Bodfish or Little Arthur Creek watersheds or from less productive sites upstream in Uvas Creek.

Juvenile steelhead densities were highest at sites in the Bodfish Creek watershed. Despite the higher fish densities, fish were small with most measuring less than 75 mm SL. They probably required two years to reach smolt size (Smith 1982; Hayes et al. 2008; Satterthwaite et al. 2009; Sogard et al. 2009). The scarcity of yearlings was likely because of low overwinter survival due to poor overwintering habitat (Smith 2007; Sogard et al. 2009). Very few yearlings that might have moved from Bodfish Creek were found during summer sampling in Uvas Creek in this study, and past sampling (Smith 2007) did not find steelhead rearing in the Pajaro River or in its lagoon in summer. Analysis of size at first annulus formation for the relatively scarce Age 1 and Age 2 fish collected in October 2005 and 2006 showed that nearly all grew to at least 70 mm SL during their first year (Table 8). However a substantial proportion of the YOY from these sites were less than 70 mm in October of both years, indicating that the heavy overwinter mortality affected smaller fish most. Because of their smaller size, the scarcity of yearlings, and the likelihood that fish would have to spend 2 years in the stream before reaching smolt size, the relative contribution of Bodfish Creek fish to smolt production and adult returns is probably substantially less than that of the much larger, faster-growing fish in Uvas Creek.

In Uvas Creek, fish densities were lowest at the Highway 152 site in October of both years. This was unexpected because stream flow volume and the amount of suitable fast-water habitat were greater compared to sites farther downstream, and other habitat conditions (e.g., lower shade and turbidity levels) were superior to those upstream at Watsonville Road. The low densities at Highway 152 may be due to localized water pollution or higher rates of competition and predation. A series of agricultural drain pipes which originate from adjacent nurseries and a botanical theme park discharge into Uvas Creek at the Highway 152 site. On multiple occasions I observed these pipes discharging highly turbid waters into Uvas Creek. Recently an investigation by staff from the California Department of Fish and Game and the State Water Resources Control Board was conducted on the sources of these discharges (Bone 2007). During the investigation an additional, larger pipe was found that discharges into the creek upstream of the Highway 152 site. A neighbor adjacent to this location formally complained about the discharge, particularly the odor and foam associated with its effluent. The fact that other fish species were relatively common and persistent at this site indicates that any potential toxicity effects associated with this effluent were not high enough to substantially affect all species but may have affected only steelhead or its prey.

Another potential cause for the low steelhead abundance at Highway 152 is competition with sympatric juvenile Sacramento pikeminnow and predation by adult pikeminnow (Brown and Moyle 1997; Reese and Harvey 2002). During both electrofishing efforts and underwater observations of microhabitat, I observed numerous juvenile and adult pikeminnow sharing fast-water habitats with juvenile steelhead at this site. Farther upstream, pikeminnow were relatively scarce in 2005 and 2006, and at downstream sites, adult pikeminnow were scarce and juveniles were not as abundant as at

Highway 152 in both years. Elevated turbidity levels may be limiting pikeminnow feeding efficiency upstream, causing them to congregate farther downstream where visibility is better for catching prey.

Steelhead Growth

Although juvenile steelhead were generally more abundant in tributaries and upstream sites in Uvas Creek, growth rates for YOY fish were much higher at downstream sites on Uvas Creek (Table 6). The large discrepancy in growth rates between upstream (Uvas Road, Old Creek Road, and Watsonville Road) and downstream sites (Miller Avenue and Luchessa Avenue) was influenced by multiple interacting factors, including longitudinal differences in productivity, driven by differences in substrate conditions, canopy closure, water temperature, seasonal turbidity patterns, and possibly fish density. Many of these factors also influenced steelhead abundance among sites.

Role of Substrate Conditions.—Accumulation of fine sediments on the substrate surface and within the substrate is likely to be adversely affecting insect productivity and steelhead production at upstream sites. In spring, the reservoir was still turbid with stored winter runoff, and reservoir releases had high suspended sediment concentrations (Figure 37). The fine sediments settled with distance downstream (Figure 35) and cleared entirely by mid June as the reservoir cleared. The sediments were concentrated within the interstitial spaces of cobbles and gravels in fast water habitats, and thick accumulations were found on the bottoms of long pools and glides. Accumulations of fine sediments became less apparent with distance downstream (Highway 152 to

Luchessa Avenue) indicating that the fine sediments had mostly settled farther upstream or were flushed due to higher winter and spring stream flows below unregulated tributaries (Little Arthur and Bodfish creeks).

The filling of pore spaces within the substrate is probably contributing to reduced invertebrate production at upstream sites (Tables 3 and 4) (Gurtz and Wallace 1984; Erman and Erman 1984; Waters 1995; Kaller and Hartman 2004) as well as steelhead growth (Table 6) and abundance (Waters 1995; Suttle et al. 2004). Suttle et al. (2004) found that when they increased the deposition of fine sediment to a section of stream channel in a northern California river, juvenile steelhead growth and survival declined. They attributed these declines to a decline in food availability caused by an increase in the amount of burrowing invertebrate taxa that were not available as prey, and to higher overall fish activity levels.

Role of Canopy Closure.—Growth of juvenile steelhead was substantially greater in reaches with reduced canopy closure and higher invertebrate production (e.g., Miller Avenue) (Table 6). Upstream of Miller Avenue the percent canopy closure and channel shading increased significantly (Figure 14); based on visual observations the abundance of algae on the substrate also declined considerably. Total invertebrate biomass collected at the two more heavily-shaded upstream sites (Uvas Road and Watsonville Road) was considerably lower relative to the downstream, sunnier site (Miller Avenue) (Figure 41; Tables 3 and 4). These findings are consistent with other studies that show lower canopy closure and increased light levels generally result in greater stream productivity (Murphy et al. 1981; Bilby and Bisson 1992; Hill et al. 1995; Quinn et al. 1997; Ambrose et al.

2004) and, in some cases, salmonid production (Wilzbach et al. 1986; Wilzbach et al. 2005; Nislow and Lowe 2006). For example, Wilzbach et al. (2005) found a strong growth response in juvenile rainbow trout and coastal cutthroat trout (*Oncorhynchus clarki*) to opening of the riparian canopy, which they attributed to greater stream productivity and increased trout feeding efficiency. In Uvas Creek, the low ambient light conditions at upstream sites are likely reducing steelhead response time to drifting prey and overall feeding efficiency. Wilzbach et al. (1986) found a logarithmic relationship between trout foraging efficiency and pool surface light levels (regulated by forest canopy), and they clearly demonstrated that the mean percentage of drifting prey captured by cutthroat trout was greater in more open, sunny pools compared to well-forested, shady pools.

Although my invertebrate sampling was limited, the results did show that invertebrate biomass (collected as drift and on multi-plate samplers) was substantially greater at Miller Avenue compared to the two shady upstream sites. In six Oregon streams, Hawkins et al. (1982) found that overall invertebrate abundance was greater in streams with more open canopies, and that canopy condition had a greater influence compared to substrate type on both total invertebrate abundance and guild. Further, Behmer and Hawkins (1986) compared abundance and production of invertebrates in open and shaded sites in a Utah mountain stream and found that mean biomass was greater in more open canopy sites for all taxa, with the exception of black fly (Simuliidae) which was more abundant in shadier sites. Similarly, in Uvas Creek nearly all taxa collected from all sites were more abundant at Miller Avenue, with the exception of filtering black fly larvae, which were absent from multi-plate samplers at this site but found in much greater abundance in shaded fast water habitats at the Watsonville Road and Uvas Road sites where stream flows were higher (Table 3).

Role of Water Temperature.—Longitudinal differences in water temperature patterns also contributed to the large disparity in growth rates for YOY steelhead in Uvas Creek. Growth rates were higher at downstream sites where water temperatures peaked earlier in summer and where the diel range of water temperatures was greatest.

In early summer, sites downstream of Highway 152 experienced warm daytime water temperatures that often exceeded 20ºC for much of the day, but cooled during night and early morning hours. The high daytime temperatures imposed greater metabolic costs and increased absolute food demands, but they also improved food conversion efficiency and digestive rate (Myrick and Cech 2005), which allowed the fish to feed more frequently throughout the day (Elliot 1973). Growth is improved as long as food is abundant. During night and early morning, the cooler water temperatures allowed for a metabolic reprieve when visibility for drift feeding was poor due to lower ambient light levels, and therefore fish likely moved to less energetically demanding microhabitats at those times (Metcalfe et al. 1997).

Water temperature patterns at downstream sites were more influenced by diel air temperature patterns, canopy closure, and low stream flow volume relative to upstream sites. Mean temperatures were slightly higher than they were upstream, but diurnal fluctuation was more pronounced. The lower stream flow allowed for greater rate of heat exchange with the atmosphere (warming during the day and cooling at night), while the less developed riparian canopy increased sun exposure and solar heating during the day (Poole and Berman 2001). This was most evident at Miller Avenue where flow volumes were lower, riparian canopy was minimal and both the diurnal and seasonal ranges of air and water temperatures were greatest.

At upstream sites, water temperatures were more heavily influenced by the temperature of bottom waters (hypolimnion) released from Uvas Reservoir, although this influence decreased with distance downstream. The diurnal range of water temperatures was lower due to the thermal buffering of the reservoir's water column and the higher flow volumes. In early summer, Uvas Reservoir was stratified with cool temperatures on the bottom. Water temperatures in Uvas Creek immediately downstream of the dam were cool in early summer but they increased with distance downstream due to exposure to warmer air temperatures (Poole and Berman 2001). In late August and early September of 2005 and 2006, Uvas Reservoir became well mixed (Figures 19, 27, 39, 40). This occurred with relatively little reduction in reservoir volume and apparently because of strong winds and longer nights. Once the reservoir was well mixed, water temperatures in the hypolimnion peaked, and temperatures in Uvas Creek immediately downstream peaked. Instead of stream flow warming with distance downstream, as occurred in early summer, temperatures cooled with distance downstream due to dense riparian shade and cooler air temperatures.

Growth for YOY steelhead during spring and early summer at upstream sites (Uvas Road, Old Creek Road, and Watsonville Road) was moderate, but much lower compared to downstream sites. This was evident after comparing the large differences in the mean YOY sizes among sites from July/August in 2006 (Table 6). The slower growth, relative to downstream sites, may have been due in part to the diurnally cool waters released from Uvas Reservoir which maintained lower metabolic rates, food demand, and food conversion efficiency.

Between July/August and the end of October, change in mean YOY fish sizes was minimal at these sites (Uvas Road, Old Creek Road, and Watsonville Road) indicating that conditions for continued growth had declined (Table 6). By the end of August, Uvas Reservoir became well mixed and warm. The warm waters released downstream resulted in increased metabolic demands and food conversion efficiency, however, low productivity caused by high canopy shading and degraded substrate conditions (discussed above) and poor visibility caused by elevated turbidity levels (discussed below), limited both food resources and the ability for fish to feed efficiently. Also, the lower diurnal range of water temperatures exposed fish to elevated temperatures for longer periods; sometimes above 20ºC throughout day and night. Under these conditions, elevated metabolic demands were maintained into the night when feeding was not possible.

In Bodfish and Blackhawk Canyon creeks, juvenile steelhead growth rates were low and typical for small shaded, conifer-dominated streams with low summer stream flow. Stream flow declined throughout summer and fall to just a trickle, which limited rearing habitat primarily to pools, and it also reduced invertebrate drift into pools (Smith, 1982; Harvey et al. 2006; Hayes et al. 2008; Sogard et al. 2009; McCarthy et al. 2009).

Studies have found that rapid growth of juvenile steelhead can be achieved in warm water environments when food resources are abundant. A majority of these studies pertain to controlled laboratory or hatchery settings (Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005) or estuarine environments (Smith 1990; Bond 2006; Hayes et al. 2008). Using hatchery juvenile steelhead, Myrick and Cech (2005) tested the growth response, food conversion efficiency and food intake rates under three temperature treatments (11ºC, 15ºC and 19ºC). They concluded that food conversion efficiency and growth rates were greatest under the 19ºC temperature treatment. At Miller Avenue in Uvas Creek, monthly mean water temperatures peaked at 19.2ºC in July which indicates that these temperature conditions were in fact suitable for rearing juvenile steelhead and that rapid growth was possible, assuming food resources were abundant enough to meet satiation. Hokanson et al. (1977) found that for constant temperature treatments, maximum growth rates for rainbow trout were achieved at 17.2ºC when fed excess rations. In addition, they found that trout do not acclimate to mean temperature values, but more closely to a value between the mean and maximum daily temperatures.

Studies that document rapid growth and first-year smolting by stream-reared steelhead experiencing warm summer temperatures are more limited. Some studies have found that steelhead grow relatively large in downstream reaches of watersheds (Shapovalov and Taft 1954; Moore 1980; Smith 1982; Davis 1995; Alley and Associates 2007), which they attributed to greater productivity, warmer temperatures, higher stream flows and earlier emergence time compared to cooler, shaded, low flow upstream reaches or tributaries. In Uvas Creek and two other Santa Clara County streams, Smith (1982) found that steelhead smolted as yearlings due to the augmented summer/fall stream flow below reservoirs.

In a study on steelhead rearing in a warm, unshaded, but high flow and productive section of the Ventura River, Moore (1980) found that most YOY fish reached smolt size by the end of their first year. Mean YOY fork lengths for fish measured in December were 120 mm in 1976 (drought year), 116 mm in 1977 (drought year), and 150 mm in 1978 (wet year). Moore found that in all three years steelhead growth rates were greatest in months with maximum mean water temperatures (July: 19.4, 18.9, 19.4ºC; August: 20.0, 19.4, 20.0ºC) as opposed to spring months when flows were higher and cooler or fall and early winter months when stream flow, temperature, and riffle lengths were at their lowest. Moore (1980) also concluded that juvenile steelhead grew better overall in 1978 due to the higher stream flow during summer and fall which maintained greater riffle lengths and a higher abundance of drifting insects. These results, along with others (Smith and Li 1983; Alley and Associates 2007; Harvey et al. 2006), highlight the importance of stream flow and microhabitat velocity for growth and survival of rearing juvenile steelhead, particularly when elevated water temperatures are of concern.

The results of this study show that under specific environmental conditions steelhead are able to rear quite well in water temperatures considered to be above their preferred range. Without the combination of higher augmented stream flows in summer and fall and high stream productivity, rearing at these temperatures would be less successful. For example, summer water temperature patterns similar to those at Miller

Avenue would likely result in starvation for steelhead at upstream sites in Bodfish Creek, where summer habitat conditions are cool, well shaded, and flow is limited to a trickle.

Role of Turbidity.—Turbidity levels increased throughout August to October at upstream sites (Uvas Road, Old Creek Road, and Watsonville Road) as Uvas Reservoir turned over. Turbidity levels declined with distance downstream, although late summer increases were detected as far downstream as Highway 152 (Figures 35 and 36; Table 2). The decrease in turbidity with distance downstream was due to deposition in longer pools and glides, and filtering by algal mats and roots. At upstream sites, algal mats (although rare) and root clumps released plumes of fine particles when disturbed. Mean YOY sizes and relative growth rates (based on change in mean YOY fish sizes between July/August and October sampling) were significantly less than at downstream sites where turbidity levels were maintained at low levels (<10 NTU). Although turbidity levels were not excessive (< 40 NTU) they were constant throughout much of September and all of October, and presumably into winter. Such turbidity levels (10 - 40 NTU) can have adverse impacts on the feeding effectiveness, growth, and behavior of juvenile salmonids. Sigler et al. (1984) concluded that turbidity levels as low as 22 NTU reduced the growth in both length and weight of juvenile steelhead and coho salmon (*O. kisutch*). Barrett et al. (1992) found that as turbidity gradually increased up to 15 and 30 NTU, reactive distances to prey were reduced by 20% and 55%, respectively, from those at background turbidity levels (4 - 6 NTU). Berg (1982) concluded that at zero NTU prey capture success was 100% but that at relatively minor turbidity levels (10 NTU) juvenile coho salmon frequently missed prey items.

If the turbidity levels observed in Uvas Creek further reduce already limited visibility and feeding efficiency caused by dense shading, then perhaps this combination forced steelhead to switch feeding strategies, or to use less optimal habitats for feeding which would result in reduced growth compared to downstream sites. Using experimental tanks, Swetka and Hartman (2001) found that the growth rates of brook trout decreased as turbidity levels increased between 0 and > 40 NTU, and they also found that the reduced visibility and prey recognition forced brook trout to switch to less energetically efficient feeding strategies at levels between 10 - 20 NTU. In Uvas Creek, reduced feeding efficiency at upstream sites in September also coincides with increased metabolic cost due to elevated water temperatures of releases from the reservoir which likely resulted in substantially reduce growth rates.

The cause of the seasonal turbidity increase is not clear, but there is evidence to suggest that the turbidity is organic and linked to seasonal water column dynamics in Uvas Reservoir. The increased turbidity levels in Uvas Creek downstream of the dam are consistent with the timing of de-stratification in Uvas Reservoir in late August and early September (Figure 38). Uvas Reservoir is oriented northwest to southeast in line with prevailing summer winds, and thus greater fetch and water column mixing occur near Uvas Dam. In early- to mid-summer when the reservoir was nearly full, the water column remained stratified with a cool and relatively clear hypolimnion that provided clear water downstream into Uvas Creek. Although the storage and depth gradually declined slowly warming the releases, the reservoir's water column de-stratified quite rapidly and fully mixed in September (Figures 39 and 40). Strong late summer winds and longer nights were apparently able to mix warm, well oxygenated, and biologically turbid waters from the surface waters (epilimnion) to the bottom. The color and clarity of the water in Uvas Creek from the reservoir downstream to below Watsonville Road turned from clear in early summer to an opaque and light grey-green color, which is consistent with biologically rich lake water.

The seasonal turbidity increase also appears to be a relatively new phenomenon. This assumption is based largely on the fact that these higher turbidity levels were not observed in Uvas Creek during the 1970’s or early 1980’s. In 1978, Smith and Li (1983) were able to easily make underwater observations of juvenile steelhead throughout September - November at Uvas Road, Old Creek Road, and Watsonville Road sites (J. Smith pers. comm. 2007). In September and October of 2005 and 2006, similar attempts to observe juvenile steelhead at the same sites were unsuccessful due to extremely low visibility (less than 30 cm) caused by high turbidity.

Factors explaining the change in turbidity in Uvas Reservoir and downstream in Uvas Creek are beyond the scope of this study but should be investigated further because of turbidity’s impact on steelhead growth. Possible explanations may include changes in nutrient delivery into Uvas Reservoir following the 2002 Croy Fire in the upper watershed, a decline in algal abundance on the substrate in Uvas Creek (i.e., lower ability to filter particulate matter from stream flow) downstream of the reservoir caused by the recent increase riparian canopy closure, or a combination of both processes.

Role of Fish Density and Competition.—Several studies have reported density-dependent effects on salmonid growth (Jenkins et al. 1999; Keeley 2001; Boholin et al.

2002; Harvey et al. 2005). Jenkins et al. (1999) found that average size (length and mass) for YOY brown trout in eastern California streams was negatively correlated with fish density and that larger fish were generally less affected by increases in fish density than smaller individuals. Keeley (2001) studied the response to food and space competition in juvenile steelhead of different size classes and found that when emigration was not an option and competition for food increased, growth declined. Fish mortality and the variance of size distribution increased, and smaller fish utilized less optimal feeding positions with greater frequency. However, Keeley (2001) also found that when emigration was permitted (as was the case in Uvas Creek), overall mean size of fish that remained increased and that the fish that chose to emigrate were smaller and in worse physical condition. Density-dependent effects similar to those found by Keeley (2001) may have occurred in Uvas Creek especially at downstream sites (e.g., Miller Avenue) where stream flow and the availability of fast-water habitat were lower. Fish sizes were comparatively larger and competition for food and space increased as fish grew, possibly pushing smaller fish downstream.

In addition to intra-specific competition, inter-specific competition with sympatric species such as juvenile Sacramento pikeminnow may also be limiting growth and survival of juvenile steelhead at some sites. Based on underwater observations and fish sampling, pikeminnow (especially younger juveniles) were abundant and they shared fast-water habitats at downstream sites. Reese and Harvey (2002) found that the growth of dominant juvenile steelhead in waters with 20 - 23ºC temperatures was reduced by more than 50% and the fish defended smaller territories in the presence of pikeminnow.

However, in waters with 15 - 18ºC temperatures the presence of pikeminnow had no effect on steelhead growth. They also found that for sub-dominant steelhead, the effects of intra-specific competition exceeded the effects of inter-specific competition in all temperature treatments.

Steelhead Mesohabitat and Microhabitat Use

In Uvas Creek, juvenile steelhead showed a consistent preference for mesohabitats with higher stream flow velocities (Table 7), where they could take advantage of more abundant drifting invertebrates (Chapman and Bjornn 1969; Everest and Chapman 1972; Smith and Li 1983).

There were differences in mesohabitat use between upstream sites and downstream sites that were presumably a result of longitudinal differences in stream flow and seasonal ontogenetic shifts (Everest and Chapman 1972; Bisson et al. 1988). Use of riffle habitats was substantially higher at upstream sites. This was due to the greater abundance of riffles at these sites, higher stream flow volumes, and coarser substrate, which created deeper and more useable riffles for the smaller fish. Larger yearlings were more abundant in deeper water at the heads of pools. At Miller Avenue lower stream flow made riffles too shallow by the middle of summer, especially for the larger YOY fish (≥150 mm SL), which explains their greater use of deeper head pool and run habitats during fall when sampling took place.

Fish were collected in both glide and pool habitats; however, they were not detected in these habitats during underwater observations. The use of glides occurred when there was sufficient cover present. For example, at Miller Avenue juvenile steelhead were collected in glides that had an abundance of *Hydrilla* or surface algal mats. At other sites, some fish were collected in glides where dense accumulations of small and large woody debris were present. Overall, use of pool habitat (excluding head of pool) was more uncommon. In both 2005 and 2006, densities in pool habitat were greatest at sites upstream of Highway 152. Older fish (Age 2 and Age 3) were almost exclusively found (or at least captured) in deeper complex pools.

My data also show that steelhead utilize specific microhabitats that help them maximize net energy gains. Steelhead used focal points, or normal swimming positions, with velocities much lower than the either mean water column or feeding loci velocities. Larger juvenile steelhead used focal points with faster velocities in order to satisfy greater absolute food demands. These results are consistent with those of previous studies (Smith and Li 1983; Vondracek and Longanecker 1993). More specifically, my results on microhabitat selection, along with my limited invertebrate drift data, are consistent with the results found by Smith and Li (1983) for the same stream, although they were able to observe steelhead at wider range of sites and water temperatures.

Changes in Habitat Conditions, Fish Abundance, and Growth

Since the construction of Uvas Dam and Reservoir in 1957, habitat conditions downstream have changed gradually and substantially over time due to a variety of factors. In general, stream habitat conditions downstream of Uvas Dam are typical for most systems in Mediterranean climates where 50 years or more of regulated stream flow exist (Ligon et al. 1995; Collier et al. 1996; Gordon and Meentemeyer 2006).

Changes in Riparian Canopy Conditions.—Historic evidence indicates that much of Uvas Creek downstream of Watsonville Road was typical of the sycamore alluvial woodland community (Grossinger et al. 2008). This community type is described as often having intermittent stream flow, braided channel morphology, and a sparsely vegetated riparian zone dominated by mature California sycamores. Just upstream of Watsonville Road, the channel is naturally more entrenched and confined, due to the area's geology. Percolation, as described earlier, is limited between Uvas Dam and Watsonville Road, so stream flow, even prior to construction of Uvas Dam, usually persisted down to this area and thus supported a denser riparian forest (Grossinger et al. 2008).

As recently as the late 1970's and early 1980's (20 to 25 years of regulated flow), the riparian canopy downstream of Watsonville Road was still quite open (Figure 50). Summer stream flow releases were typically 0.28 m^3/s (10 f^3/s), which maintained stream flow downstream to past Santa Teresa Boulevard (between Santa Teresa Boulevard and Miller Avenue) in most years. At sites closer to the Uvas Dam (Uvas Road and Old Creek Road) the canopy, although naturally more dense than downstream sites, was also more open relative to current conditions (Figures 51 A and B). These sites were also dominated by a mixture of mature sycamores, alders and willows which were set farther back from the wetted stream channel, while understory vegetation was usually scarce. Recently, the density of the riparian forest has increased considerably at upstream sites such as Uvas Road and Old Creek Road (Figures 51 B and 52 B) but also at sites farther downstream between Watsonville Road and Highway 152. Willow and alder density has increased substantially downstream of Watsonville Road in a reach that was historically dominated by sycamores.

Increases in riparian forest density, and canopy closure, in recent decades are attributable to reservoir effects on stream flow in Uvas Creek. Average flood flows immediately downstream of the reservoir have been reduced substantially (Kondolf et al. 2001) which has limited the intensity and frequency of major channel scouring events (Figure 52 A). Originally, Uvas Reservoir was constructed for the purpose of water storage with little emphasis on flood protection. However, continued development on the historic floodplain within the City of Gilroy and surrounding rural areas has increased the need for greater flood control prevention. In recent years (since 1998), releases between storms have been maximized (up to 4.5 m^3/s or 160 f^3/s) in order to provide flood storage and reduce peak flows downstream. As a result, channel scouring downstream of the dam has been reduced and the survival of saplings has increased to create a denser riparian canopy (Figure 52 B).

The continued availability of water during summer/fall has also contributed to the increase in tree density and change in species composition in reaches downstream of Watsonville Road. The relatively wet years (1992 - 2006) since the last major drought (1987 - 1991) have provided sufficient water to meet the minimum base flow releases outlined in the original MOA (Anonymous 1956). The perennial flows from upstream reservoir releases have substantially reduced the natural stream dry-back zone that would have killed and thinned riparian vegetation. Dry-back in 1988 - 1991 thinned riparian vegetation, and a severe dry-back in 1977, when the reservoir dried below the outlet valve, had more widespread effects (J. Smith pers. comm. 2007). However those events happened almost 20 - 30 years ago.

Change in Substrate Conditions.—The amount of fine sediment in the channel between Uvas Dam and Highway 152 has increased considerably since the 1970's (J. Smith pers. comm. 2009). Previously, sand was the dominant substrate in most large pools at upstream sites, but now many of these pools have large accumulations of silt and decomposing vegetation debris. The coarse substrate in fast water habitats was generally free of fine sediments, however now the cobbles and gravels in these same habitats are infused with fine sediments, and when disturbed, sediment plumes are common. Downstream of Highway 152, substrate quality in 2005 and 2006 was similar to conditions in previous decades. This is apparently due to greater frequency and magnitude of peak winter flows from Little Arthur and Bodfish creeks (Kondolf et al. 2001) capable of periodically flushing fine sediments. The decline in substrate quality, coupled with increased shade, has resulted in a decline in stream primary productivity, invertebrate production, and fish growth and abundance in these reaches.

Change in Steelhead Growth Rates.—Juvenile steelhead, on average, did not grow as large in most reaches of Uvas Creek as they did in the 1970's. The high growth that I observed in downstream reaches in 2005 and 2006 was found throughout Uvas Creek during the 1970's (Table 11, J. Smith unpublished data). For example, in October 1978, mean standard lengths for YOY steelhead at Uvas Road, Old Creek Road, and Watsonville Road were 142 mm, 133 mm, and 115 mm, respectively. In comparison, mean standard lengths at these same sites in October 2006 were, 80 mm, 81 mm, and 75 mm, respectively. There has been little or no change in the density of the riparian canopy cover or other habitat conditions at the three sites in the Bodfish Creek watershed which continues to produce YOY fish sizes comparable to those of previous decades (Tables 6 and 11).

Management Recommendations

The results of this study suggest several potential actions that could lead to improved rearing habitat and steelhead production in Uvas Creek downstream of Uvas Reservoir. Uvas Creek is a heavily managed system and its riparian corridor has changed significantly from historic conditions (Grossinger et al. 2008). The quality of rearing habitat has declined, based on the low fish densities and smaller fish sizes. Returning portions of Uvas Creek downstream of Uvas Reservoir back to its pre-altered or natural condition as a largely braided intermittent system (Grossinger et al. 2008) is not a realistic option because it currently supports a substantial portion of the remaining rearing habitat in the stream and in the entire Pajaro watershed. However improving some specific habitat attributes in Uvas Creek downstream of the dam, such that they resemble conditions that were previously more productive, is feasible and would likely result in improved steelhead growth and abundance. Not only would an increase in juvenile abundance likely improve adult runs, but the production of a greater abundance of larger smolt-size YOY fish each year would ensure both better ocean survival and likelihood of the fish returning as adults (Bond 2006; Bond et al. 2008). Some of these potential management actions are discussed below.

Summer and Fall Stream Flow Releases.—The increased stream flow volume released during the summer and fall of 2005 and 2006 provided additional rearing habitat for juvenile steelhead but had different outcomes with respect to water storage and quality. In 2005, stream flows were maintained between 0.28 - 0.37 m^3/s (10 - 14 f^3/s) which extended and maintained rearing habitat to just downstream of Miller Avenue throughout the dry season. Apparently, all of this flow percolated into the deeper production aquifer. Juvenile steelhead at Miller Avenue grew exceptionally well, but densities were low due to a limited amount of fast-water habitats. In 2006, late spring storms provided sufficient water storage to test whether or not an additional increase in stream flows would result in additional benefits to steelhead, and therefore stream flows were maintained between 0.5 - 0.64 m^3/s (17 and 22.5 f^3/s) during most of summer and fall. The enhanced releases extended rearing habitat to downstream of U.S. Highway 101. However, with the exception of a single open canopy run habitat near Luchessa Avenue, fish densities were low in the expanded live stream. In addition, fish densities were actually reduced at five of seven sites despite the increased flow in 2006 (Tables 5 and 9). Fish sizes in 2006 were also about the same at all sites except Miller Avenue, where higher flows in 2006 did increase the abundance of fast water habitat and mean YOY size by 15% (Table 6). More fast-water habitat at Highway 152 might also have increased fish abundance, except for the effects of possible pollution.

Much of the increased flow in 2006 was not percolated into the deeper production aquifer and instead was either lost to the Pajaro River or percolated in a shallow perched aquifer that is unusable for agricultural or municipal supplies (J. Abel pers. comm. 2008).

Also, the increased stream flow releases in 2006 reduced the reservoir volume at a slightly faster rate which meant that warm and more turbid water was released approximately 2 weeks earlier in summer than in 2005. The lower reservoir volume also reduced the availability of water needed for smolt out-migration and other flows during the following spring, which turned out to be a dry year.

Based on the minimal gains in steelhead production between the two flow release strategies and the inability to percolate much of the extra flow, a flow release strategy more like that of 2005 (10 - 14 f^3/s) that continuously maintains flow throughout summer and fall to Luchessa Avenue appears to best for steelhead. The lower releases may reduce late summer temperatures and increase reservoir carryover.

Addition of Habitat Forming Structures.—Even with the additional stream flow releases, juvenile steelhead densities at downstream sites, such as Miller Avenue, were limited due to the scarcity of suitable fast-water habitats, particularly head of pool or deep riffles. In conjunction with the increased flow releases, strategic placement of boulders, anchored root wads, or other structures within these downstream reaches would create specific feeding habitats with the combination of cover, increased depth, and flow velocity. In turn, a greater abundance of these habitats could produce more and larger smolt-size steelhead. Normally, the addition of structures is used to create complex pools for overwintering habitat; however, overwintering habitat is not limited in Uvas Creek, but fast-water feeding habitat is limited, especially at downstream sites. Ideal locations for these structures would be within or immediately downstream of exposed and sunny areas dominated by coarser substrate where invertebrate production would be high.

Much of Uvas Creek between Miller Avenue and Highway 152 is readily accessible through the adjacent linear parkway or service roads in the Eagle Ranch Community and therefore these areas are desirable locations for in-stream habitat improvement.

Riparian Canopy Opening.—From Uvas Road downstream to Highway 152 juvenile steelhead survival and growth is currently limited, in part, due to the high shading and low light levels caused by the dense riparian forest. A plan to selectively girdle or remove trees at specific habitats within these reaches should be considered, as it would reduce shading, increase stream productivity, and likely produce larger YOY steelhead. The increased light levels would also improve feeding efficiency for juvenile steelhead. More abundant algal growth on the substrate would not only improve production of invertebrates in Uvas Creek but would also filter turbid waters released from Uvas Reservoir in late summer and fall.

Using a selective approach at specific sites, or habitat units, while leaving the denser canopy intact over longer slow pools and glides, would minimize potential water temperature increases. Girdling, as opposed to tree removal, would be more cost effective, less intrusive, and the standing snags within the riparian forest would provide habitat for species of cavity-nesting birds. Specific species could be targeted. At a minimum, the removal of non-native evergreen species, such as the highly invasive evergreen acacia, should be considered at upstream sites. Sycamores should be left alone, but willows and alders in areas that would not normally support such high densities could be selected for girdling.

Increase Frequency and Intensity of Peak Flows.—Winter stream flow releases from Uvas Dam should be adjusted to increase the intensity, frequency and duration that Uvas Reservoir spills. This would mean reducing or eliminating between-storm "flood protection" releases of up to 4.5 m^3s (160 f^3/s, the outlet capacity) from Uvas Dam, as long as flood risk is not increased. The increase in large reservoir spills would benefit steelhead and other wildlife by scouring saplings and dense underbrush that are currently limiting light and stream productivity and by flushing fine sediments that have accumulated, particularly at sites closer to the dam. In addition, more frequent spilling events and channel scouring could potentially limit the long-term need to girdle or remove trees.

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Figures

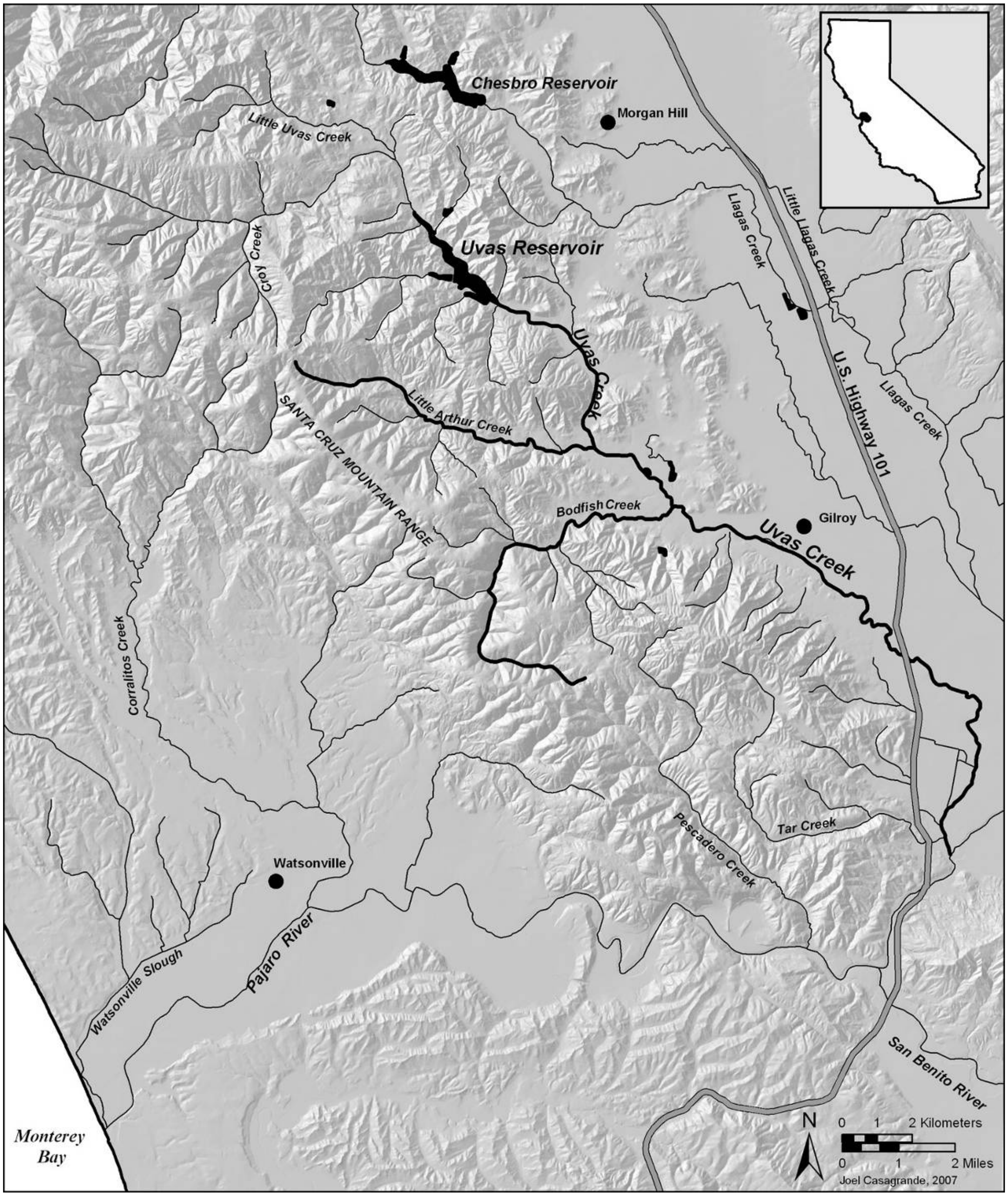

FIGURE 1.—Uvas Creek watershed also showing the lower Pajaro River and surrounding areas.

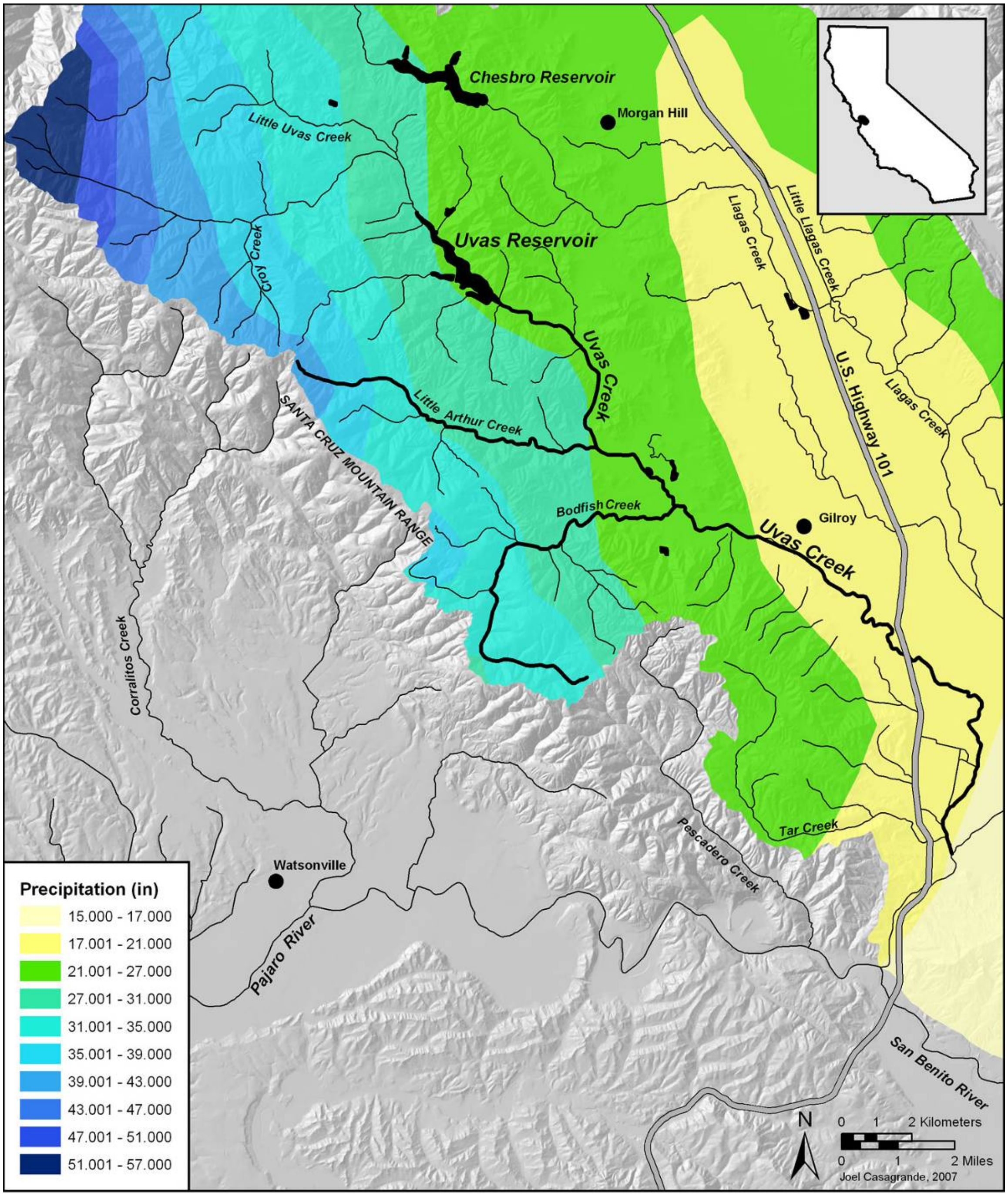

FIGURE 2.—Mean annual precipitation for the Uvas Creek watershed and surrounding areas. Data Source: The PRISM Group, Oregon State University. The data are mean annual precipitation for the climatological period 1971-2000.

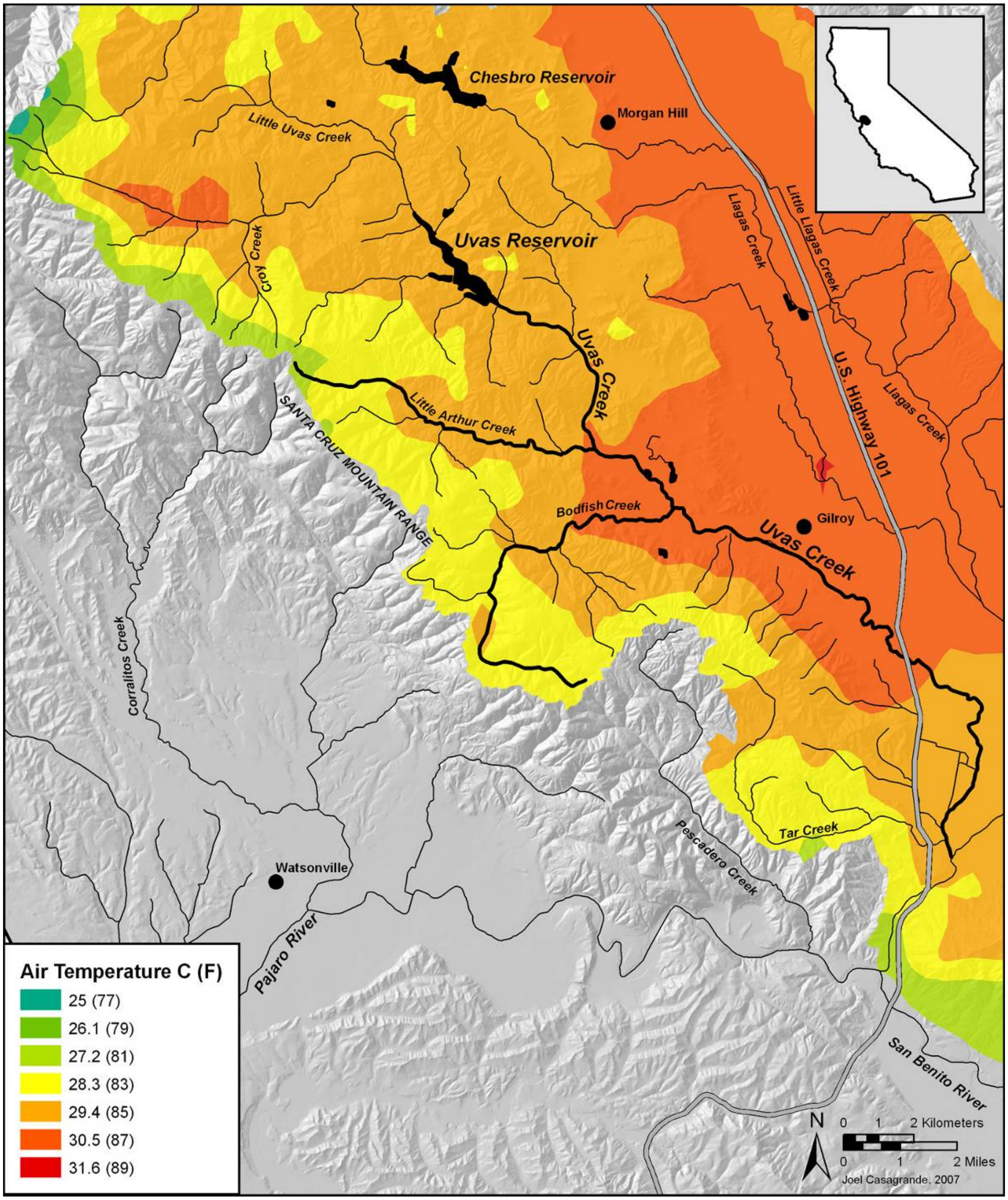

FIGURE 3.—Mean annual maximum air temperature for the Uvas Creek watershed and surrounding areas. Data source: The PRISM Group, Oregon State University. Mean annual maximum air temperature data are mean July maximums for the climatological period 1971-2000.

FIGURE 4.—Location of habitat assessment reaches in Uvas Creek July and August 2005.

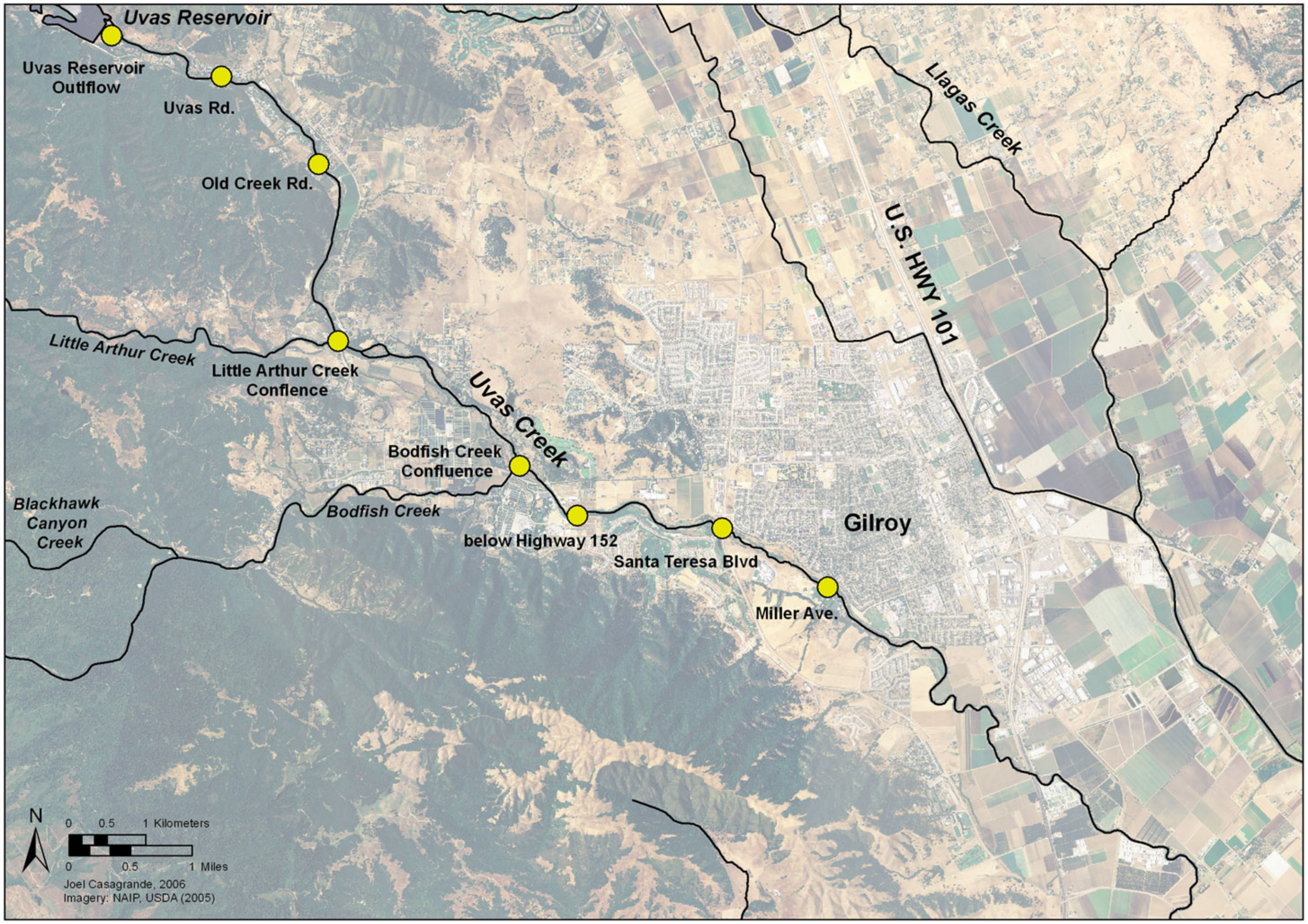

FIGURE 5.—Location of water temperature data loggers in Uvas Creek.

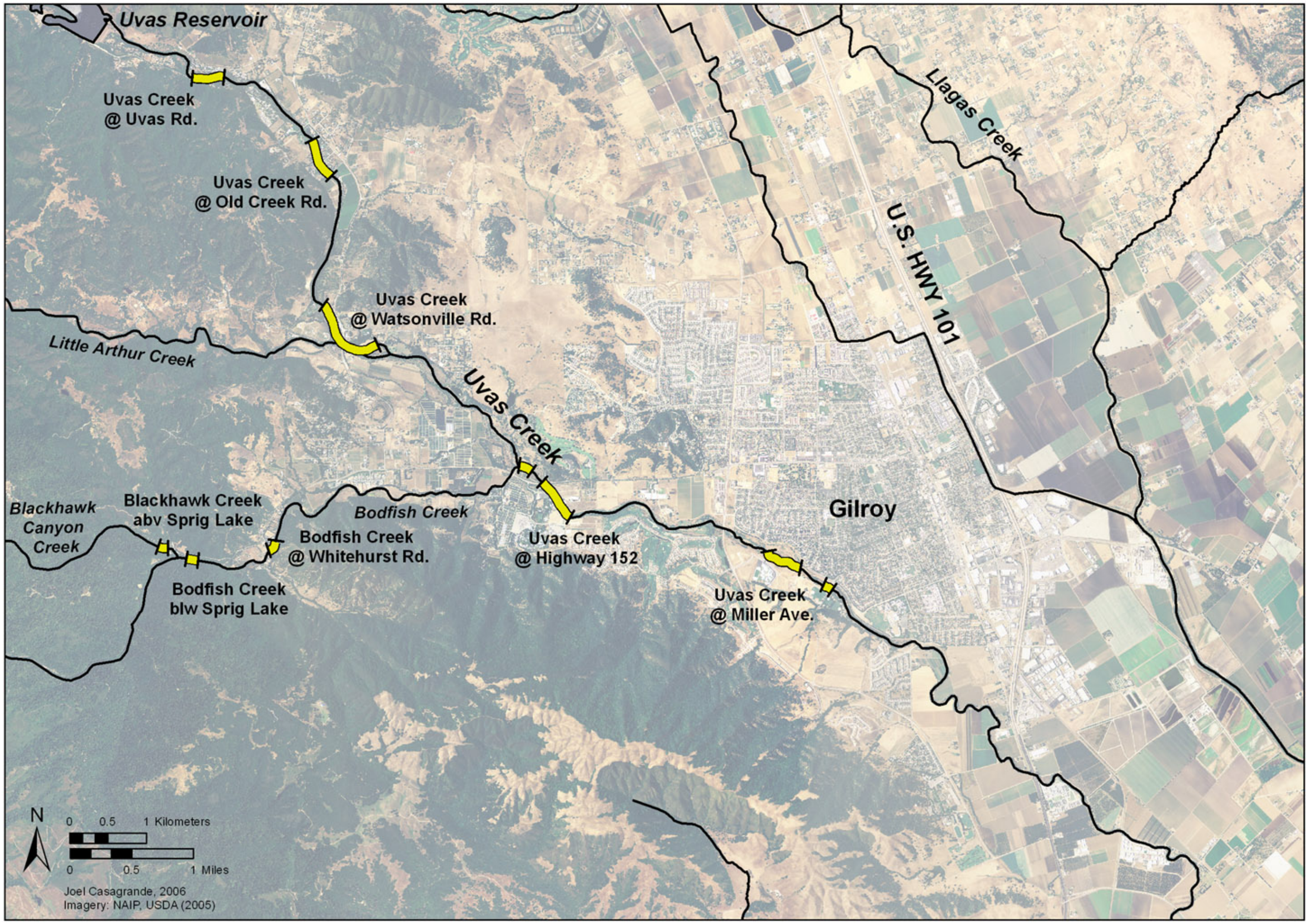

FIGURE 6.—Location of reaches sampled for steelhead in the Uvas Creek watershed, October 2005.

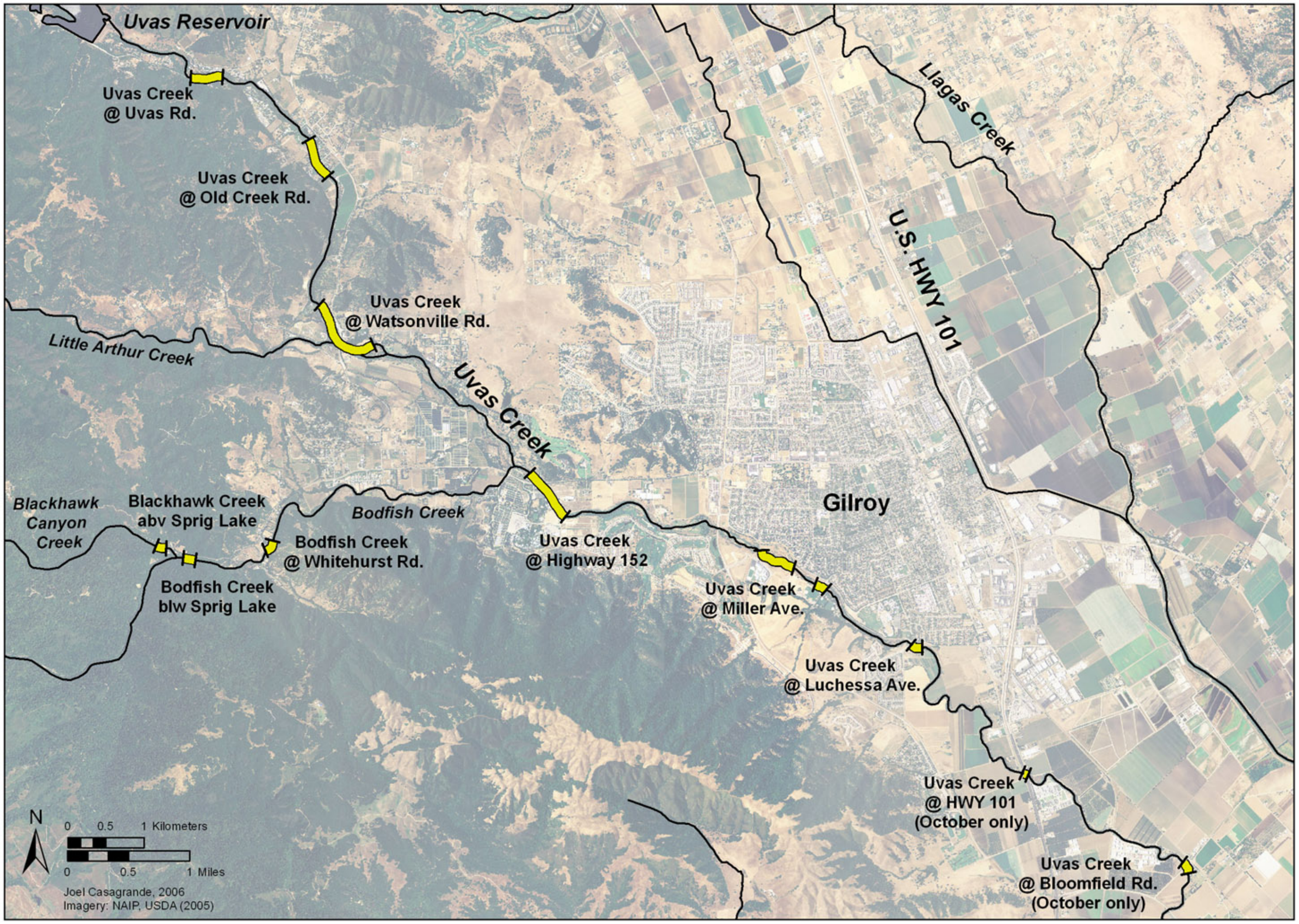

FIGURE 7.—Location of reaches sampled for steelhead in the Uvas Creek watershed, July/August and October 2006. Note: Reach lengths in map depict stream lengths sampled in October 2006; shorter distances were sampled in July 2006.

A.

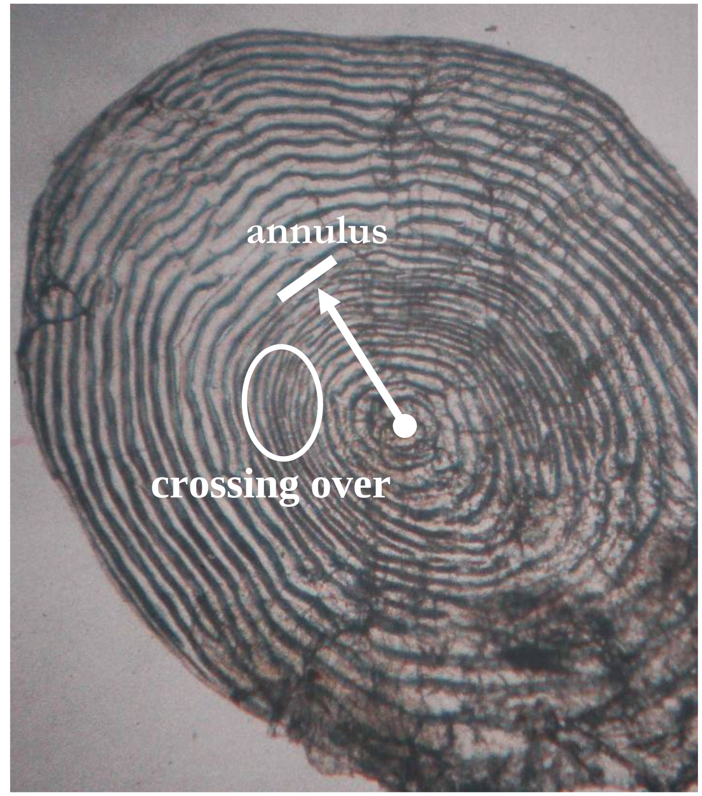

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FIGURE 8.—Scales collected from: A) a 180 mm SL YOY (Age 0) at Miller Avenue and B) a 135 mm SL yearling (Age 1) steelhead at Watsonville Road, showing annulus and crossing over.

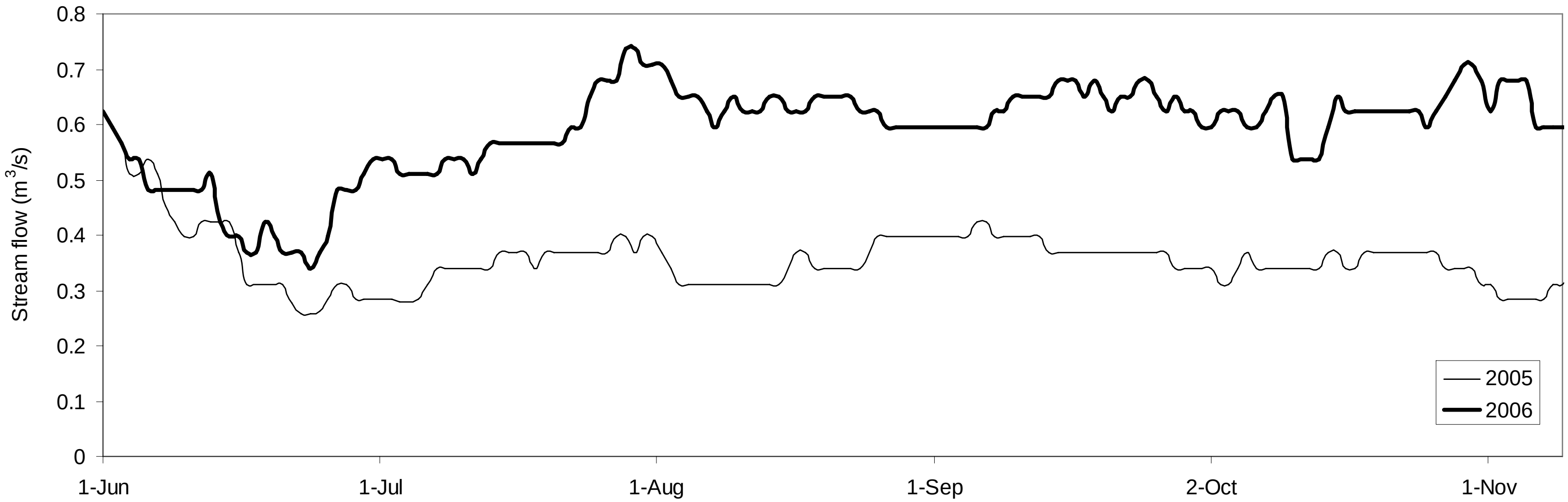


FIGURE 9.—Daily mean stream flow released from Uvas Dam recorded at the Uvas Dam release ALERT Gage (1 June - 10 Nov 2005 and 2006).

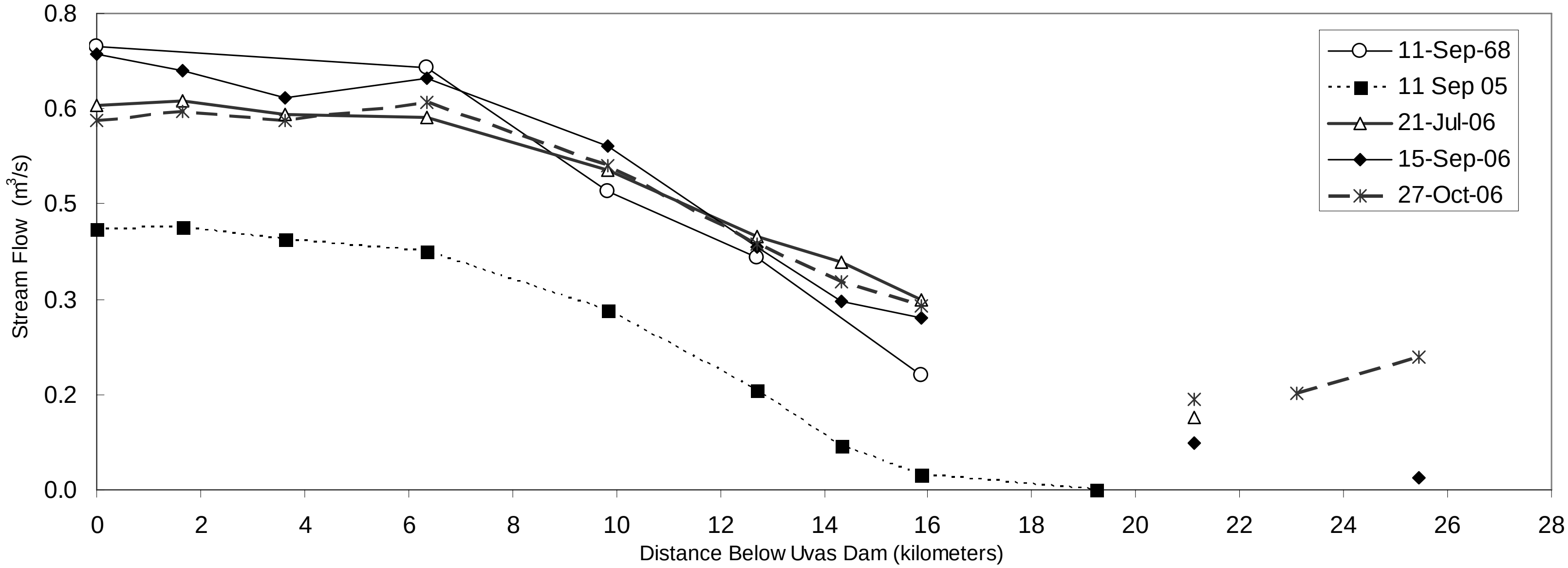


FIGURE 10.—Stream discharge measured at various sites by the SCVWD during percolation tests on Uvas Creek downstream of Uvas Dam. River kilometer 0 is Uvas Dam and the Pajaro River confluence is at 27.5 river kilometers. In summer there are no tributary surface water contributions.

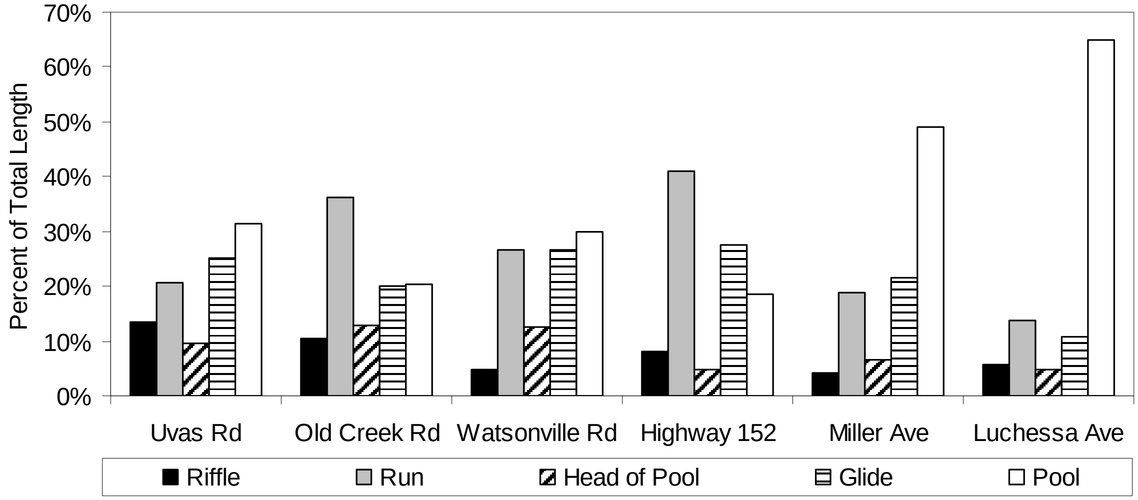


FIGURE 11.—Percent by length of mesohabitat types in reaches of Uvas Creek. Reaches are in order from upstream (left) to downstream (right).

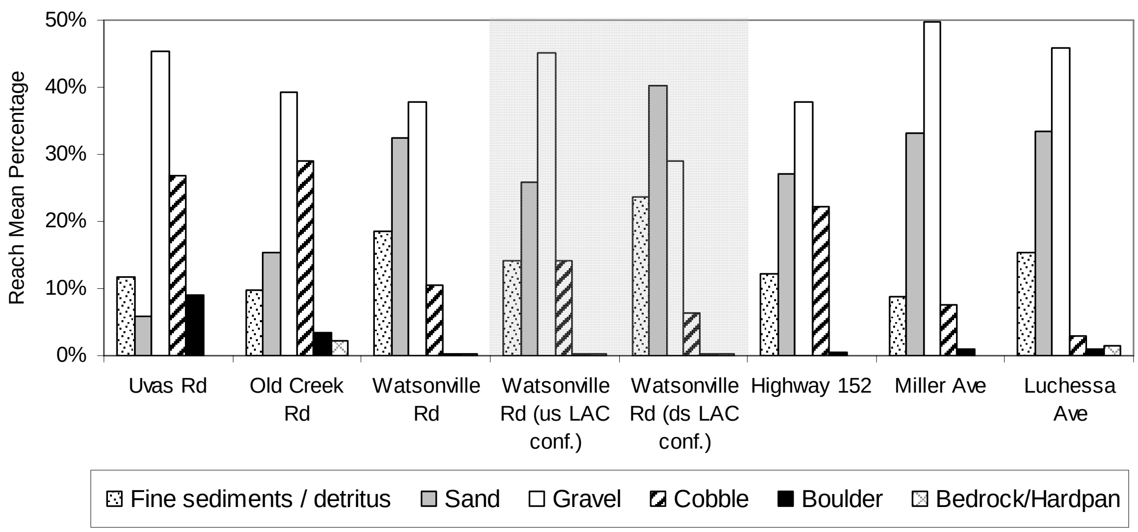


FIGURE 12.—Reach mean substrate composition for sites in Uvas Creek. Mean percentages are weighted by habitat unit length. Reaches are in order from upstream (left) to downstream (right). Area shaded in gray is a comparison of reaches at Watsonville Road upstream (us) and downstream (ds) of Little Arthur Creek confluence (LAC).

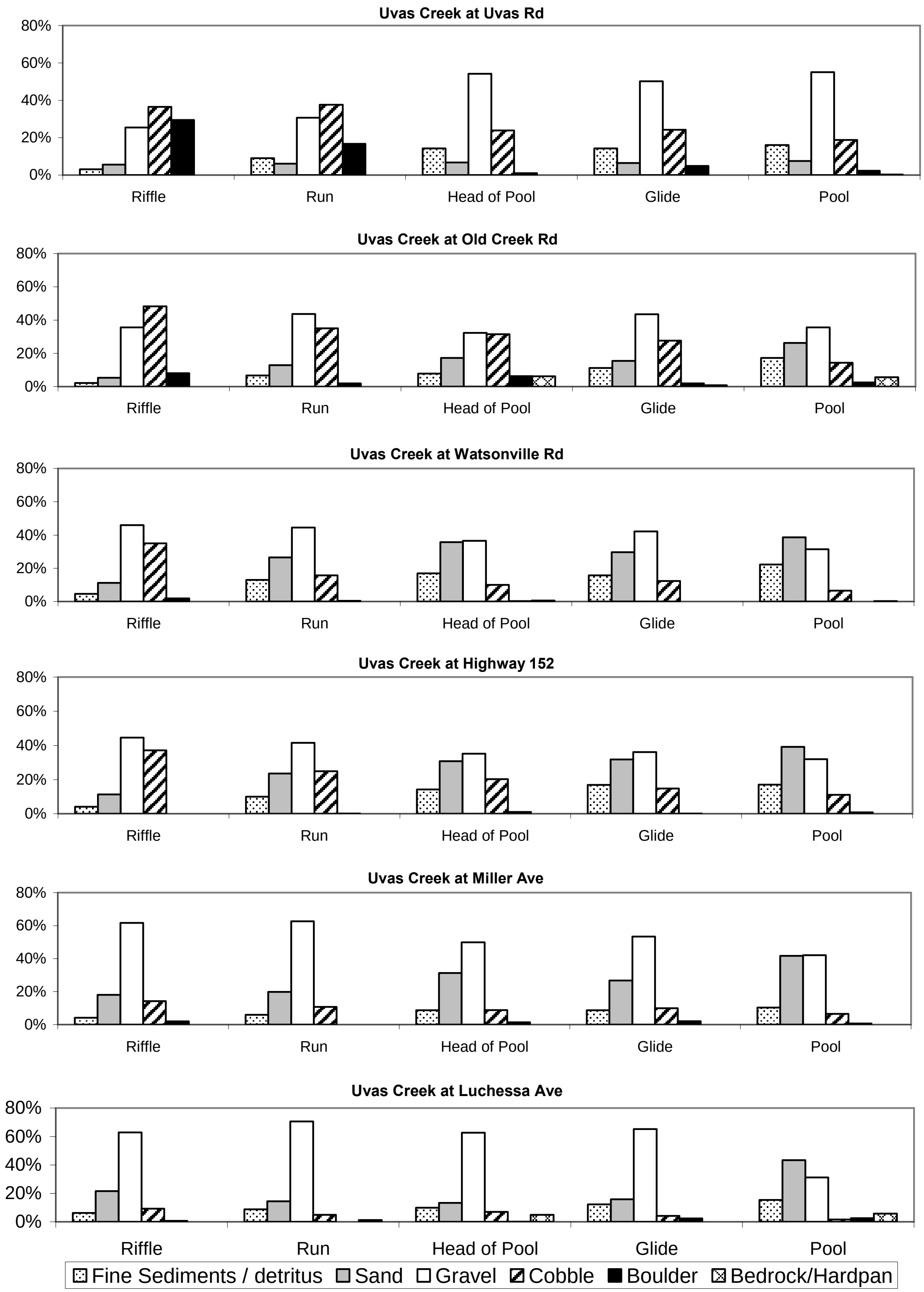


FIGURE 13.—Percent substrate composition per mesohabitat type at sites in Uvas Creek, summer 2005.

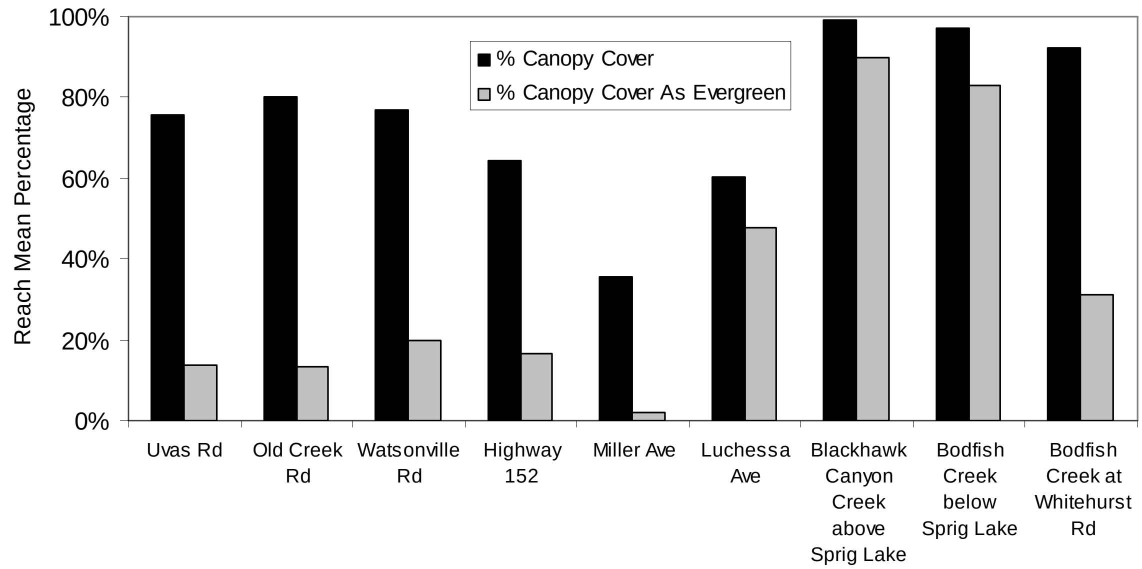


FIGURE 14.—Reach mean percent canopy cover at sites in Uvas Creek and Bodfish Creek watershed. Reach average percentages are weighted by habitat unit length. Reaches are in order from upstream (left) to downstream (right).

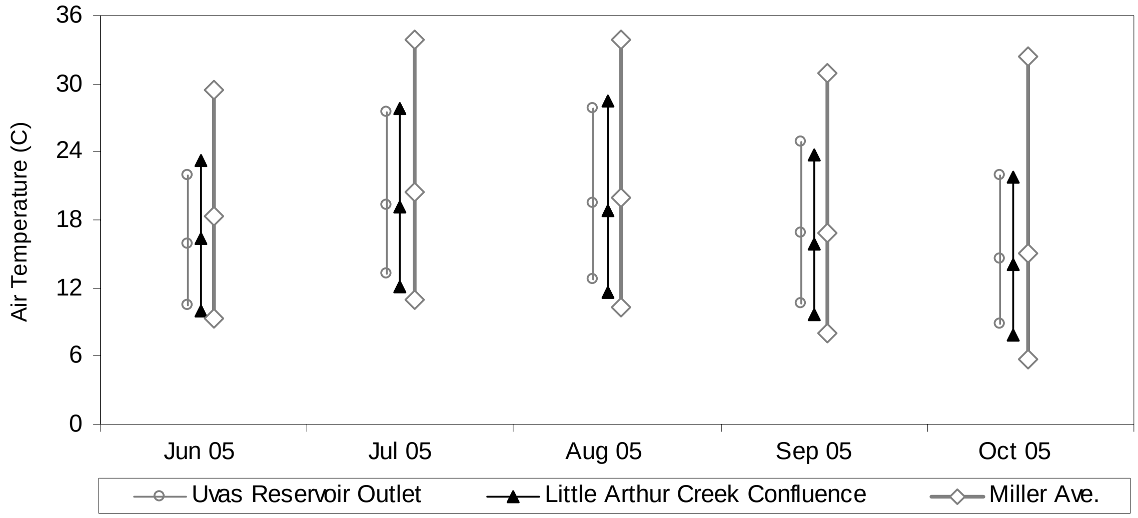


FIGURE 15.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) air temperatures at three sites along Uvas Creek June - October, 2005. Sites are in order from upstream (left) to downstream (right). Data for June 2005 at Miller Avenue are based on data from June 10 - 30th Data values are listed in Table B-12 in Appendix B.

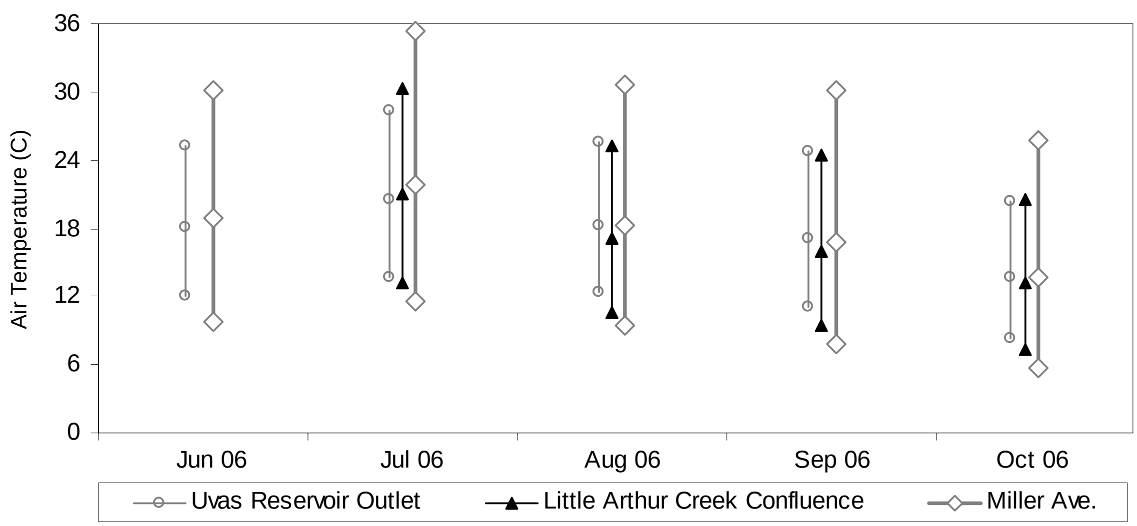


FIGURE 16.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) air temperatures at three sites along Uvas Creek June - October, 2006. Sites are in order from upstream (left) to downstream (right). Data values are listed in Table B-12 in Appendix B.

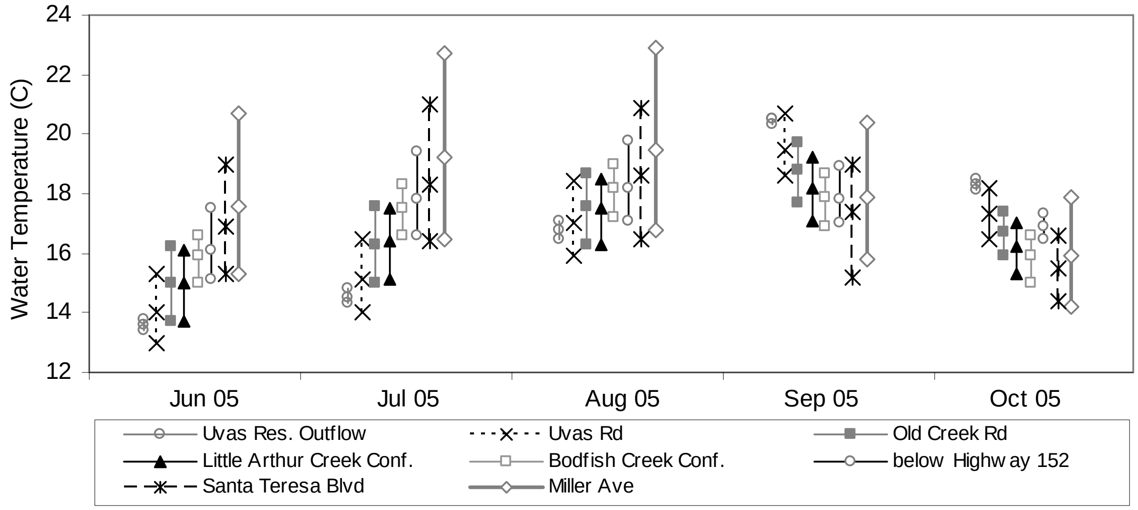


FIGURE 17.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) water temperatures at eight sites along Uvas Creek June - October, 2005. In the figure, sites are in order from upstream (left) to downstream (right). Data for June 2005 at Santa Teresa Boulevard and Miller Avenue are based on data from June 10 - 30th. All data values are listed in Table B-13 in Appendix B.

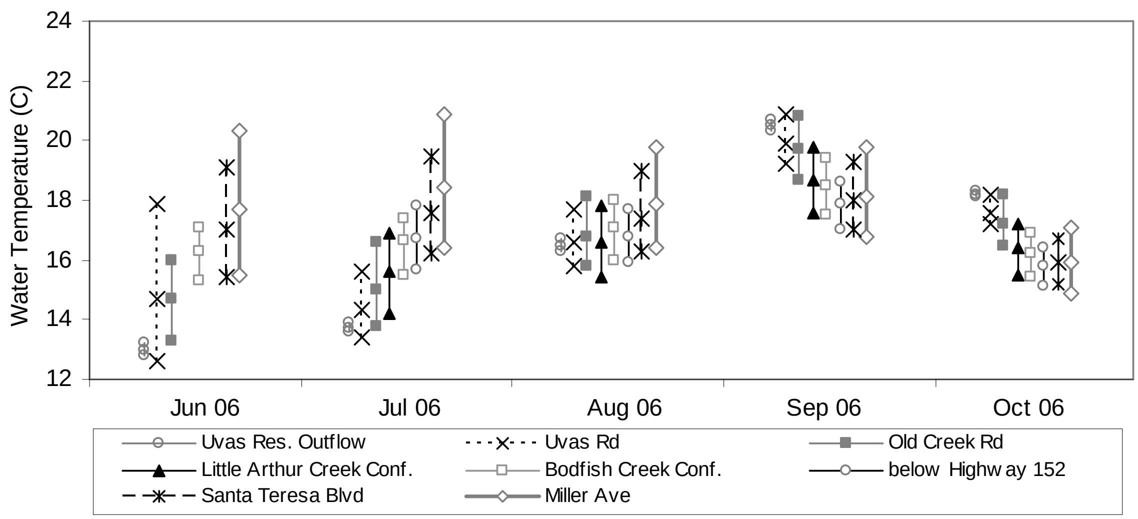


FIGURE 18.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) water temperatures at eight sites along Uvas Creek June - October, 2006. In the figure, sites are in order from upstream (left) to downstream (right). Data for the Little Arthur Creek confluence and below Highway 152 sites are not available for June 2006. All data values are listed in Table B-13 in Appendix B.

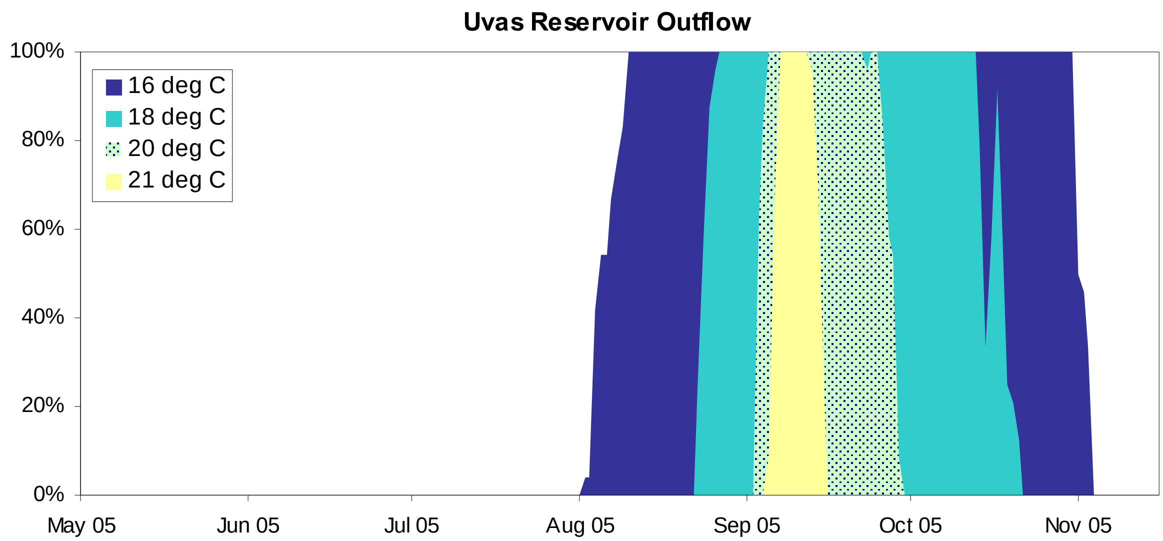


FIGURE 19.—Daily percent exceedance for selected water temperature thresholds at the Uvas Reservoir outflow below Uvas Dam, summer and fall 2005. Data records: 04 May 05 – 19 Nov 05.

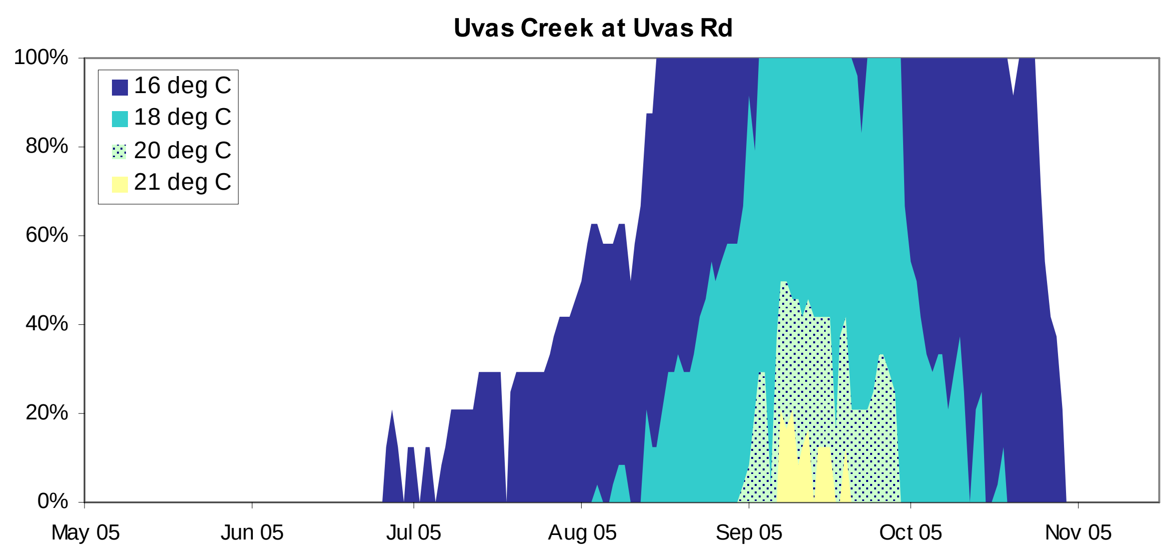


FIGURE 20.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Uvas Road, summer and fall 2005. Data records: 04 May 05 – 19 Nov 05.

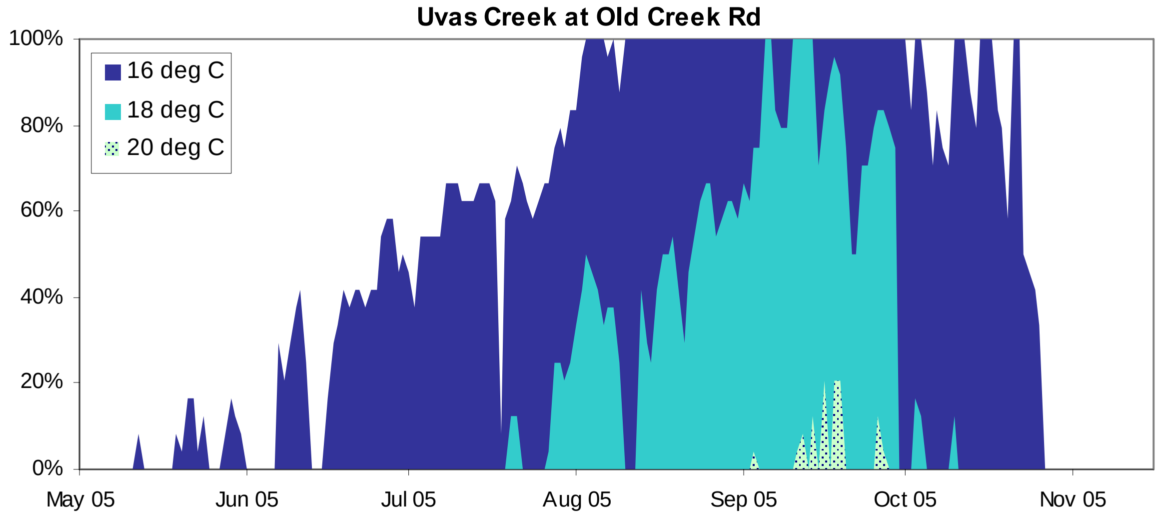


FIGURE 21.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Old Creek Road, summer and fall 2005. Data records: 04 May 06 – 19 Nov 05.

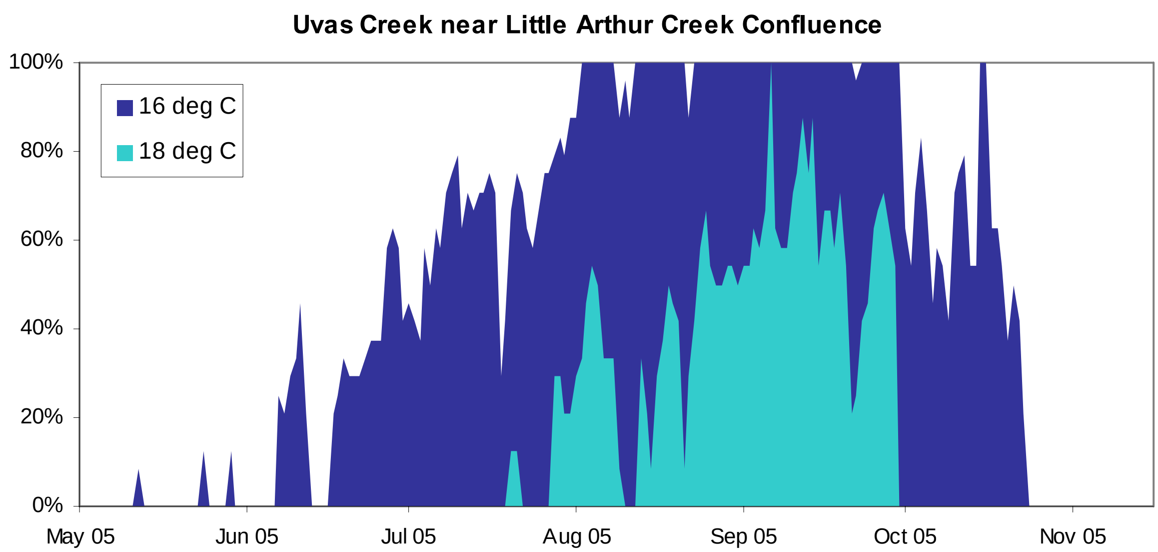


FIGURE 22.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek near the Little Arthur Creek Confluence, summer and fall 2005. Data records: 04 May 05 – 19 Nov 05.

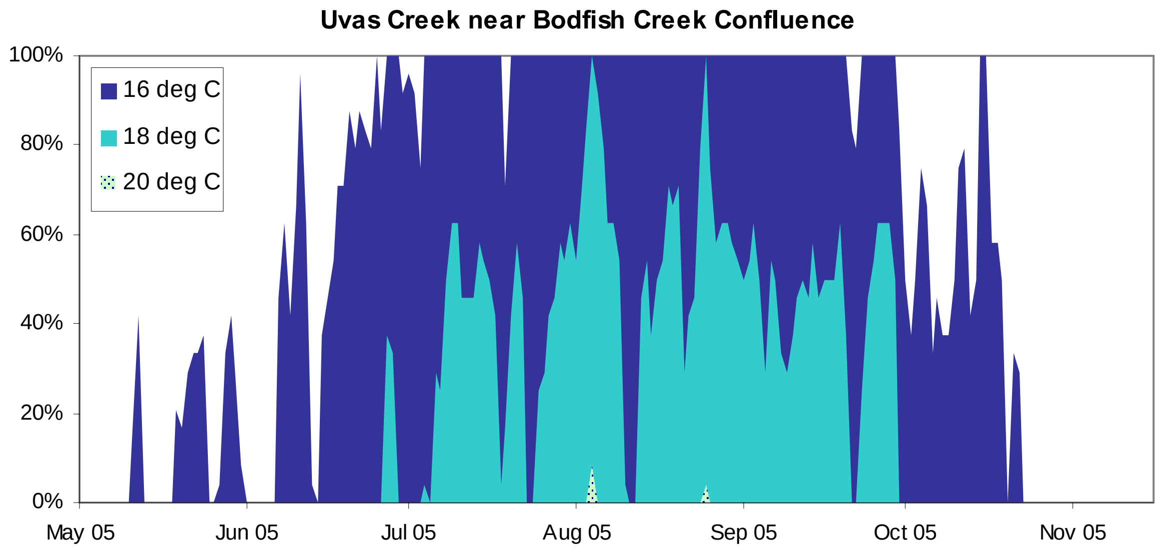


FIGURE 23.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek near the Bodfish Creek confluence, summer and fall 2005. Data records: 04 May 05 – 19 Nov 05.

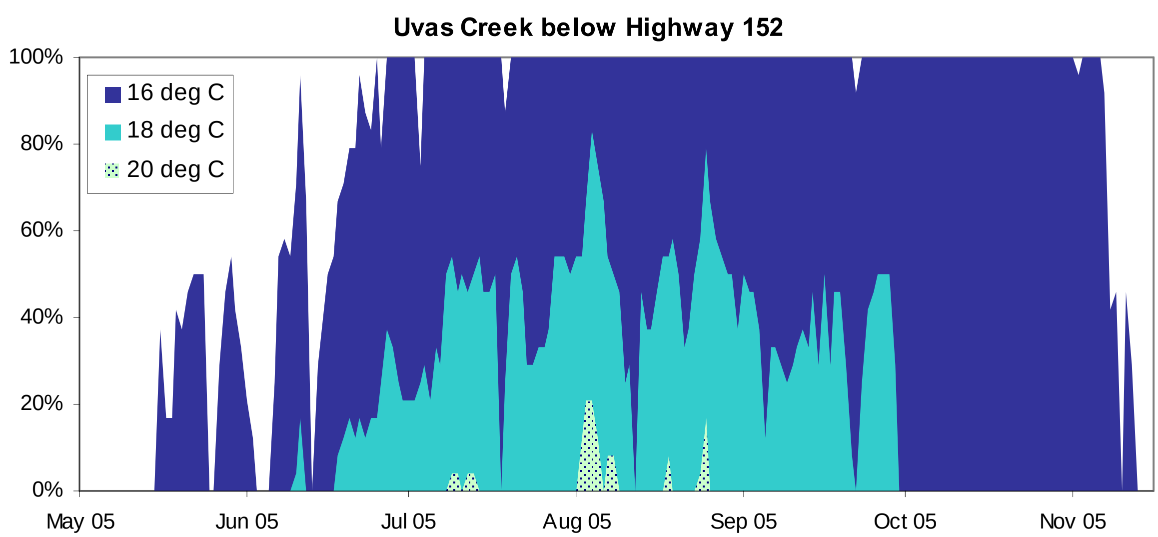


FIGURE 24.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek below Highway 152, summer and fall 2005. Data records: 17 May 05 – 19 Nov 05.

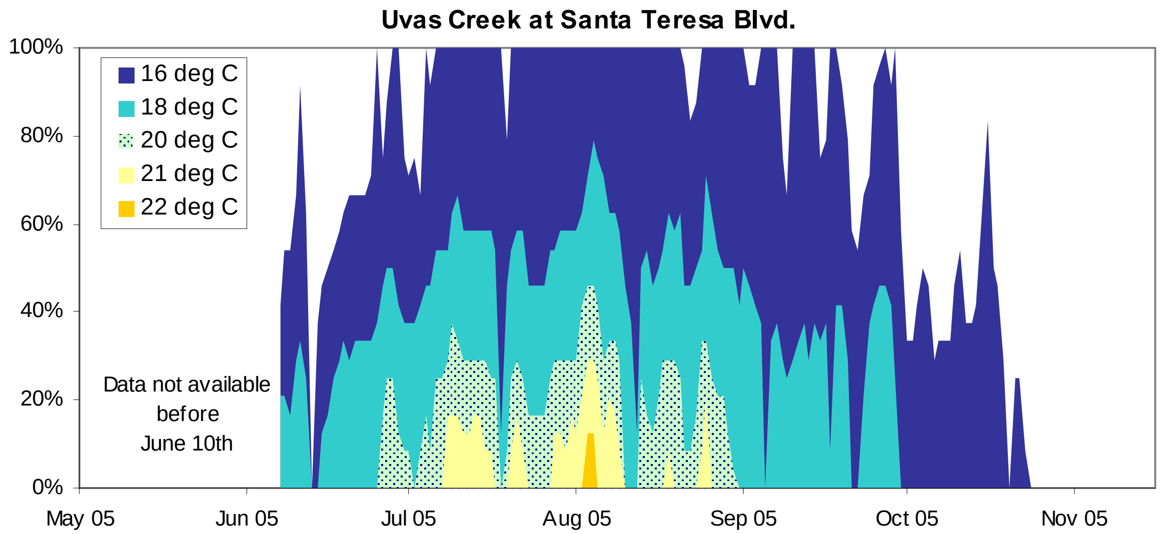


FIGURE 25.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Santa Teresa Boulevard, summer and fall 2005. Data records: 10 Jun 05 – 19 Nov 05.

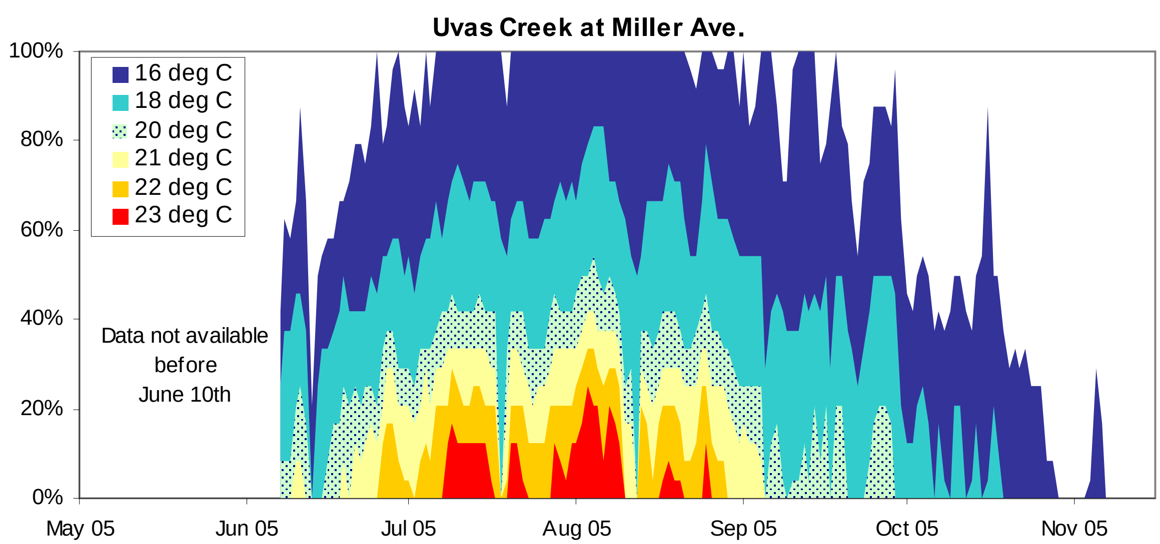


FIGURE 26.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Miller Avenue, summer and fall 2005. Data records: 10 Jun 05 – 19 Nov 05.

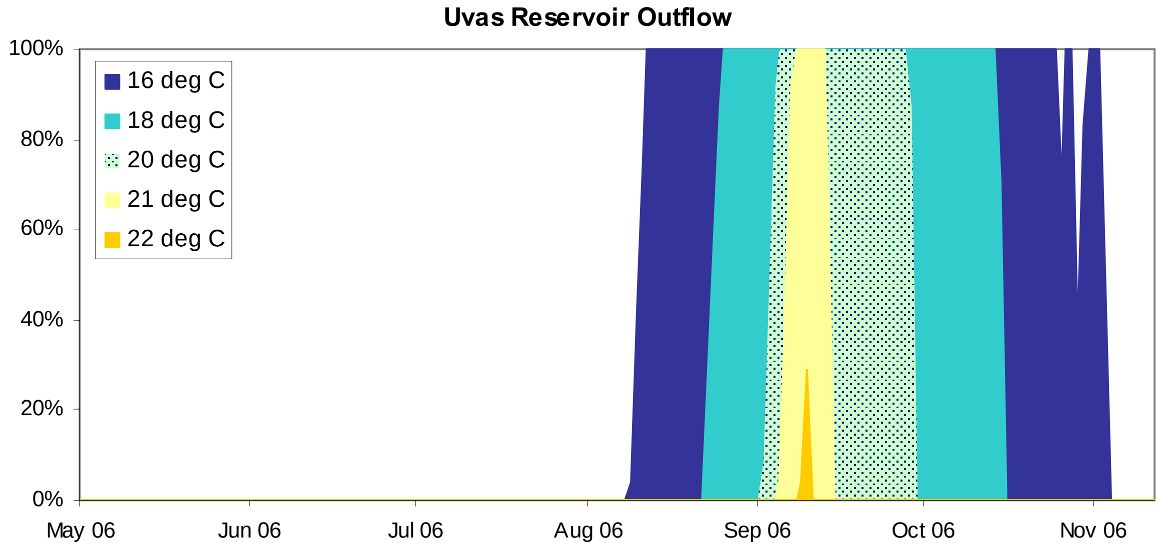


FIGURE 27.—Daily percent exceedance for selected water temperature thresholds at the Uvas Reservoir outflow below Uvas Dam, summer and fall 2006. Data records: 04 May 06 – 06 Nov 06.

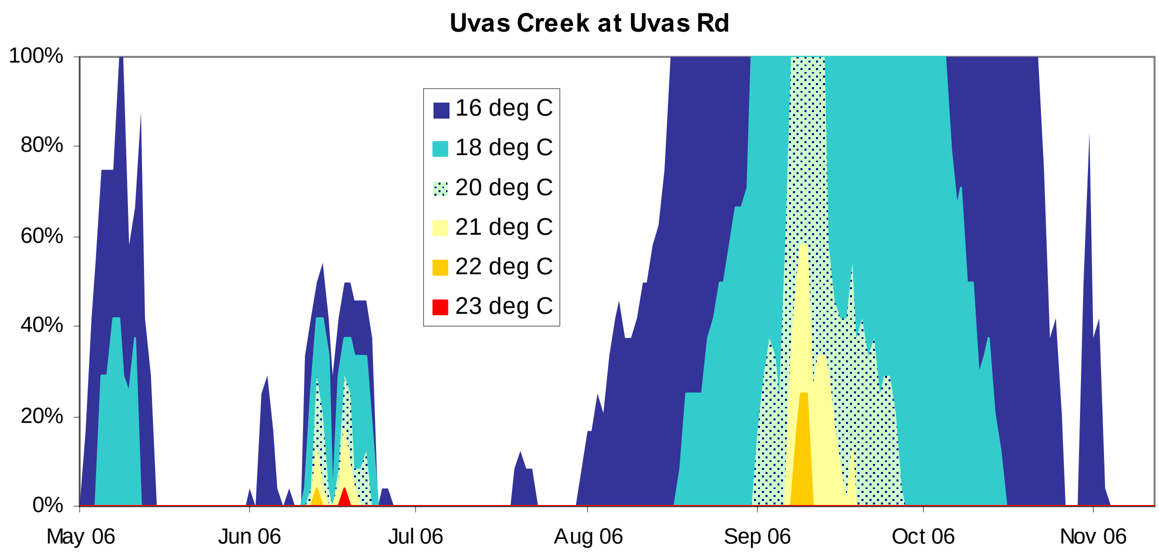


FIGURE 28.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Uvas Road, summer and fall 2006. Data records: 04 May 06 – 06 Nov 06.

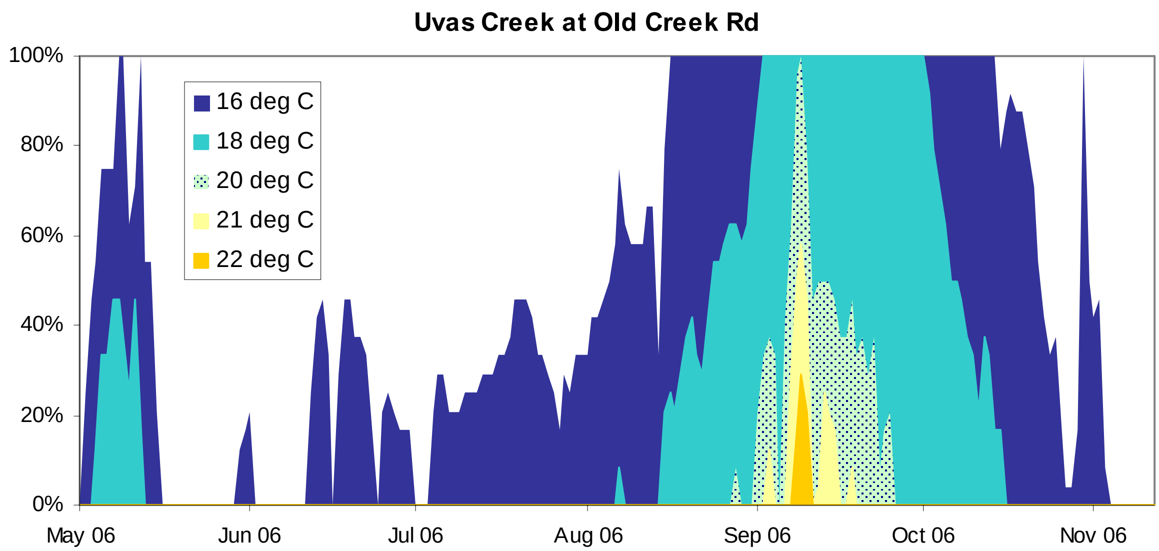


FIGURE 29.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Old Creek Road, summer and fall 2006. Data records: 04 May 06 – 06 Nov 06.

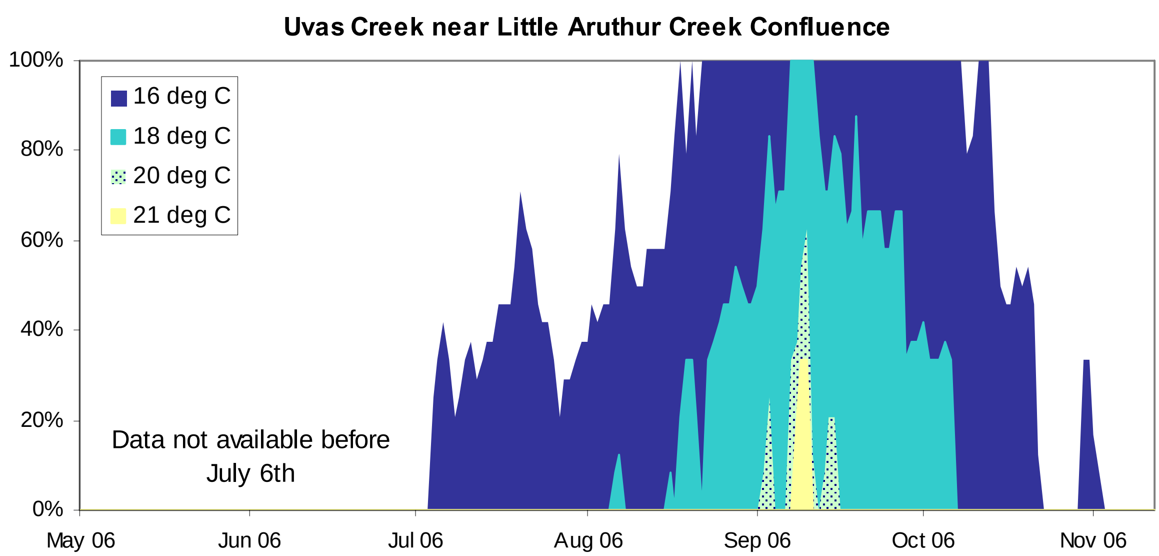


FIGURE 30.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek near the Little Arthur Creek confluence, summer and fall 2006. Data records: 05 Jul 06 – 06 Nov 06.

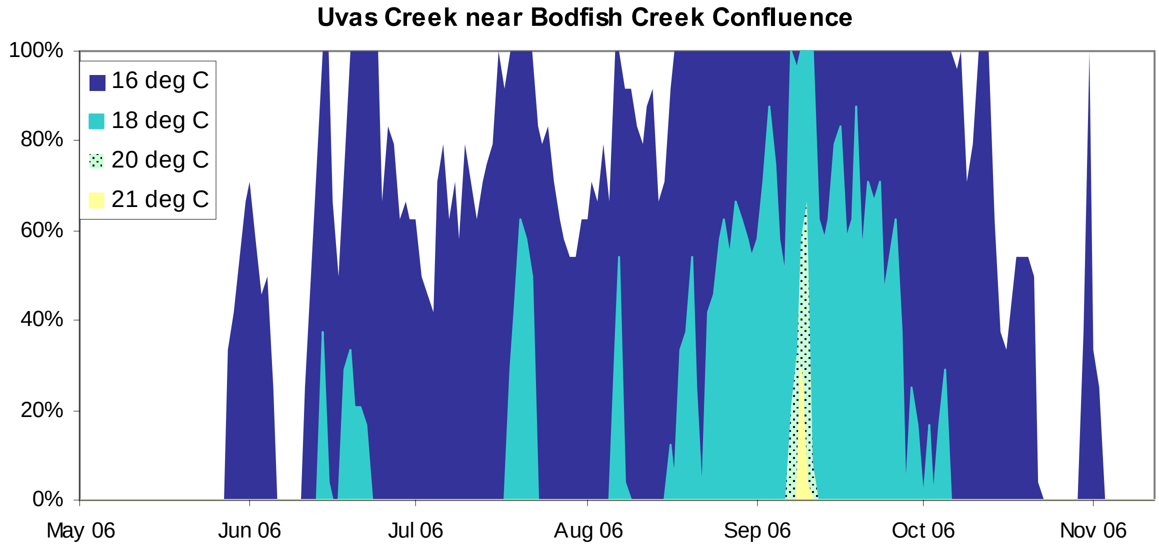


FIGURE 31.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek near the Bodfish Creek confluence, summer and fall 2006. Data records: 26 May 06 – 08 Nov 06.

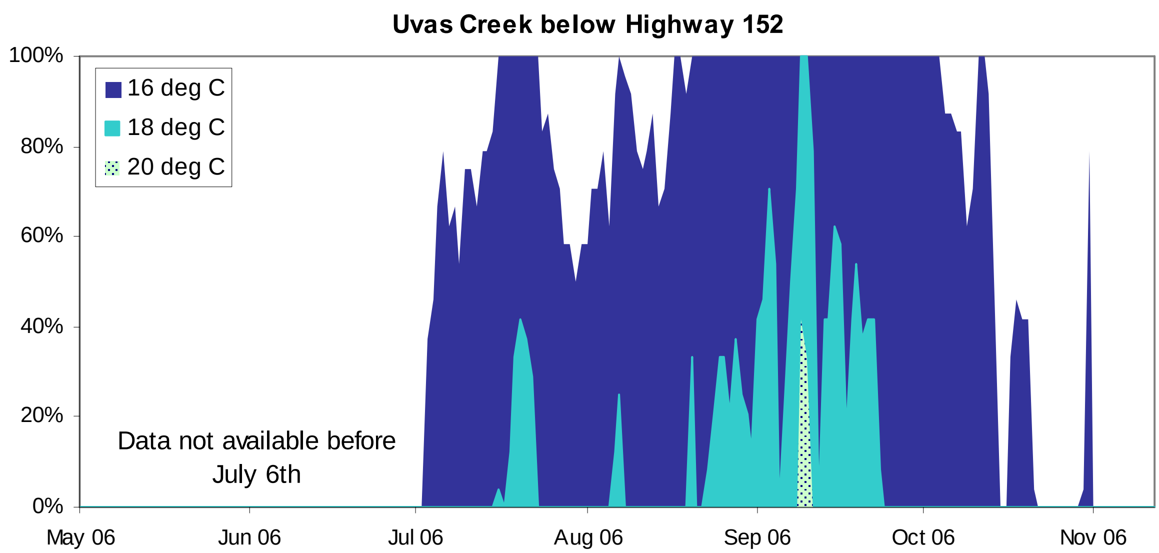


FIGURE 32.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek below Highway 152, summer and fall 2006. Data records: 05 Jul 06 – 08 Nov 06.

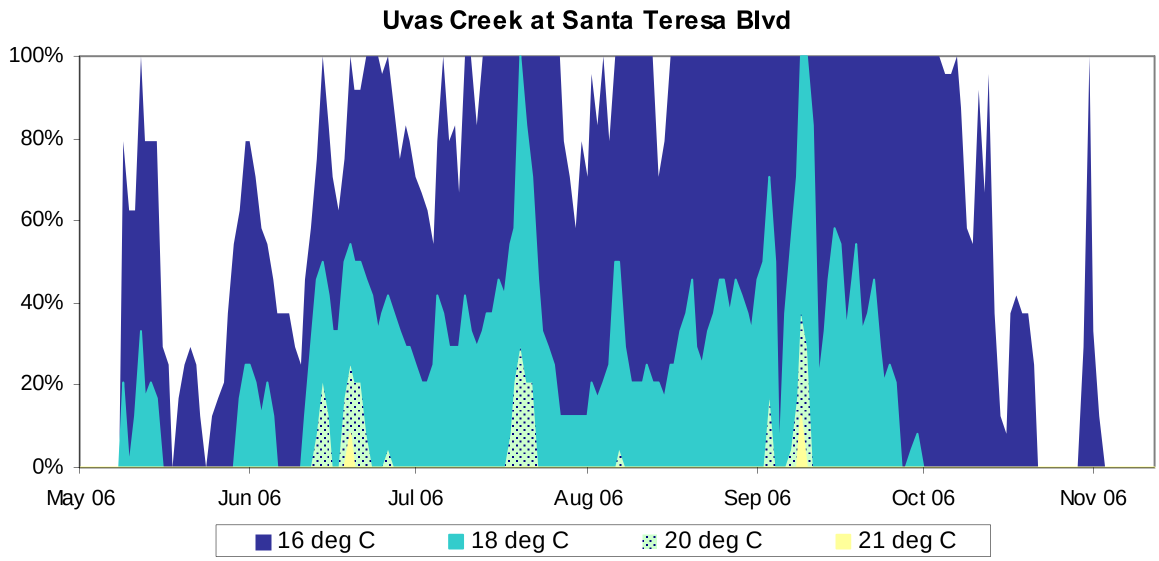


FIGURE 33.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Santa Teresa Boulevard, summer and fall 2006. Data records: 12 May 06 – 08 Nov 06.

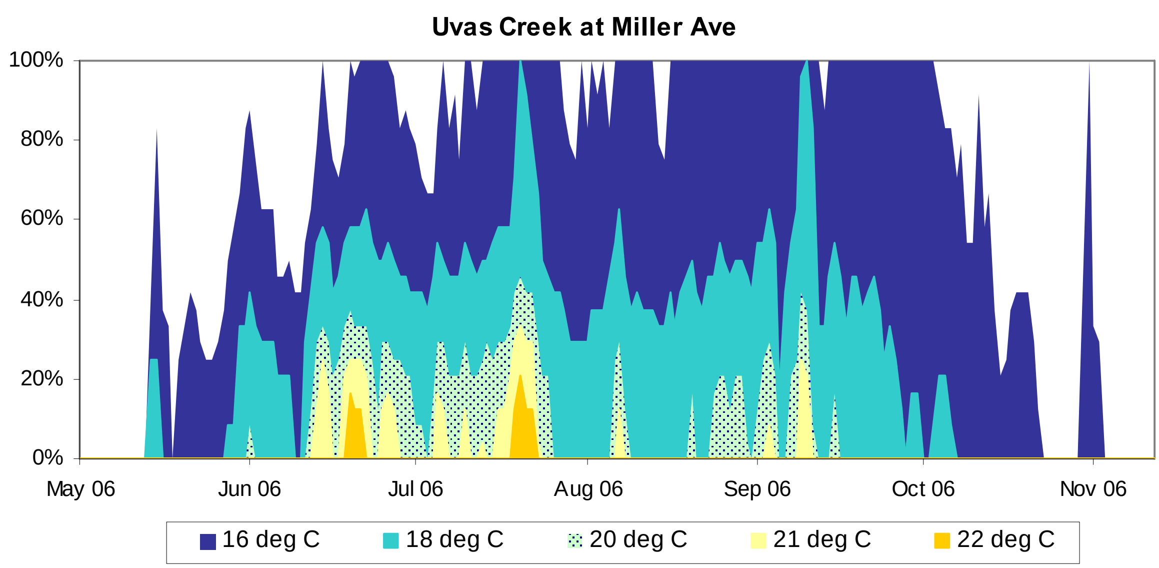


FIGURE 34.—Daily percent exceedance for selected water temperature thresholds for Uvas Creek at Miller Avenue, summer and fall 2006. Data records: 17 May 06 – 08 Nov 06.

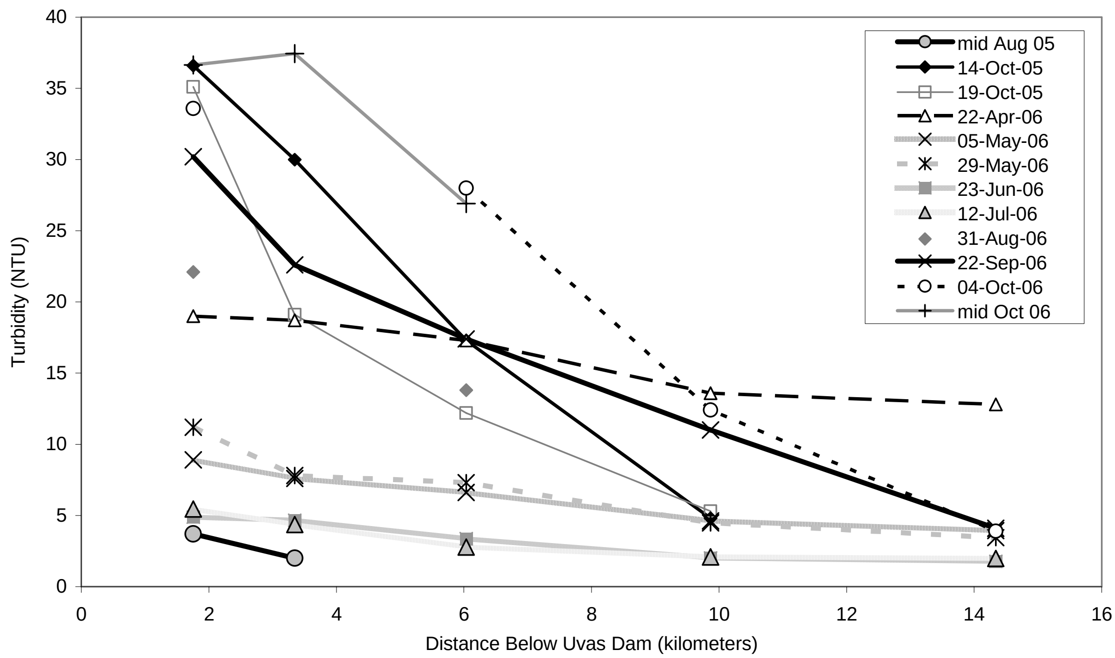


FIGURE 35.—Turbidity in Uvas Creek by river kilometer downstream of Uvas Dam for dates in 2005 and 2006 (river kilometer 0 is at Uvas Dam and river kilometer 14.3 is at Miller Avenue). Note: Only two sites monitored "mid Aug 2005" over 11 day period 5 - 16 August. Only two sites monitored on Aug 31st 2006. The upper three sites in "mid Oct 2006" were monitored over a 10 day period 13 - 23 October.

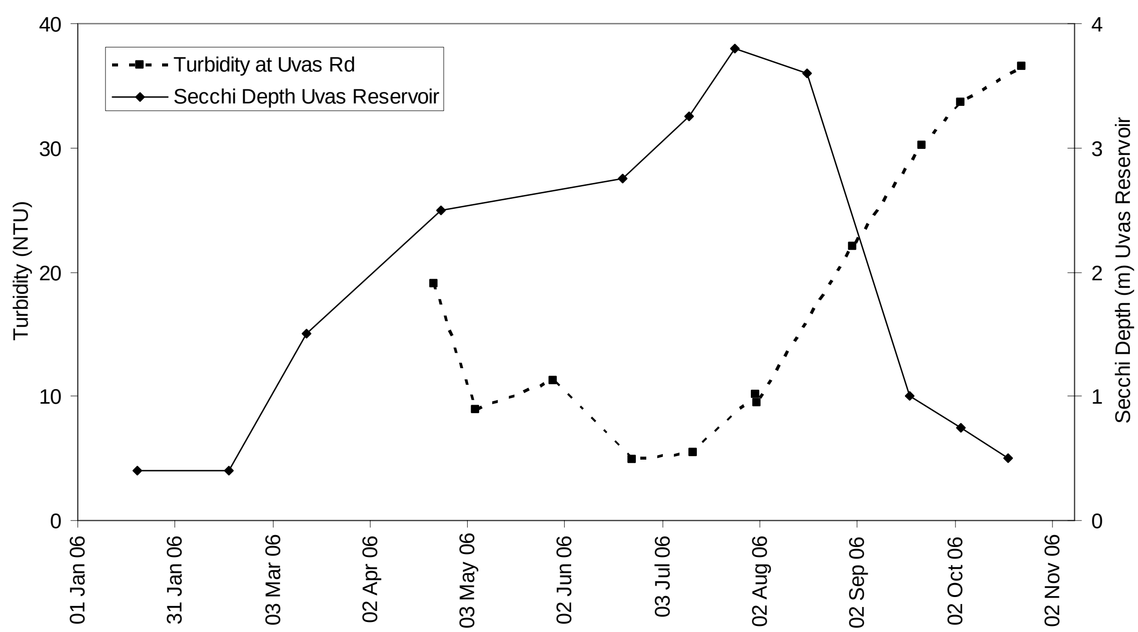


FIGURE 36.—A 2006 seasonal comparison of secchi depth measured in Uvas Reservoir near Uvas Dam and in-stream turbidity measured in Uvas Creek at Uvas Road (1.7 kilometers downstream of Uvas Dam).

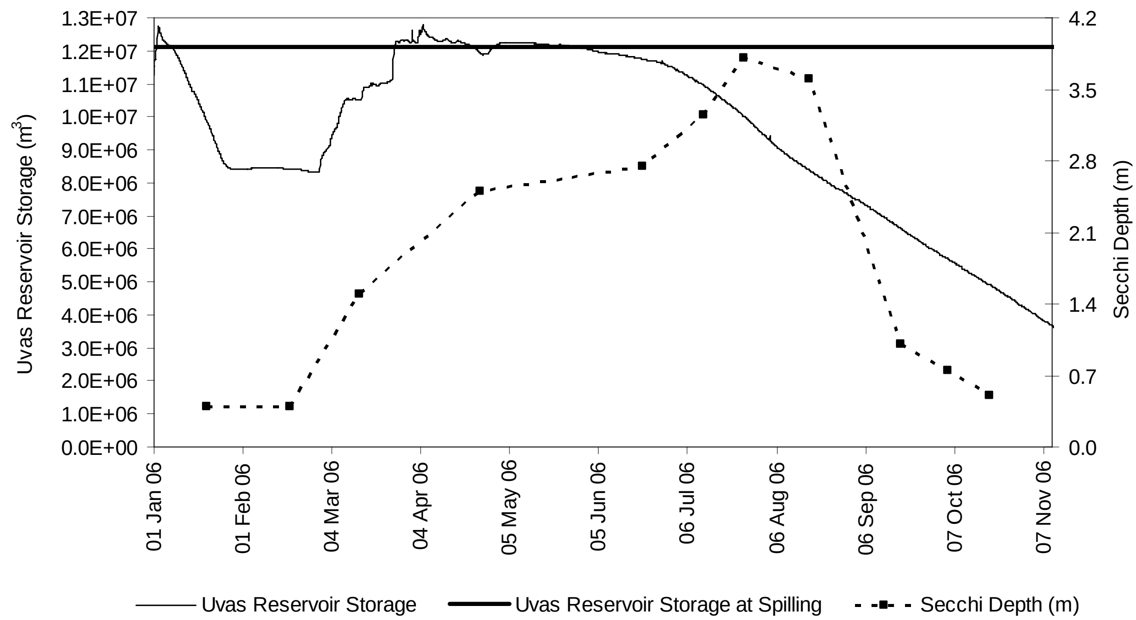


FIGURE 37.—A comparison of Uvas Reservoir water storage and secchi depth measured in Uvas Reservoir, 2006. Note: 1.2E+07 m^3 = 9,835 acre-feet.

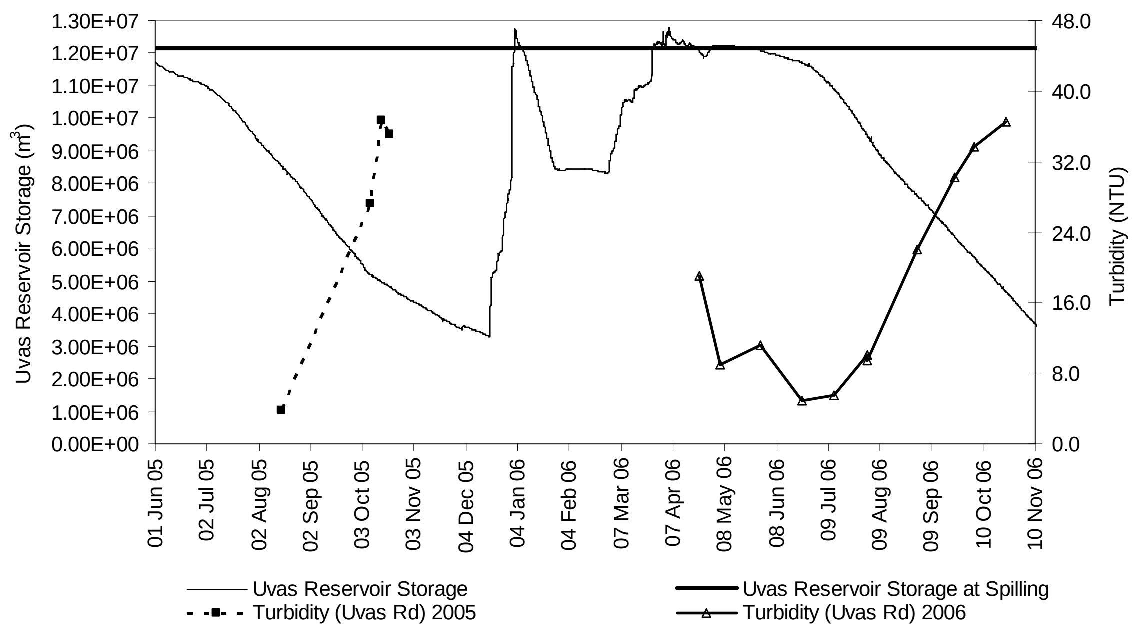


FIGURE 38.—A comparison of Uvas Reservoir water storage and turbidity measured at Uvas Road approximately 1.7 kilometers (1 mile) downstream of Uvas Dam. Note: 1.2E+07 m^3 = 9,835 acre-feet.

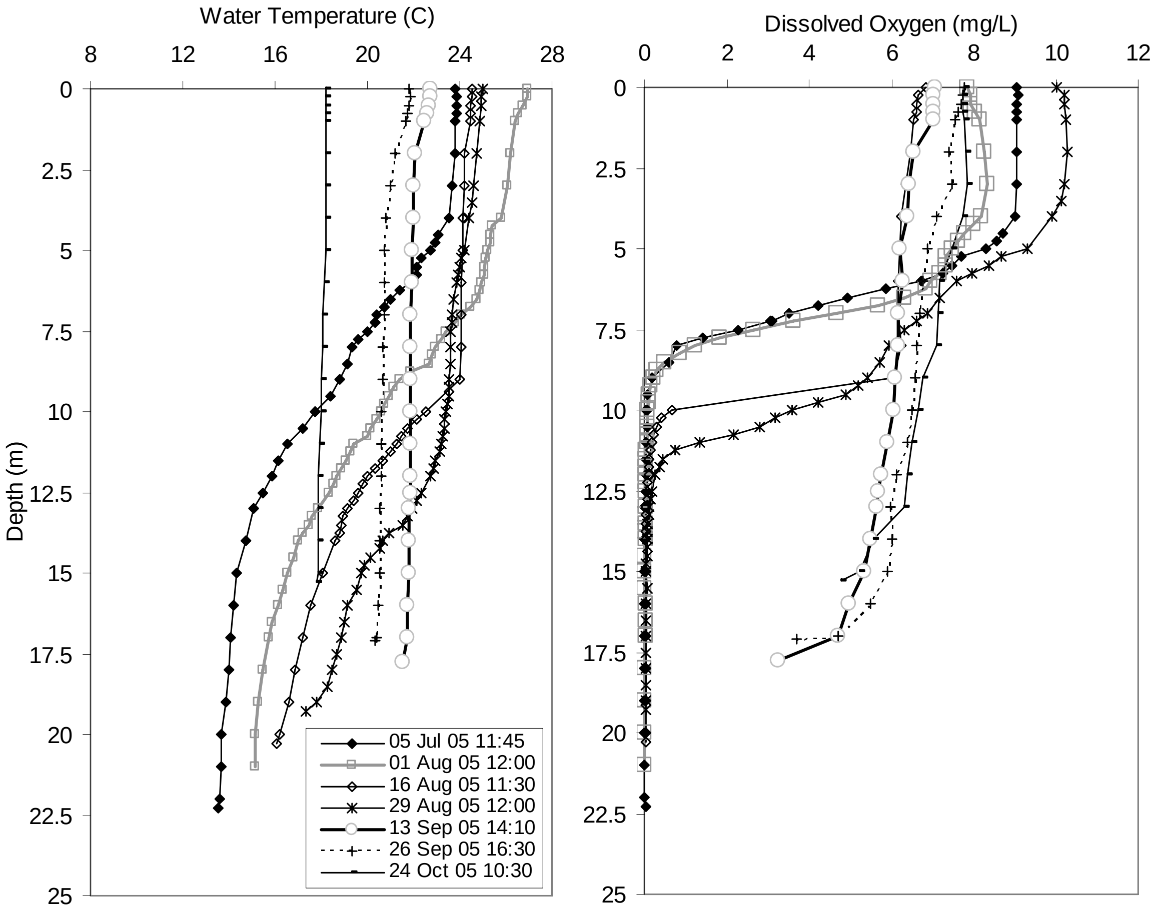


FIGURE 39.—Surface to bottom water temperature and dissolved oxygen concentrations collected in Uvas Reservoir near Uvas Dam, July through October 2005.

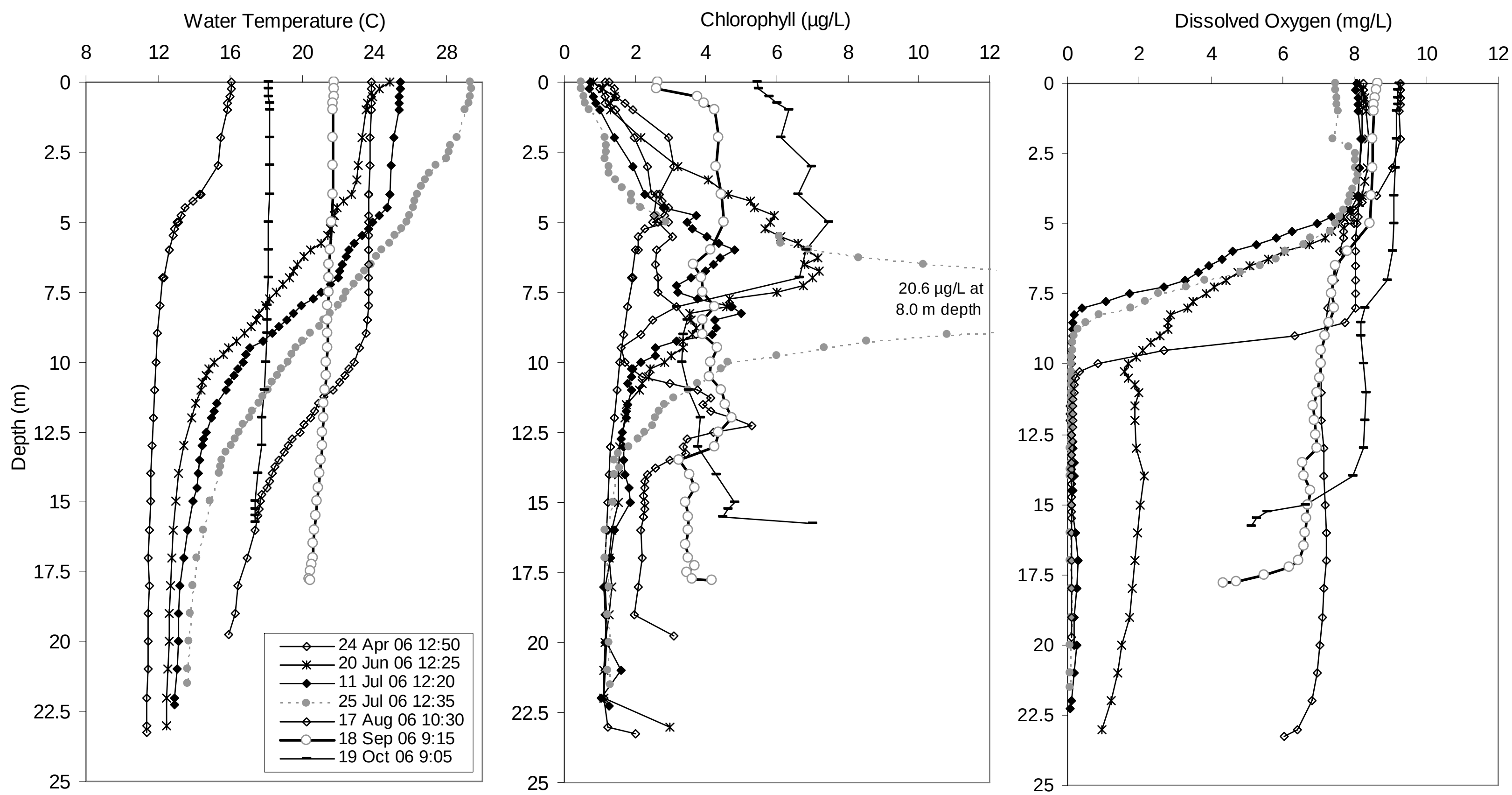


FIGURE 40.—Surface to bottom water temperature, chlorophyll-*a*, and dissolved oxygen concentrations collected in Uvas Reservoir near Uvas Dam, April through October 2006.

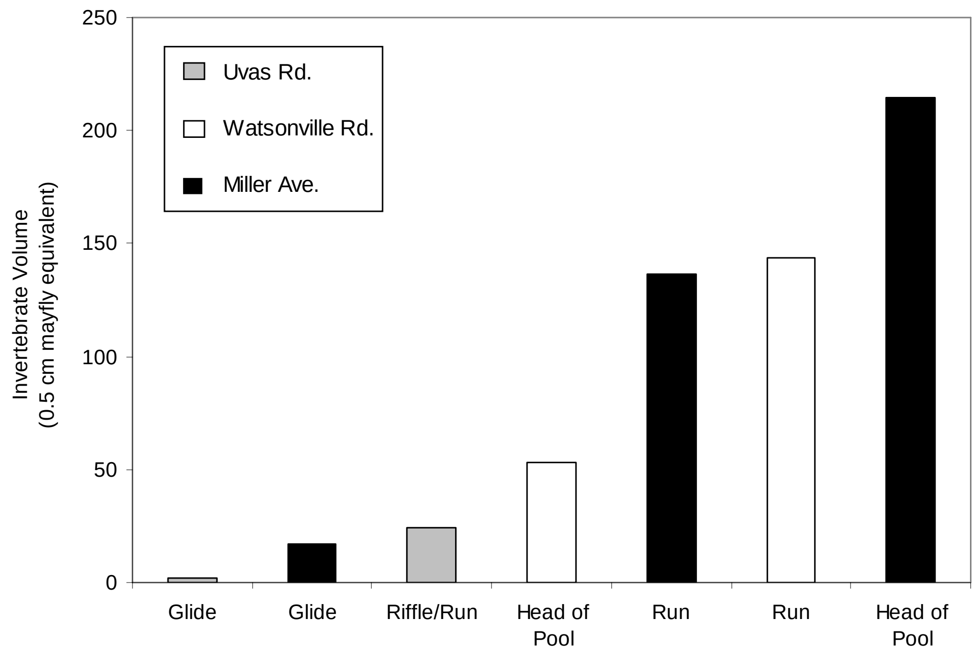


FIGURE 41.—Macroinvertebrate volumes collected with multi-plate samplers at three sites and mesohabitat types in Uvas Creek, September 2006.

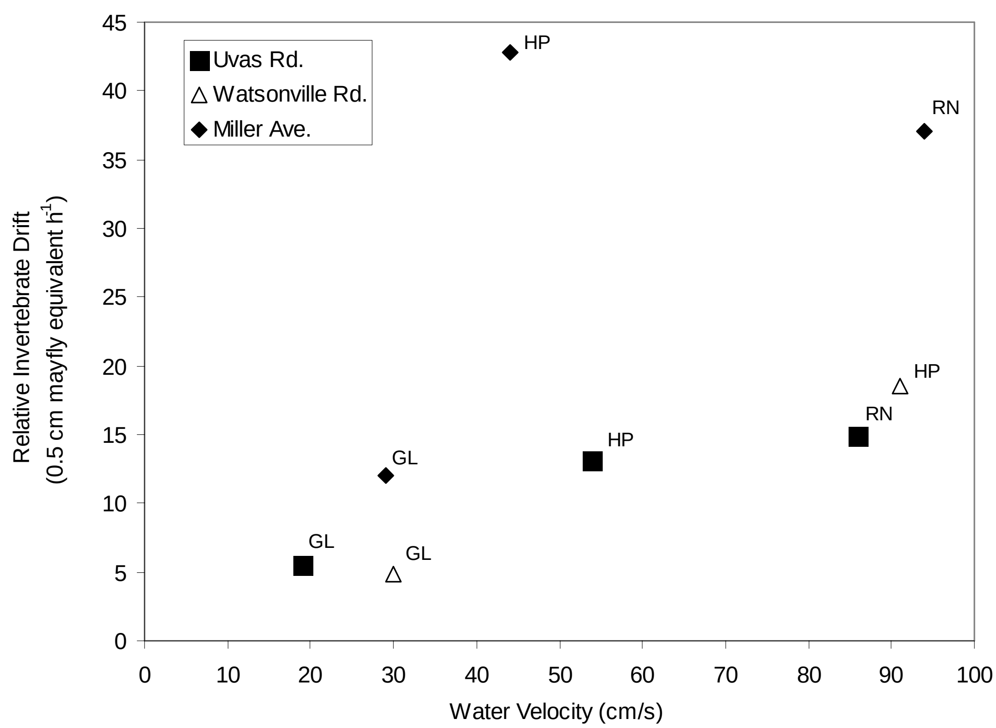


FIGURE 42.—Relative invertebrate drift rates for different habitat velocities at three sites and mesohabitat types in Uvas Creek, September 2006 (GL=glide; HP=Head of Pool; RN=Run).

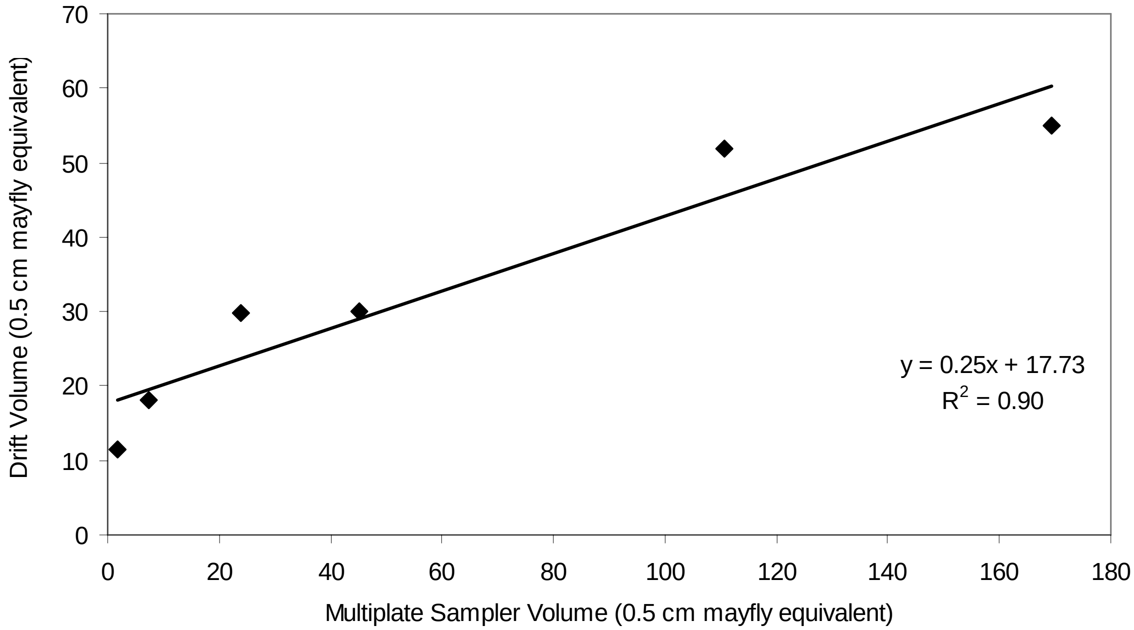


FIGURE 43.—Comparison of insect (*Planariidae* and *Physidae* excluded) drift volume and the volume colonized on multi-plate samplers at different sites and mesohabitat types in Uvas Creek, September 2006.

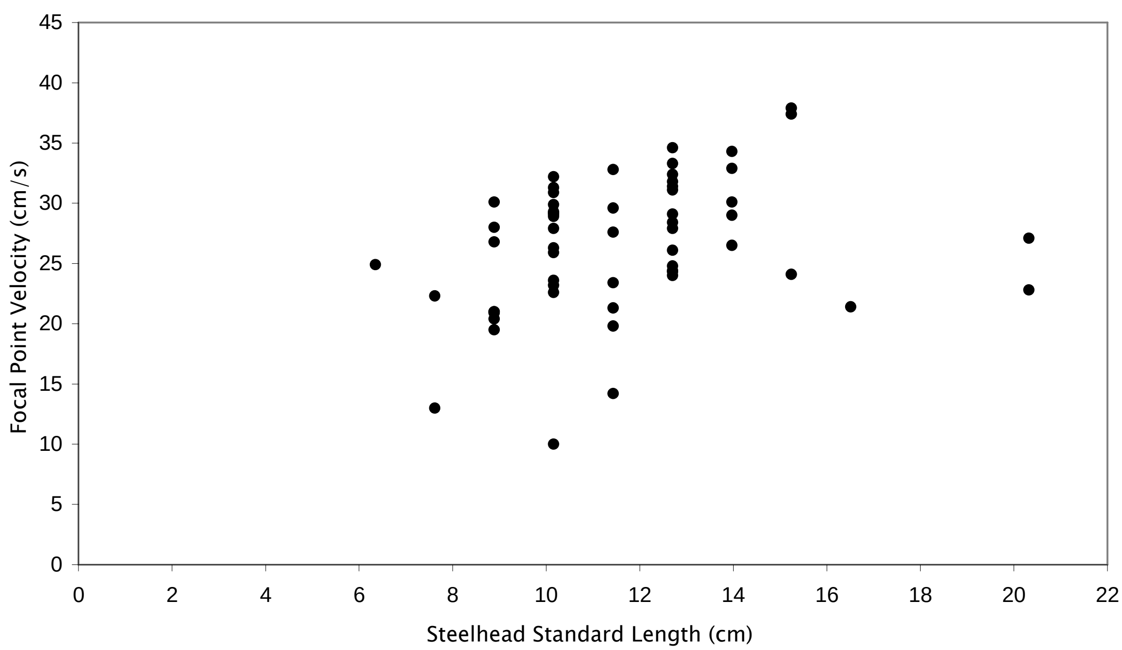


FIGURE 44.—Velocities at focal points (stationary feeding position) versus juvenile steelhead standard lengths in Uvas Creek during August and September 2005 and July 2006.

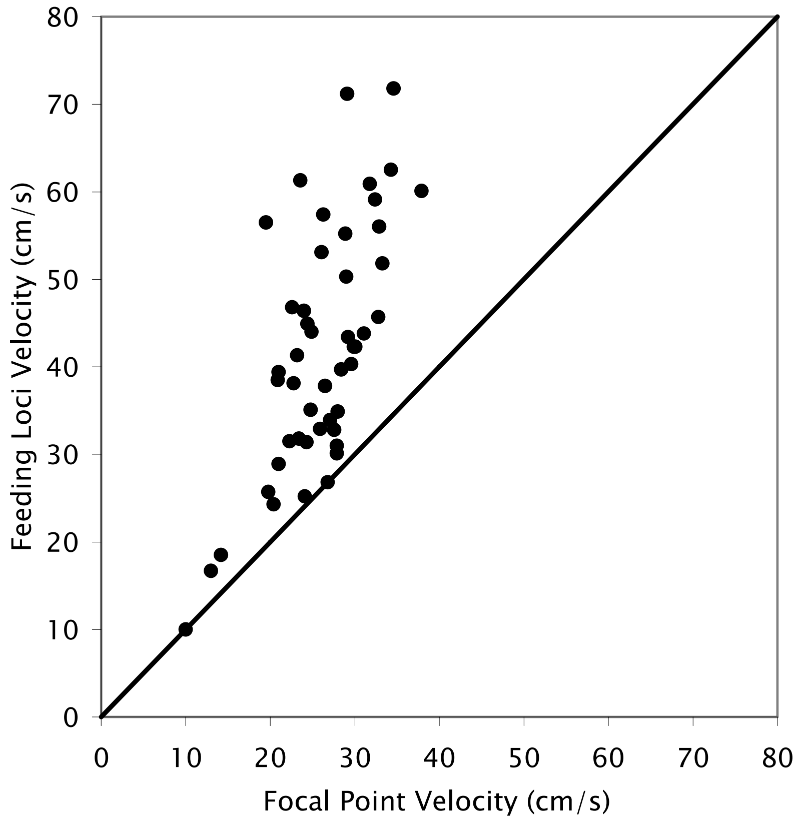


FIGURE 45.—Velocities at focal points versus the feeding loci (position of food intercept) for juvenile steelhead in Uvas Creek during August and September 2005 and July 2006.

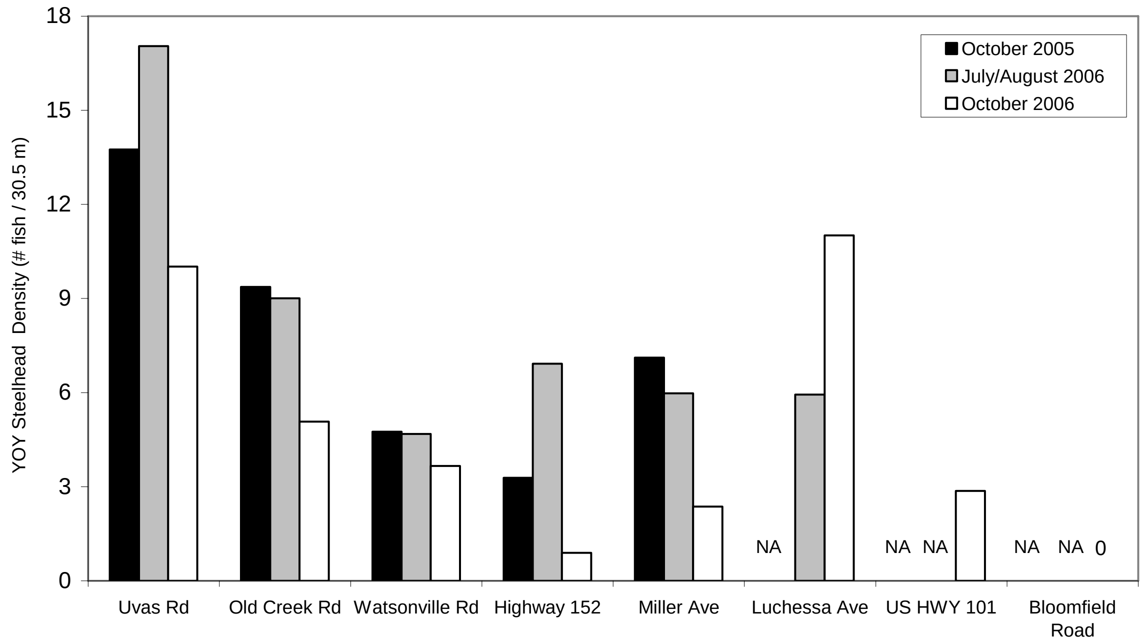


FIGURE 46.—Young of the year (YOY) juvenile steelhead densities (# fish per 30.5 m) collected at sites in Uvas Creek in October 2005, July/August 2006, and October 2006.

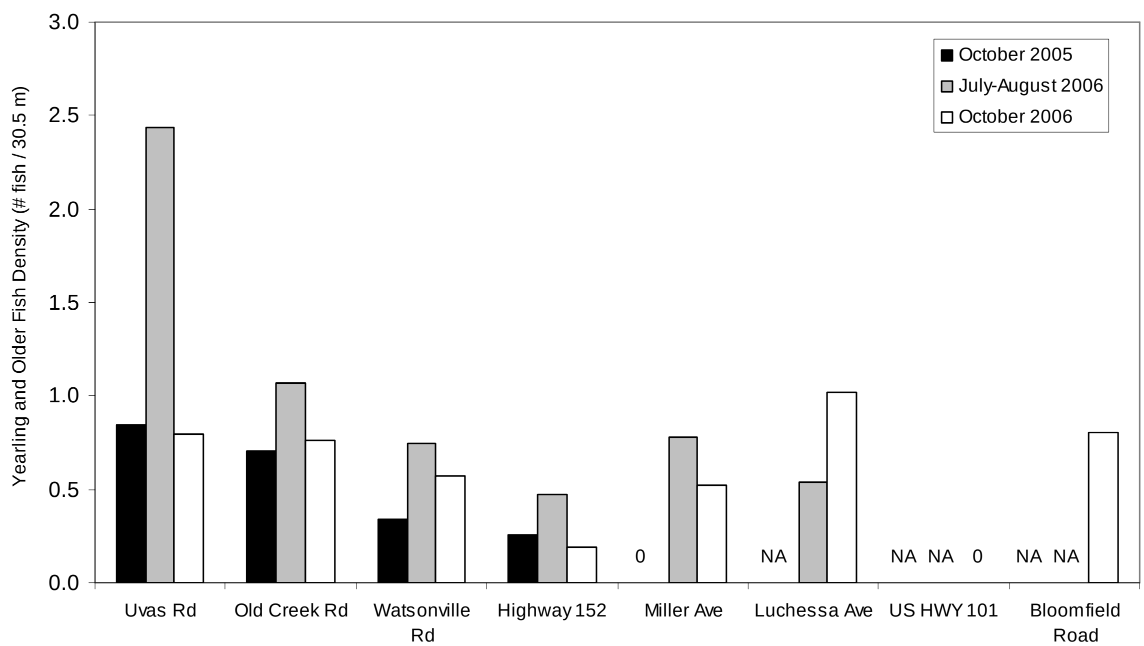


FIGURE 47.—Yearling and older steelhead densities (# fish per 30.5 m) collected at sites in Uvas Creek October 2005, July/August 2006, and October 2006.

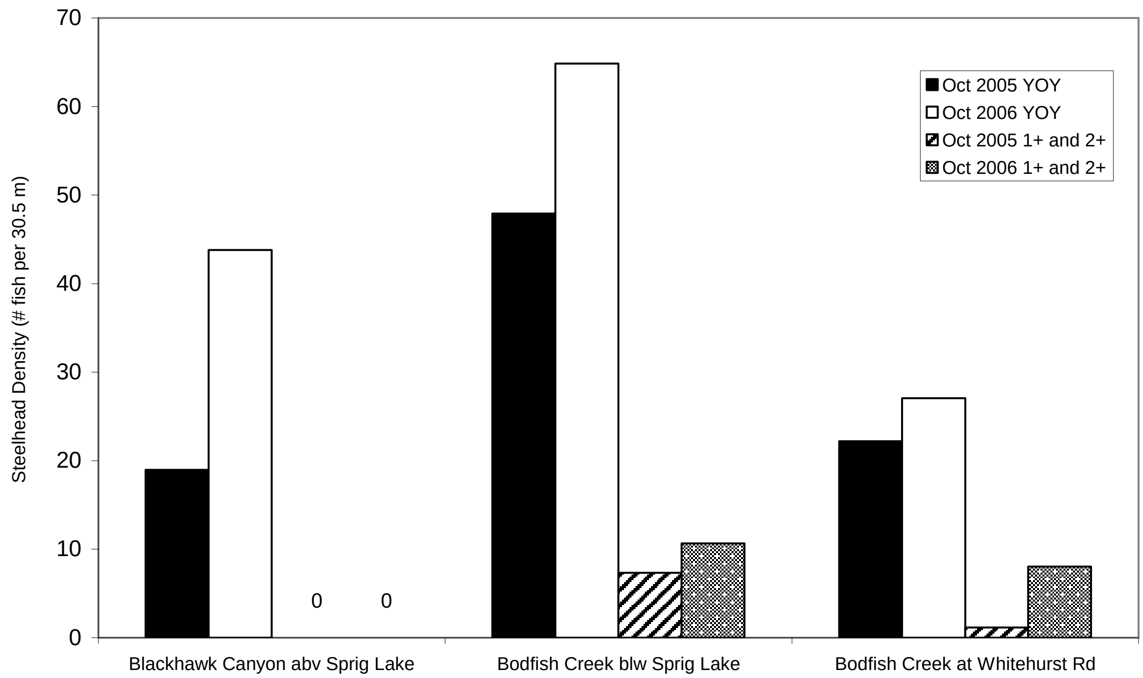


FIGURE 48.— Young of the year (YOY) and yearling and older fish densities collected at sites in the Bodfish Creek Watershed October 2005 and October 2006.

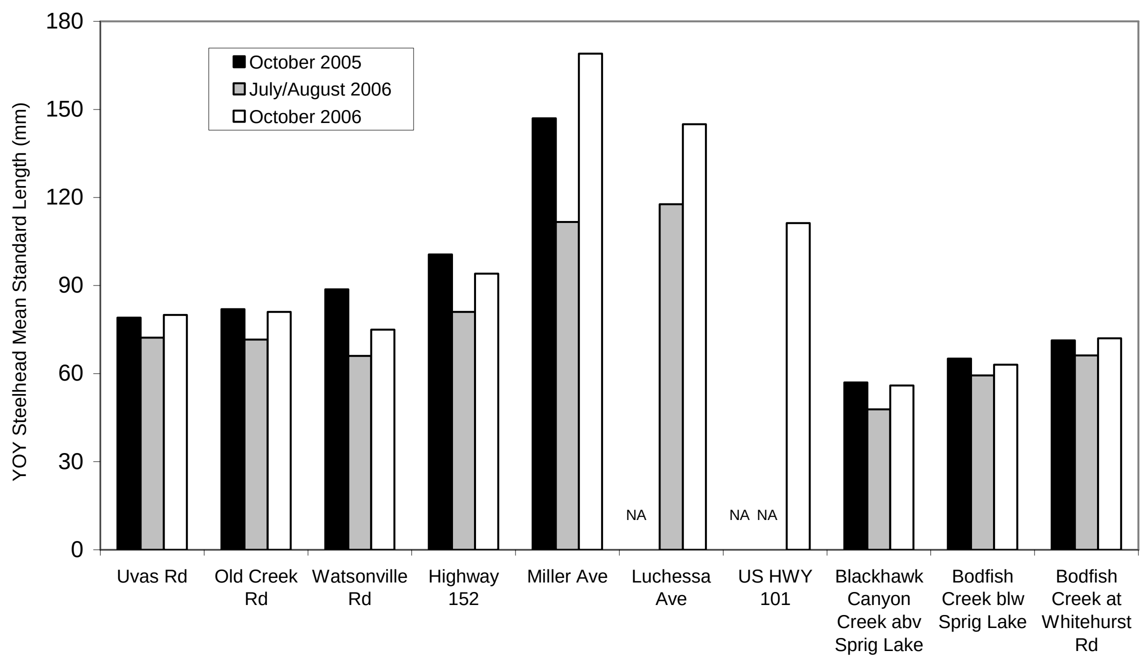
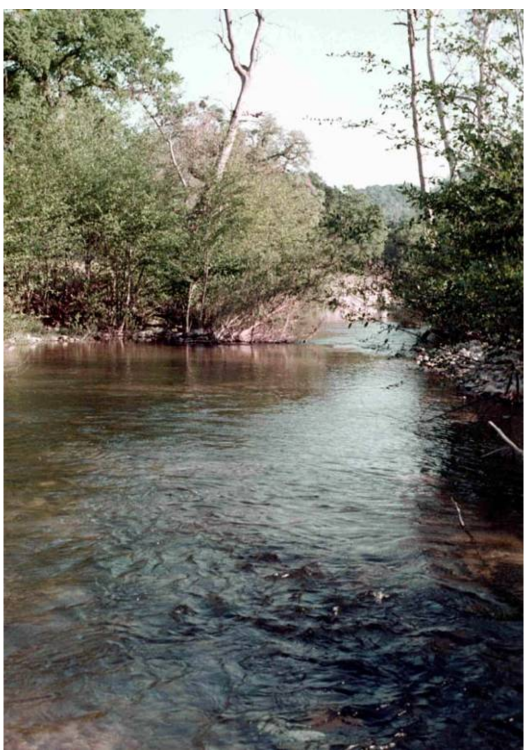
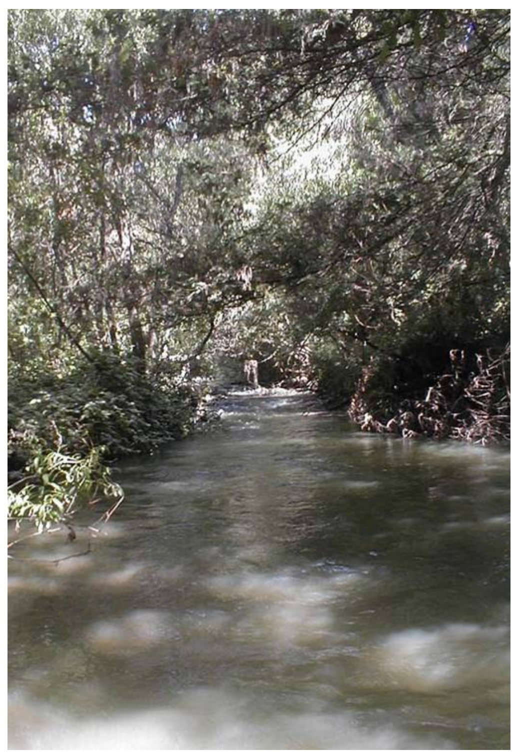


FIGURE 49.—Mean standard length for YOY steelhead collected at sites in Uvas Creek and Bodfish Creek watersheds in 2005 and 2006.

Figure 50.—Uvas Creek looking upstream from the Highway 152 Bridge in the fall of 1979. Note the mature California sycamores and sparse understory conditions. (Photo courtesy of Jerry Smith).



A.



B.

FIGURE 51.—Uvas Creek downstream of Old Creek Road during fall 1978 (A) and at approximately the same location on 29 July 2006 (B). (Photo A, courtesy of Jerry Smith)


A.

B.

FIGURE 52.—Uvas Creek downstream from Watsonville Road, looking downstream, in January 1983 (A) and on 25 July 2006 (B). (Photo A, courtesy of Jerry Smith)

Tables

TABLE 1.—Stream flow volumes at various sites (kilometers below Uvas Dam) on Uvas Creek downstream of Uvas Dam as measured by the SCVWD during percolation tests. Reach loss/gain and reach loss/gain per river kilometer are also provided.

Date		Uvas Dam Release (0.0)	Uvas Rd (1.7)	Old Creek Rd (3.6)	Watsonville Rd (6.4)	Highway 152 (9.8)	Santa Teresa Blvd (12.7)	Miller Ave (14.3)	Luchessa Ave (15.9)	U.S. 101 (19.2)	Bolsa Rd Fish Ladder (21.1)	Highway 25 (23.1)	Carnadero Preserve Vehicle Xing (25.4)
11 Sep 68	**stream flow (m^3/s)**	**0.70**			**0.66**	**0.47**	**0.37**		**0.18**				
	reach loss / gain (m^3/s)				-0.04	-0.19	-0.10		-0.19				
	reach loss/gain ($m^3 \cdot sec^{-1} \cdot km^{-1}$)				-0.01	-0.05	-0.04		-0.06				
11 Sep 05	**stream flow (m^3/s)**	**0.41**	**0.41**	**0.39**	**0.37**	**0.28**	**0.16**	**0.07**	**0.02**	**2.832E-07**			
	reach loss / gain (m^3/s)		0.00	-0.02	-0.02	-0.09	-0.13	-0.09	-0.04	-0.02			
	reach loss/gain ($m^3 \cdot sec^{-1} \cdot km^{-1}$)		0.00	-0.01	-0.01	-0.03	-0.04	-0.05	-0.03	-0.01			
21 Jul 06	**stream flow (m^3/s)**	**0.61**	**0.61**	**0.59**	**0.59**	**0.50**	**0.40**	**0.36**	**0.30**		**0.11**		
	reach loss / gain (m^3/s)		0.01	-0.02	-0.01	-0.08	-0.10	-0.04	-0.06		-0.18		
	reach loss/gain ($m^3 \cdot sec^{-1} \cdot km^{-1}$)		0.00	-0.01	0.00	-0.02	-0.04	-0.03	-0.04		-0.04		
15 Sep 06	**stream flow (m^3/s)**	**0.69**	**0.66**	**0.62**	**0.65**	**0.54**	**0.38**	**0.30**	**0.27**		**0.07**		**0.02**
	reach loss / gain (m^3/s)		-0.03	-0.04	0.03	-0.11	-0.16	-0.08	-0.03		-0.20		-0.05
	reach loss/gain ($m^3 \cdot sec^{-1} \cdot km^{-1}$)		-0.02	-0.02	0.01	-0.03	-0.06	-0.05	-0.02		-0.04		-0.02
27 Oct 06	**stream flow (m^3/s)**	**0.58**	**0.59**	**0.58**	**0.61**	**0.51**	**0.39**	**0.33**	**0.29**		**0.14**	**0.15**	**0.21**
	reach loss / gain (m^3/s)		0.01	-0.01	0.03	-0.10	-0.12	-0.06	-0.04		-0.15	0.01	0.06
	reach loss/gain ($m^3 \cdot sec^{-1} \cdot km^{-1}$)		0.01	-0.01	0.01	-0.03	-0.04	-0.04	-0.03		-0.03	0.01	0.02
	average reach loss / gain (m^3s)		0.00	-0.02	0.01	-0.11	-0.12	-0.07	-0.04				
	average reach loss/gain ($m^3 \cdot sec^{-1} \cdot km^{-1}$)		0.00	-0.01	0.00	-0.03	-0.04	-0.04	-0.03				

TABLE 2.—Turbidity and transparency tube readings from five sites on Uvas Creek during summer and fall of 2005 and 2006. Note:* indicates readings where 120 cm (detection limit of tube) was barely visible (i.e., at or near 120 cm). Values in parentheses and bold are estimated based on a calibration of the two methods (R^2 =0.90).

Site	Date/Time	Turbidity (NTU)	Transparency (cm)	Site	Date/Time	Turbidity (NTU)	Transparency (cm)
Uvas Rd	16 Aug 05 15:24	4	**(>120)**	HWY 152	02 Aug 05 15:33	3	**(>120)**
	07 Oct 05 15:09	27	37		07 Oct 05 16:00	**(≤ 7)**	>120
	11 Oct 05 10:33	**(27)**	29		11 Oct 05 11:14	**(≤ 7)**	>120
	14 Oct 05 10:45	37	23		14 Oct 05 10:30	5	>120
	19 Oct 05 10:20	35	23		19 Oct 05 00:00	5	>120
	26 Oct 05 10:35	10	72		08 Apr 06 14:00	**(24)**	33
	22 Apr 06 13:52	19	38		22 Apr 06 14:40	14	70
	05 May 06 14:41	9	75		05 May 06 15:17	5	>120
	29 May 06 15:41	11	77		29 May 06 16:20	4	>120
	23 Jun 06 13:43	5	>120		23 Jun 06 13:27	2	>120
	12 Jul 06 14:19	6	120*		12 Jul 06 14:59	2	>120
	01 Aug 06 09:15	10	77		22 Sep 06 11:25	11	68
	01 Aug 06 16:15	9	75		04 Oct 06 11:55	12	51
	31 Aug 06 12:57	22	36				
	22 Sep 06 10:52	30	30	Miller Ave	15 Jul 05 00:00	**(≤ 7)**	>120
	04 Oct 06 11:05	34	26		02 Aug 05 15:45	**(≤ 7)**	>120
	23 Oct 06 09:05	37	22		07 Oct 05 16:10	**(≤ 7)**	>120
					08 Apr 06 15:25	**(26)**	31
Old Creek Rd	05 Aug 05 16:05	2	**(>120)**		22 Apr 06 15:00	13	75
	07 Oct 05 15:45	**(11)**	72		05 May 06 15:33	4	>120
	11 Oct 05 10:43	**(23)**	37		29 May 06 16:33	3	>120
	14 Oct 05 10:50	30	26		23 Jun 06 13:12	2	>120
	19 Oct 05 10:27	19	31		12 Jul 06 15:28	2	>120
	22 Apr 06 14:07	19	55		22 Sep 06 11:41	4	>120
	05 May 06 14:50	8	97		04 Oct 06 09:45	4	>120
	29 May 06 15:53	8	89				
	23 Jun 06 13:51	5	>120				
	12 Jul 06 14:29	4	>120				
	25 Jul 06 09:00	9	70				
	28 Jul 06 09:25	10	77				
	28 Jul 06 16:05	8	90				
	22 Sep 06 11:00	23	36				
	17 Oct 06 09:00	37	23				
Watsonville Rd	19 Jul 05 17:01	6	**(>120)**				
	22 Jul 05 16:42	4	**(>120)**				
	07 Oct 05 15:54	**(≤ 7)**	>120				
	11 Oct 05 11:01	**(15)**	55				
	14 Oct 05 12:00	17	39				
	19 Oct 05 10:40	12	57				
	08 Apr 06 15:00	**(19)**	44				
	22 Apr 06 14:20	17	56				
	05 May 06 14:58	7	120*				
	29 May 06 16:05	7	120*				
	23 Jun 06 14:00	3	>120				
	12 Jul 06 14:45	3	>120				
	26 Jul 06 09:00	9	68				
	26 Jul 06 16:00	6	110				
	31 Aug 06 11:57	14	48				
	22 Sep 06 11:12	17	38				
	04 Oct 06 10:35	28	29				
	13 Oct 06 10:55	27	31				

TABLE 3.—Macroinvertebrate taxa, number, volume and percent biomass collected with multi-plate samplers at three sites and different mesohabitat types in Uvas Creek, September 2006.

Site (Mesohabitat)	Order	Family		Number	Volume	Percent of Total Biomass
Uvas Rd (Glide)	Diptera	Chironomidae		5	1.0	57%
	Tricoptera	Hydropsychidae		3	0.6	36%
	Ephmeroptera	Baetidae		1	0.1	7%
		Total Number of Taxa	**3**	**Total**	**1.8**	
Uvas Rd (Riffle/Run)	Tricoptera	Hydropsychidae		52	15.0	63%
	Diptera	Simuliidae		12	3.0	13%
	Ephmeroptera	Baetidae		9	3.0	13%
	Plecoptera	Perlodidae		6	3.0	13%
		Total Number of Taxa	**4**	**Total**	**24.0**	
Watsonville Rd (Run)	Tricoptera	Hydropsychidae		301	119.0	83%
	Diptera	Simuliidae		119	18.0	13%
	Plecoptera	Perlodidae		13	4.5	3%
	Coleoptera	Dytisidae		1	1.0	1%
	Ephmeroptera	Baetidae		4	1.0	1%
		Total Number of Taxa	**5**	**Total**	**143.5**	
Watsonville Rd (Head of Pool)	Tricoptera	Hydropsychidae		72	37.0	70%
	Tricladida	Planariidae		16	8.0	15%
	Diptera	Simuliidae		32	4.0	8%
	Coleoptera	Elmidae		6	2.0	4%
	Ephmeroptera	Baetidae		7	2.0	4%
		Total Number of Taxa	**5**	**Total**	**53.0**	
Miller Ave (Glide)	Tricladida	Planariidae		14	9.5	56%
	Tricoptera	Lepidostomatidae		4	3.5	21%
	Tricoptera	Hydropsychidae		13	2.8	16%
	Coleoptera	Elmidae		7	1.3	7%
	Basommatophora	Physidae		21		
		Total Number of Taxa	**5**	**Total**	**17.0**	
Miller Ave (Run)	Tricoptera	Hydropsychidae		306	90.0	66%
	Tricladida	Planariidae		86	26.0	19%
	Ephmeroptera	Baetidae		26	9.0	7%
	Coleoptera	Elmidae		28	6.0	4%
	Tricoptera	Lepidostomatidae		3	4.5	3%
	Ephmeroptera	Leptohyphidae		1	1.0	1%
	Diptera	Chironomidae		2	0.1	0%
	Basommatophora	Physidae		26		
		Total Number of Taxa	**8**	**Total**	**136.6**	
Miller Ave (Head of Pool)	Tricoptera	Hydropsychidae		519	162.0	76%
	Tricladida	Planariidae		72	45.0	21%
	Coleoptera	Elmidae		24	4.5	2%
	Ephmeroptera	Baetidae		8	3.0	1%
		Total Number of Taxa	**4**	**Total**	**214.5**	

TABLE 4.—Macroinvertebrate taxa, number, volume, and percent biomass collected with drift nets at three sites and different mesohabitat types in Uvas Creek, September 2006.

Site (Mesohabitat)	Order	Family		Number	Volume	Percent of Total Biomass
Uvas Rd (Glide)	Ephemeroptera	Baetidae		104	11.0	96%
	Diptera	Chironomidae		4	0.3	2%
	Diptera	Simuliidae		2	0.3	2%
		Total Number of Taxa	**3**	**Total**	**11.5**	
Uvas Rd (Run/Riffle)	Ephmeroptera	Baetidae		89	23.5	68%
	Tricladida	Planariidae		3	2.5	7%
	Diptera	Simuliidae (adult)		2	2.0	6%
	Ephmeroptera	Baetidae (adult)		11	2.0	6%
	Diptera	Chironomidae		12	2.0	6%
	Diptera	Simuliidae		7	1.5	4%
	Diptera	Chironomidae (pupae)		2	0.8	2%
	Coleoptera	Elmidae		3	0.5	1%
		Total Number of Taxa	**7**	**Total**	**34.8**	
Uvas Rd (Head of Pool)	Ephmeroptera	Baetidae		182	14.0	54%
	Diptera	Chironomidae (pupae)		16	2.5	10%
	Tricladida	Planariidae		3	2.5	10%
	Diptera	Simuliidae (adult)		5	2.0	8%
	Diptera	unknown (adult)		1	1.5	6%
	Diptera	Simuliidae		7	1.3	5%
	Tricoptera	Hydropsychidae		2	1.0	4%
	Diptera	Chironomidae		6	0.8	3%
	Coleoptera	Elmidae		1	0.3	1%
		Total Number of Taxa	**7**	**Total**	**25.8**	
Watsonville Rd (Glide)	Ephemeroptera	Baetidae		34	5.0	53%
	Diptera	Chironomidae (pupae)		22	4.0	42%
	Diptera	Simuliidae		1	0.3	3%
	Coleptera	Elmidae		1	0.1	1%
	Diptera	Chironomidae		1	0.1	1%
		Total Number of Taxa	**5**	**Total**	**9.5**	
Watsonville Rd (Run)	NO DATA; NET FAILED					
Watsonville Rd (Head of Pool)	Ephemeroptera	Baetidae		60	14.0	48%
	Diptera	Simuliidae		14	4.5	15%
	Tricoptera	Lepidostomatidae		6	3.5	12%
	Diptera	Chironomidae		8	1.8	6%
	Diptera	Chironomidae (pupae)		7	1.8	6%
	Tricoptera	Hydropsychidae		3	1.8	6%
	Diptera	Tipulidae		5	1.0	3%
	Tricoptera	Leptoceridae		1	1.0	3%
		Total Number of Taxa	**7**	**Total**	**29.3**	
Miller Ave (Glide)	Ephmeroptera	Baetidae		56	15.0	83%
	Ephmeroptera	Leptohyphidae		1	1.0	6%
	Tricoptera	Lepidostomatidae		1	1.0	6%
	Diptera	Chironomidae		2	0.5	3%
	Diptera	Simuliidae		1	0.5	3%
	Basommatophora	Physidae		1		
		Total Number of Taxa	**6**	**Total**	**18.0**	

TABLE 4.—Cont.

Site (Mesohabitat)	Order	Family	Number	Volume	Percent of Total Biomass
Miller Ave (Run)	Tricoptera	Hydropsychidae	5	10.5	20%
	Ephmeroptera	Baetidae	40	10.0	19%
	Ephmeroptera	Baetidae (adult)	13	8.0	15%
	Ephmeroptera	Leptohyphidae	4	7.0	13%
	Tricoptera	Lepidostomatidae	3	5.5	11%
	Hemiptera	Corixidae	3	3.0	6%
	Coleoptera	Gyrinidae	1	2.0	4%
	Ephmeroptera	Ephemerellidae (adult)	1	2.0	4%
	Diptera	Chironomidae	3	1.0	2%
	Tricoptera	Leptoceridae	1	1.0	2%
	Coleoptera	Elmidae	3	0.8	1%
	Diptera	Chironomidae (pupae)	1	0.8	1%
	Diptera	Simuliidae	1	0.4	1%
	Basommatophora	Physidae	4		
		Total Number of Taxa 12	**Total**	**51.9**	
Miller Ave (Head of Pool)	Ephmeroptera	Baetidae	97	21.0	37%
	Tricoptera	Hydropsychidae	12	21.5	38%
	Ephmeroptera	Ephemerellidae	3	3.5	6%
	Ephmeroptera	Leptohyphidae	2	3.5	6%
	Tricladida	Planariidae	3	2.0	4%
	Diptera	Chironomidae	7	1.5	3%
	Diptera	Simuliidae	4	1.3	2%
	Tricoptera	Lepidostomatidae	1	1.0	2%
	Tricoptera	Leptoceridae	1	1.0	2%
	Coleoptera	Elmidae	3	0.8	1%
		Total Number of Taxa 9	**Total**	**57.0**	

TABLE 5.—Steelhead captured, population estimates (per site), and densities per 30.5 m (100 ft) for selected sites on Uvas Creek and in the Bodfish Creek watershed during October 2005.

Site	Total Distance shocked (m)	Total # of Fish	Total # of YOY (% of total)	Total # of Yearlings + older fish	Total Pop. Estimate	Pop. Estimate of YOY	Pop. Estimate of Yearlings + older fish	Density: fish / 30.5 m	Density: YOY / 30.5 m	Density: Yearlings + older fish / 30.5 m
					Based On Population Estimates					
Uvas Creek Watershed										
Uvas Creek at Uvas Rd.	345	138	130 (94)	8	165.3	155.7	9.6	14.6	13.8	0.8
Uvas Creek at Old Creek Rd.	346	100	93 (93)	7	114.4	106.4	8.0	10.1	9.4	0.7
Uvas Creek at Watsonville Rd.	618	90	84 (93)	6	103.2	96.3	6.9	5.1	4.8	0.3
above Little ArthurCreek Conf.	351	55	51 (93)	4	64.6	59.9	4.7	5.6	5.2	0.4
below Little Arthur Creek Conf.	266	35	33 (94)	2	38.6	36.4	2.2	4.4	4.2	0.3
Uvas Creek at Highway 152	558	42	39 (93)	3	64.8	60.2	4.6	3.5	3.3	0.3
Uvas Creek at Miller Ave.	452	98	98 (100)	0	105.6	105.6	0.0	7.1	7.1	0.0
Total	*798*	*468*	*444 (95)*	*24*						
Bodfish Creek Sub-watershed										
Blackhawk Canyon above Sprig Lake	113	61	61 (100)	0	70.2	70.2	0.0	19.0	19.0	0.0
Bodfish Creek below Sprig Lake	91	158	137 (87)	21	164.8	142.9	21.9	55.3	47.9	7.3
Bodfish Creek at Whitehurst Rd.	109	80	76 (95)	4	83.4	79.2	4.2	23.4	22.2	1.2
Total	*109*	*299*	*274 (92)*	*25*						

TABLE 6.—Mean standard length and range for YOY steelhead at all sites in the Uvas Creek watershed during sampling in October 2005, July/August 2006 and October 2006. The number in parentheses represents the percent change between July/August and October 2006.

	Uvas Rd.	Old Creek Rd.	Watsonville Rd.	Highway 152	Miller Ave.	Luchessa Ave.	U.S. Highway 101	Blackhawk above Sprig Lake	Bodfish below Sprig Lake	Bodfish at Whitehurst Rd.
October 2005										
Average Size (mm)	79	82	89	101	147	NA	NA	57	65	71
Range (mm)	58-118	58-133	58-153	68-148	93 - 193			38-83	48-93	53-98
Jul/Aug 2006										
Average Size (mm)	72	72	66	81	112	118	NA	48	59	66
Range (mm)	43-113	48-108	48-103	53-128	78-148	88-143		33-68	33-88	38-98
October 2006										
Average Size (mm)	80 (10)	81 (12)	75 (12)	94 (14)	169 (34)	145 (19)	111 (NA)	56 (14)	63 (6)	72 (8)
Range (mm)	53-118	58-118	48-103	73-128	138-208	103-168	103 - 123	38-98	43-88	48-98

TABLE 7.—Distance (and %) sampled of each mesohabitat type and number of juvenile steelhead and their density in each mesohabitat type in Uvas Creek during sampling in October 2005, July/August 2006 and October of 2006.

		October-05			July / August-06			October-06		
Site	Habitat Type	Distance (m) Sampled (% of total)	# Fish	Density # of Fish / 30.5 m	Distance (m) Sampled (% of total)	# Fish	Density # of Fish / 30.5 m	Distance (m) Sampled (% of total)	# Fish	Density # of Fish / 30.5 m
Uvas Rd.	Riffle	26 (8)	34	39.9	13 (8)	41	96.1	34 (10)	37	33.7
	Run	43 (12)	34	24.2	76 (48)	30	12.1	90 (28)	44	14.9
	Head of Pool	76 (22)	32	12.9	38 (24)	10	7.9	76 (23)	18	7.3
	Glide	132 (38)	30	6.9	6 (4)	2	9.4	80 (25)	7	2.7
	Pool	69 (20)	8	3.6	25 (16)	5	6.1	44 (14)	3	2.1
Old Creek Rd.	Riffle	41 (12)	16	12.0	16 (7)	49	96.4	25 (8)	2	2.4
	Run	93 (27)	32	10.5	109 (49)	13	3.6	108 (32)	34	9.6
	Head of Pool	74 (21)	30	12.4	46 (21)	2	1.3	85 (26)	14	5.0
	Glide	85 (25)	14	5.0	18 (8)	0	0	59 (18)	6	3.1
	Pool	53 (15)	8	4.6	32 (15)	2	1.9	55 (17)	5	2.8
Watsonville Rd.	Riffle	18 (3)	5	8.5	0 (0)	0	0	0 (0)	0	0
	Run	213 (34)	36	5.2	206 (42)	42	6.2	213 (37)	45	6.4
	Head of Pool	111 (18)	26	7.1	119 (24)	18	4.6	161 (28)	21	4.0
	Glide	159 (26)	10	1.9	55 (11)	8	4.5	88 (15)	7	2.4
	Pool	116 (19)	13	3.4	113 (23)	4	1.1	118 (20)	2	0.5
Highway 152	Riffle	41 (7)	3	2.2	29 (13)	14	15.0	23 (4)	0	0
	Run	170 (30)	21	3.8	64 (30)	21	10.0	205 (39)	15	2.2
	Head of Pool	59 (11)	11	5.7	36 (17)	9	7.6	74 (14)	2	0.8
	Glide	129 (23)	8	1.9	67 (31)	3	1.4	93 (18)	0	0
	Pool	159 (28)	0	0	18 (8)	0	0	133 (25)	0	0
Miller Ave.	Riffle	30 (7)	0	0	51 (6)	0	0	12 (3)	0	0
	Run	107 (24)	25	7.1	119 (47)	17	4.3	159 (44)	17	3.3
	Head of Pool	42 (9)	45	32.5	51 (20)	27	16.3	66 (18)	15	6.9
	Glide	168 (37)	20	3.6	67 (27)	8	3.6	111 (31)	1	0.3
	Pool	105 (23)	8	2.3	0 (0)	0	0	12 (3)	0	0
Luchessa Ave.	Riffle				0 (0)	0	0	0 (0)	0	0
	Run				94 (52)	36	11.7	94 (52)	59	19.1
	Head of Pool	Not Sampled			19 (10)	0	0	19 (10)	0	0
	Glide				15 (8)	0	0	15 (8)	0	0
	Pool				53 (29)	0	0	53 (29)	0	0
Bloomfield Rd / Highway 101	Riffle							22 (18)	1	1.4
	Run							41 (35)	2	1.5
	Head of Pool	Not Sampled			Not Sampled			34 (29)	3	2.7
	Glide							10 (8)	0	0
	Pool							12 (10)	0	0

TABLE 8.—Mean standard length and range (mm) at first annulus formation for yearling and older juvenile steelhead collected in October 2005 and 2006 at sites in Uvas and Bodfish Creek watersheds. Mean standard length and range (mm) for YOY steelhead collected in October 2005 are presented for comparison, except Luchessa Avenue which has 2006 data because it was not sampled in 2005.

Site	2005 YOY Mean and (Range) Size (mm)	2005 Mean and (Range) Size at First Annulus (mm)	2006 Mean and (Range) Size at First Annulus (mm)
Uvas Creek at Uvas Rd.	79 (58-118)	92 (77-102)	85 (72-97)
Uvas Creek at Old Creek Rd.	82 (58-133)	97 (77-117)	90 (72-112)
Uvas Creek at Watsonville Rd.	89 (58-153)	97 (87-122)	81 (67-97)
Uvas Creek at Highway 152	101 (93-193)	109 (87-137)	90 (87-97)
Uvas Creek at Miller Ave.	147 (93-193)	No yearlings	95 (77-142)
Uvas Creek at Luchessa Ave.	145 (103-168)	NA	77 (72-82)
Uvas Creek at Bloomfield Rd.	NA	NA	82 (77-87)
Blackhawk Canyon above Sprig Lake	57 (38-83)	No yearlings	No yearlings
Bodifsh below Sprig Lake	65 (48-93)	79 (72-92)	76 (62-87)
Bodfish at Whitehurst Rd.	71 (53-98)	76 (72-82)	82 (72-107)

TABLE 9.—Steelhead captured, population estimates (per site), and densities per 30.5 m (100 ft) for sites in Uvas Creek, during July/August and October 2006. The third column from the right presents October 2006 density data based only on comparisons of habitat units resampled in both July and October 2006 surveys.

Site	Total Distance shocked (m)	Total # of Fish	Total # of YOY (% of total)	Total # of Yearlings + older fish	Total Pop. Estimate	Pop. Estimate of YOY	Pop Estimate of Yearlings + older fish	Density: fish/30.5 m	Density: fish / 30.5 m (Resampled Habitats)	Density: YOY / 30.5 m	Density: Yearlings + older fish/30.5 m
					Based on Population Estimates						
July / August 2006											
Uvas Creek at Uvas Rd.	159	88	77 (88)	11	101	88.6	12.7	19.5		17.0	2.4
Uvas Creek at Old Creek Rd.	221	66	59 (89)	7	73	65.1	7.7	10.1		9.0	1.1
Uvas Creek at Watsonville Rd.	493	73	63 (86)	10	88	75.8	12.0	5.4		4.7	0.7
above Little ArthurCreek Conf.	269	42	38 (90)	4	49	44.3	4.7	5.6		5.0	0.5
below Little Arthur Creek Conf.	240	31	25 (81)	6	39	31.3	7.5	4.9		4.0	1.0
Uvas Creek at Highway 152	214	47	44 (94)	3	52	48.5	3.3	7.4		6.9	0.5
Uvas Creek at Miller Ave.	253	52	46 (88)	6	56	49.5	6.5	6.8		6.0	0.8
Uvas Creek at Luchessa Ave.	180	36	33 (92)	3	38	35.1	3.2	6.5		5.9	0.5
Total	*1,518*	*362*	*322 (89)*	*40*							
October 2006											
Uvas Creek at Uvas Rd.	323	109	101 (93)	8	115	106.1	8.4	10.8	13.2	10.0	0.8
Uvas Creek at Old Creek Rd.	332	61	53 (87)	8	64	55.3	8.3	5.8	5.6	5.1	0.8
Uvas Creek at Watsonville Rd.	581	74	64 (86)	10	81	69.8	10.9	4.2	5.1	3.7	0.6
above Little ArthurCreek Conf.	295	38	34 (89)	4	42	37.1	4.4	4.3	5.8	3.8	0.5
below Little Arthur Creek Conf.	286	36	30 (83)	6	39	32.6	6.5	4.2	4.1	3.5	0.7
Uvas Creek at Highway 152	528	17	14 (82)	3	19	15.4	3.3	1.1	1.7	0.9	0.2
Uvas Creek at Miller Ave.	359	33	27 (82)	6	34	27.8	6.1	2.9	4.0	2.4	0.5
Uvas Creek at Luchessa Ave.	180	59	54 (92)	5	71	65.0	6.0	12.0	12.0	11.0	1.0
Uvas Creek at Highway 101	42	4	4 (100)	0	4	4.0	0.0	2.9		2.9	0.0
Uvas Creek at Bloomfield Rd.	76	2	0 (0)	2	2	0.0	2.0	0.8		0.0	0.8
Total	*2,421*	*359*	*318 (89)*	*41*							

TABLE 10.—Steelhead captured, population estimates (per site), and densities per 30.5 m (100 ft) for sites in Bodfish and Blackhawk Canyon creeks in August and October 2006. The third column from the right presents October 2006 density data based only on comparisons of habitat units sampled during both July and October 2006 surveys.

Site	Total Distance shocked (m)	Total # of Fish	Total # of YOY (% of total)	Total # of Yearlings + older fish	Total Pop. Estimate	Pop. Estimate of YOY	Pop Estimate of Yearlings + older fish	Density: fish/30.5 m	Density: fish / 30.5 m (Resampled Habitats)	Density: YOY / 30.5 m	Density: Yearlings + older fish/ 30.5 m
					Based on Population Estimates						
August 2006											
Blackhawk Canyon above Sprig Lake	37	83	80 (96)	3	82	79.2	3.0	67.0		64.6	2.4
Bodfish Creek below Sprig Lake	49	126	99 (79)	27	129	101.3	27.6	79.5		62.5	17.0
Bodfish Creek at Whitehurst Rd.	49	40	32 (80)	8	40	32.0	8.0	25.0		20.0	5.0
Total	*136*	*249*	*211 (85)*	*38*							
October 2006											
Blackhawk Canyon above Sprig Lake	95	137	137 (100)	0	137	137.0	0.0	43.8	62.3	43.8	0.0
Bodfish Creek below Sprig Lake	91	146	122 (84)	24	161	193.0	31.7	54.2	70.6**	64.9	10.7
Bodfish Creek at Whitehurst Rd.	102	64	45 (70)	19	64	91.0	27.0	19.0	16.4	27.1	8.0
Total	*297*	*347*	*312 (80)*	*45*							

** Only two habitat units (a run and downstream complex pool) were sampled during both surveys. In both surveys, this complex pool had the highest concentrations of fish for the entire site.

TABLE 11.—Historical YOY steelhead standard lengths (mean and range) for various sites and dates in the Uvas Creek watershed (Smith unpublished data).

Site	Date	n	Range SL (mm)	Mean SL (mm)
Uvas Creek at Uvas Rd	17-Aug-73	14	99-132	114
	19-Nov-75	11	71-145	108
	08-Oct-78	44	86-175	142
	20-Dec-80	5	124-193	156
Uvas Creek at Old Creek Rd	08-Aug-73	17	71-112	89
	15/21 Oct 1978	21	99-155	133
Uvas Creek at Watsonville Rd. (upstream)	15-Oct-78	60	69-175	101
	30-Dec-80	6	94-173	118
Uvas Creek at Watsonville Rd. (downstream)	17-Dec-73	17	94-163	125
	19-Nov-75	7	97-147	122
	21-Oct-78	110	79-160	115
	30-Dec-80	11	86-188	123
Uvas Creek at Highway 152	20-Aug-73	14	99-132	114
	Nov-73	39		143
	19-Nov-75	6	168-193	181
	08-Oct-78	15	97-191	125
	14-Dec-78	48	102-183	129
Blackhawk Canyon Creek above Sprig Lake	29-Nov-80	57	48-91	65
Bodfish Creek below Sprig Lake	08-Oct-78	29	56-86	72
	15-Dec-79	40	48-79	62
	29-Nov-80	94	51-86	67
Bodfish Creek at Whitehurst Rd	23-Oct-73	38	40-91	66
	22-Dec-73	39	43-89	67
	19-Nov-75	28	46-69	61
	08-Oct-78	69	64-114	86
	22-Nov-80	69	53-94	72

Appendices

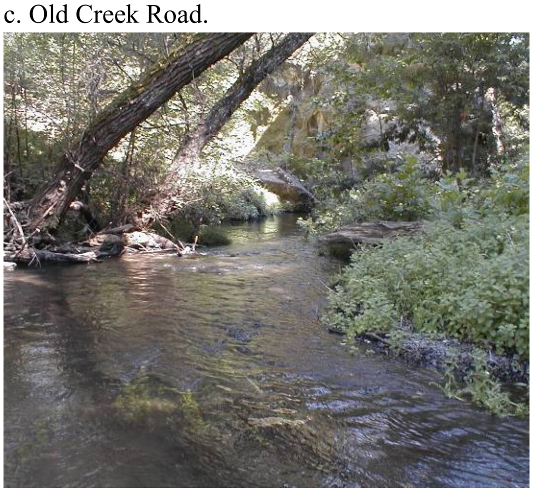
Appendix A: Photos taken at each of the six sites in Uvas Creek where stream habitat assessment and fish sampling were conducted.

a. Uvas Road.

b. Uvas Road.

c. Old Creek Road.

d. Old Creek Road.



e. Watsonville Road

f. Watsonville Road.

FIGURE A-53.—Photos taken at sites in Uvas Creek where habitat assessment and fish sampling were conducted. The photos are representative of the general range of conditions at each site.

g. Highway 152

h. Highway 152

i. Miller Avenue

j. Miller Avenue

k. Luchessa Avenue

l. Luchessa Avenue

FIGURE A-53.—Cont.

Appendix B: 2005 and 2006 Monthly average maximum, mean, and minimum air and water temperature values at various sites in Uvas Creek.

TABLE B-12.—Monthly average maximum (MAX), mean (MEAN), and minimum (MIN) air temperatures at three sites along Uvas Creek from June through October 2005 and 2006. Sites are in order from upstream (top) to downstream (bottom). Values for June 2005 at Miller Avenue are based on data available from June 10 - 30th. NA – data not available.

Site		Jun-05	Jun-06	Jul-05	Jul-06	Aug-05	Aug-06	Sep-05	Sep-06	Oct-05	Oct-06
Uvas	MAX	22.0	25.2	27.5	28.4	27.8	25.5	24.8	24.7	21.9	20.3
Reservoir	MEAN	15.9	18.1	19.3	20.6	19.4	18.2	16.8	17.1	14.6	13.7
Outflow	MIN	10.5	12.0	13.2	13.7	12.8	12.3	10.6	11.0	8.8	8.3
near Little	MAX	23.2	NA	27.8	30.3	28.4	25.3	23.8	24.4	21.7	20.5
Arthur Creek	MEAN	16.3	NA	19.2	21.0	18.9	17.1	15.9	16.0	14.1	13.2
Confluence	MIN	10.0	NA	12.1	13.2	11.6	10.6	9.7	9.5	7.9	7.3
	MAX	29.5	30.1	33.9	35.3	33.8	30.7	30.9	30.2	32.4	25.8
Miller Ave.	MEAN	18.3	18.9	20.5	21.8	19.9	18.3	16.9	16.8	15.0	13.7
	MIN	9.3	9.7	10.9	11.5	10.3	9.4	8.1	7.8	5.7	5.7

TABLE B-13.—Monthly average maximum, mean, and minimum water temperatures at various sites on Uvas Creek from June through October 2005 and 2006. Sites are in order from upstream (top) to downstream (bottom). Values for June 2005 at Santa Teresa Boulevard and Miller Avenue are based on data from June 10 - 30th. NA – data not available.

Site		Jun-05	Jun-06	Jul-05	Jul-06	Aug-05	Aug-06	Sep-05	Sep-06	Oct-05	Oct-06
Uvas Reservoir Outflow	MAX	13.8	13.2	14.8	13.9	17.1	16.7	20.7	20.7	18.5	18.3
	MEAN	13.6	13.0	14.5	13.7	16.8	16.5	20.5	20.5	18.3	18.2
	MIN	13.4	12.8	14.3	13.6	16.5	16.3	20.3	20.3	18.1	18.1
Uvas Rd	MAX	15.3	17.9	16.5	15.6	18.4	17.7	20.7	20.9	18.2	18.2
	MEAN	14.0	14.7	15.1	14.3	17.0	16.6	19.5	19.9	17.3	17.6
	MIN	13.0	12.6	14.0	13.4	15.9	15.8	18.6	19.2	16.5	17.2
Old Creek Rd	MAX	16.2	16.0	17.6	16.6	18.7	18.1	19.7	20.8	17.4	18.2
	MEAN	15.0	14.7	16.3	15.0	17.6	16.8	18.8	19.7	16.7	17.2
	MIN	13.7	13.3	15.0	13.8	16.3	15.8	17.7	18.7	15.9	16.5
near Little Arthur Creek Confluence	MAX	16.1	NA	17.5	16.9	18.5	17.8	19.2	19.8	17.0	17.2
	MEAN	15.0	NA	16.4	15.6	17.5	16.6	18.2	18.7	16.2	16.4
	MIN	13.7	NA	15.1	14.2	16.3	15.4	17.1	17.6	15.3	15.5
near Bodfish Creek Confluence	MAX	16.6	17.1	18.3	17.4	19.0	18.0	18.7	19.4	16.6	16.9
	MEAN	15.9	16.3	17.5	16.6	18.2	17.1	17.9	18.5	15.9	16.2
	MIN	15.0	15.3	16.6	15.5	17.2	16.0	16.9	17.5	15.0	15.4
near HWY 152	MAX	17.5	NA	19.4	17.8	19.8	17.7	18.9	18.6	17.3	16.4
	MEAN	16.1	NA	17.8	16.7	18.2	16.8	17.8	17.9	16.9	15.8
	MIN	15.1	NA	16.6	15.7	17.1	15.9	17.0	17.0	16.5	15.1
Santa Teresa Blvd.	MAX	19.0	19.1	21.0	19.5	20.9	19.0	19.0	19.3	16.5	16.7
	MEAN	16.9	17.0	18.3	17.6	18.6	17.4	17.4	18.0	15.5	15.9
	MIN	15.3	15.4	16.4	16.2	16.5	16.3	15.2	17.0	14.4	15.2
Miller Ave.	MAX	20.7	20.3	22.7	20.9	22.9	19.8	20.4	19.8	17.9	17.1
	MEAN	17.6	17.7	19.2	18.4	19.5	17.9	17.9	18.1	15.9	15.9
	MIN	15.3	15.5	16.5	16.4	16.8	16.4	15.8	16.8	14.2	14.9

Appendix C: October 2005 steelhead standard lengths (mm) and age distributions for sites in the Uvas Creek watershed.

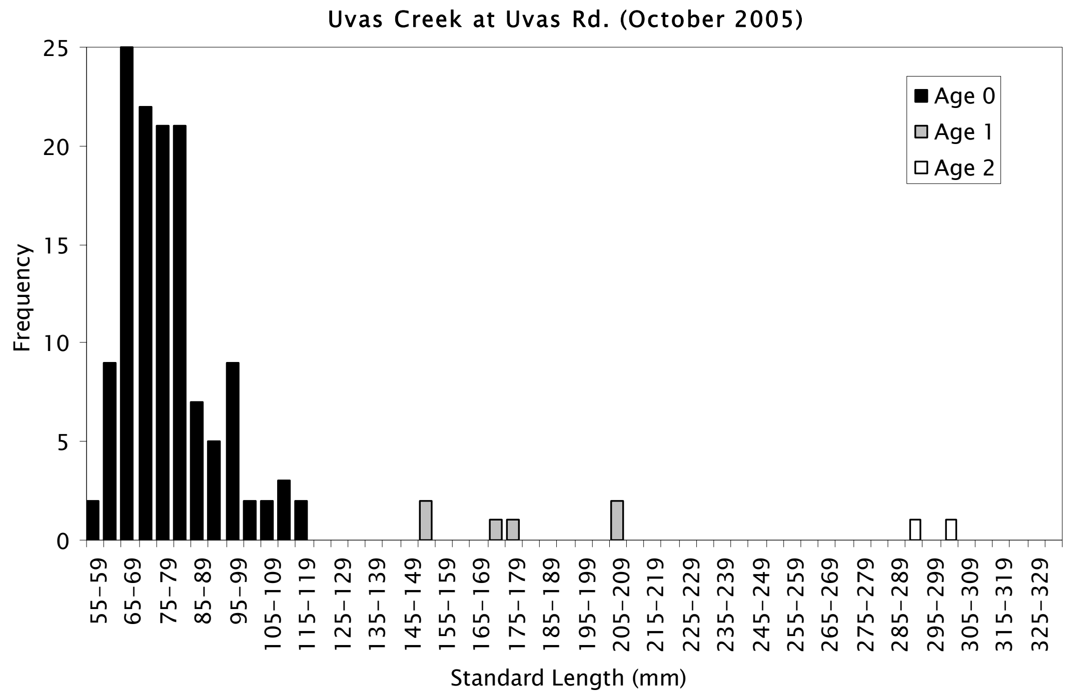


FIGURE C-54.—Steelhead standard lengths (mm) for Uvas Creek at Uvas Road, October 2005.

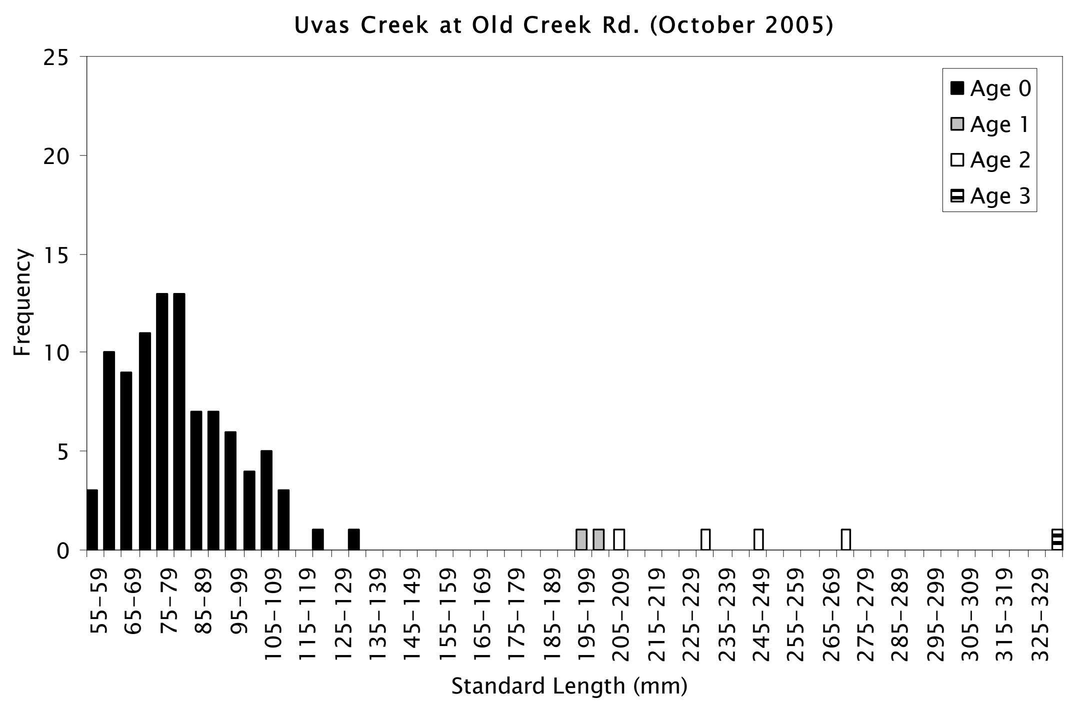


FIGURE C-55.—Steelhead standard lengths (mm) for Uvas Creek at Old Creek Road, October 2005.

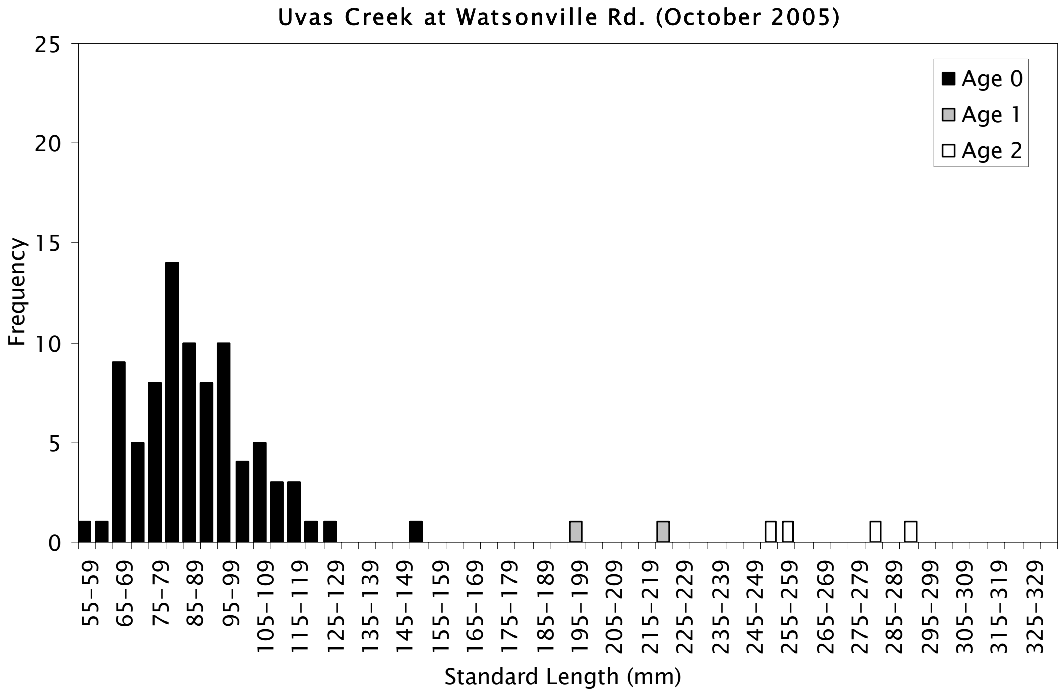


FIGURE C-56.—Steelhead standard lengths (mm) for Uvas Creek at Watsonville Road, October 2005.

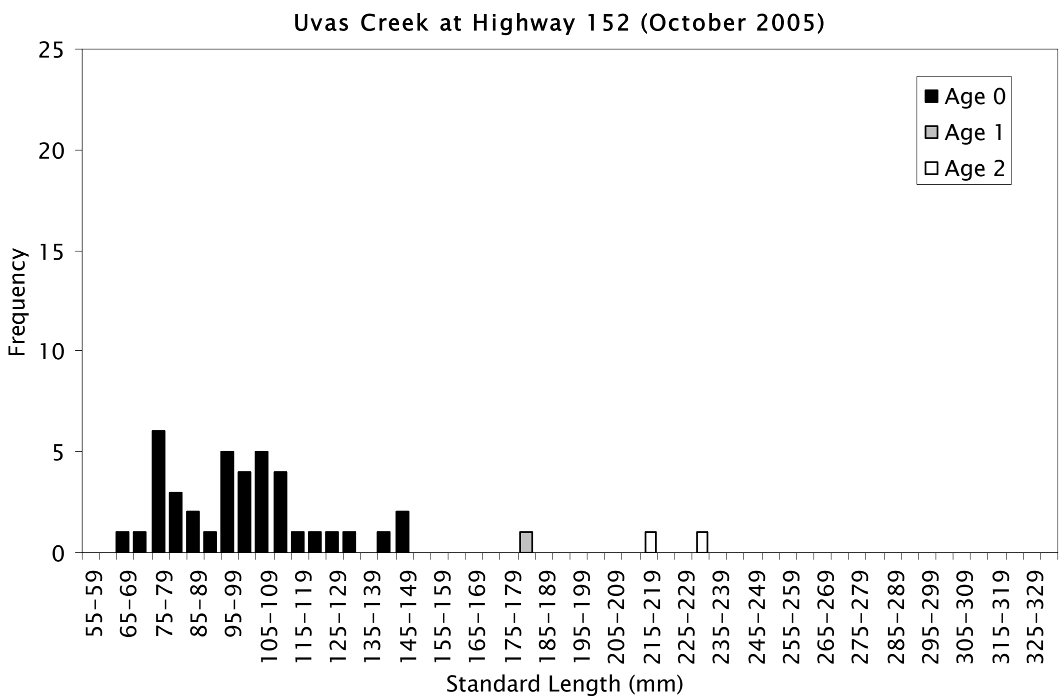


FIGURE C-57.—Steelhead standard lengths (mm) for Uvas Creek at Highway 152, October 2005.

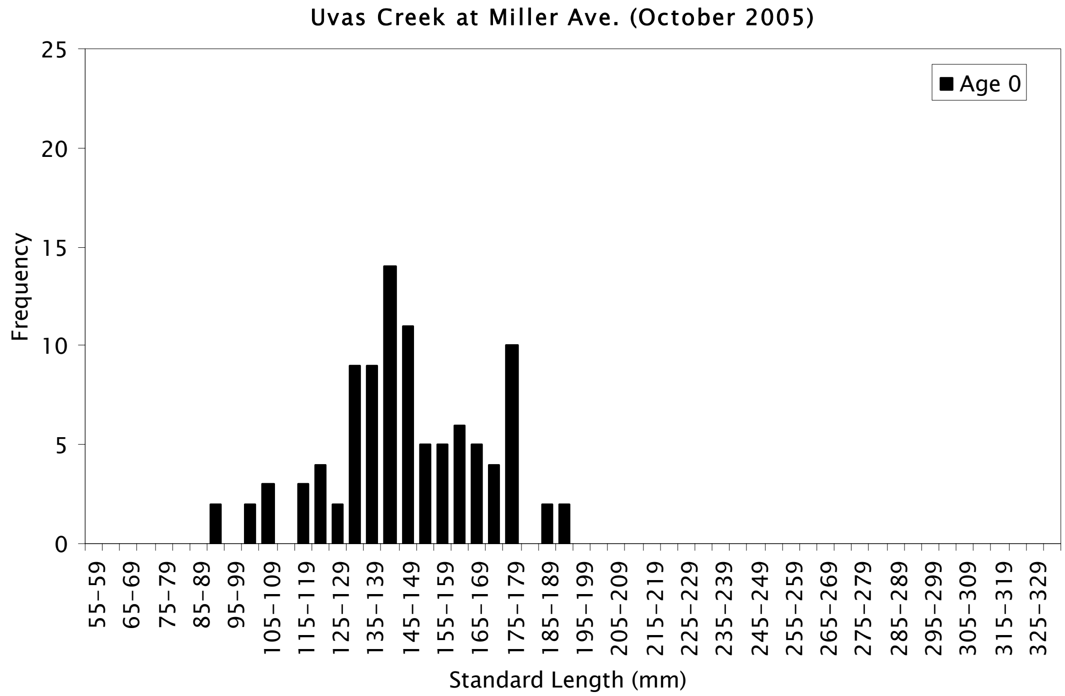


FIGURE C-58.—Steelhead standard lengths (mm) for Uvas Creek at Miller Avenue, October 2005.

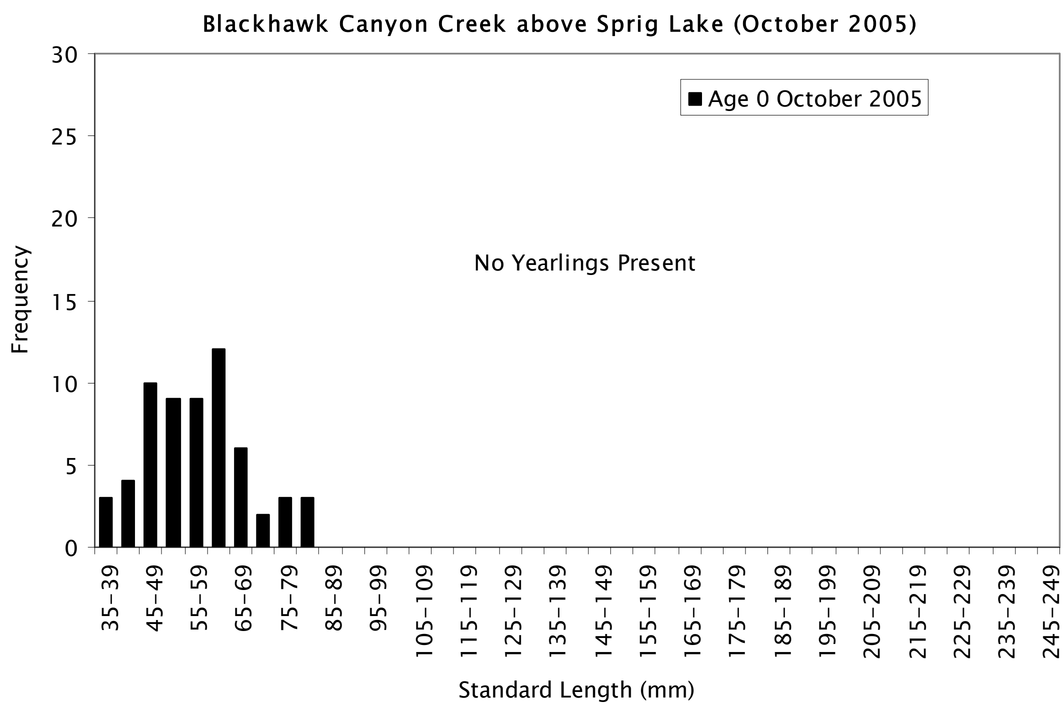


FIGURE C-59.—Steelhead standard lengths (mm) for Blackhawk Canyon Creek above Sprig Lake, October 2005.

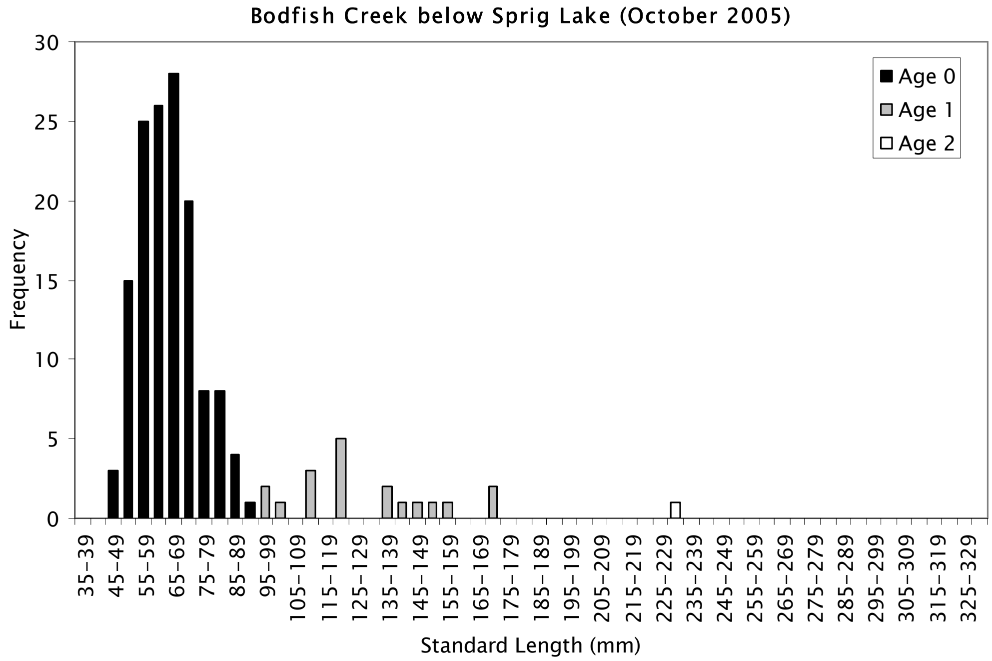


FIGURE C-60.—Steelhead standard lengths (mm) for Bodfish Creek below Sprig Lake, October 2005.

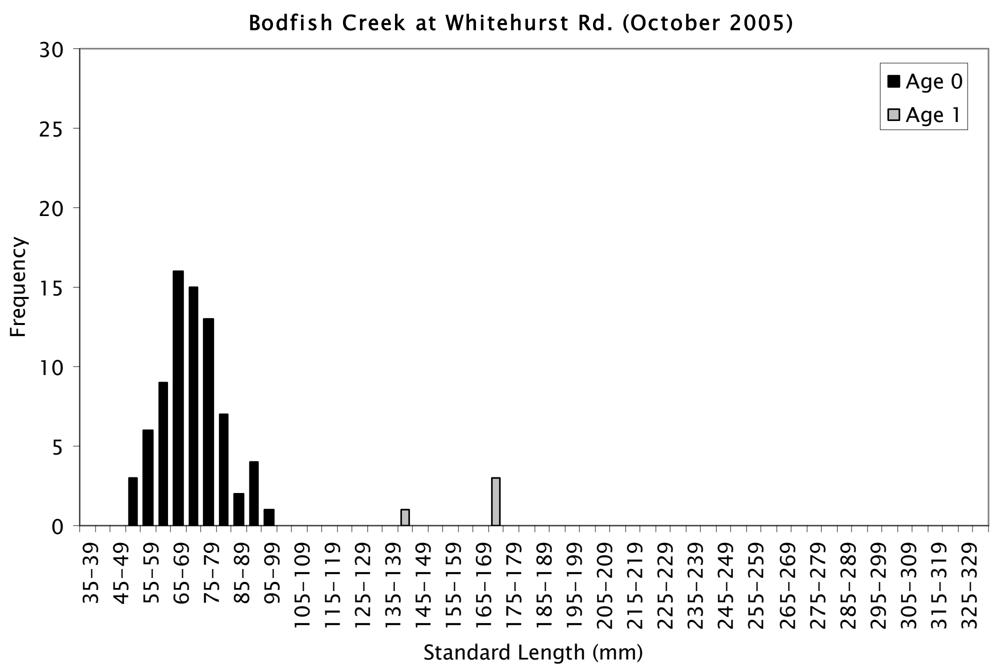


FIGURE C-61.—Steelhead standard lengths (mm) for Bodfish Creek at Whitehurst Road, October 2005.

Appendix D: 2005 yearling and older fish size (mm SL) at first annulus formation for sites in the Uvas Creek watershed.

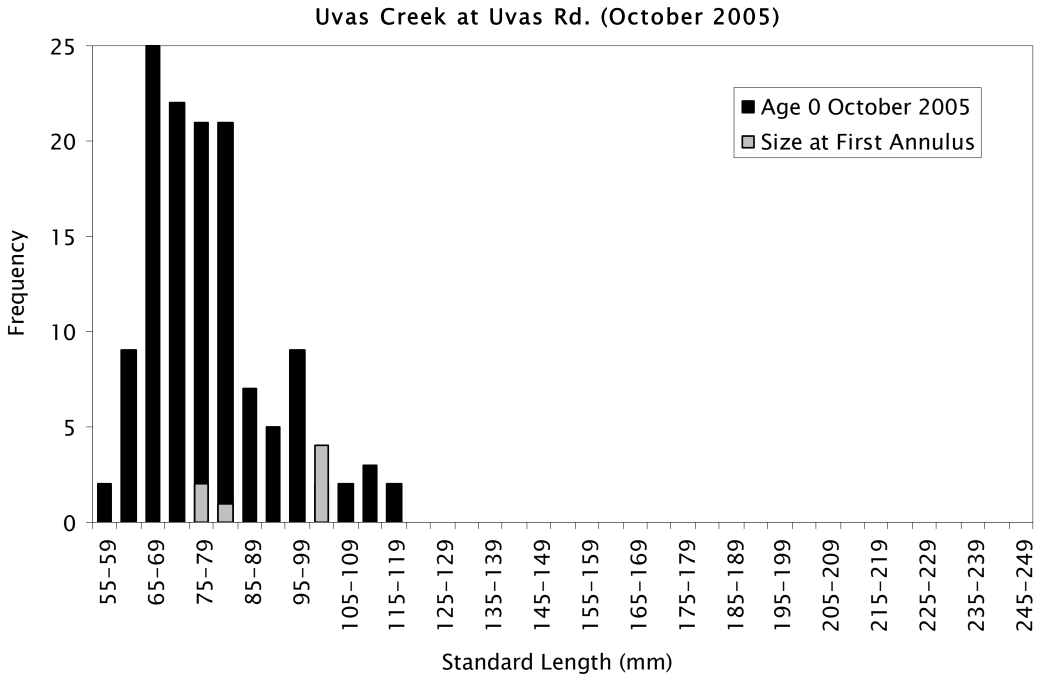


FIGURE D-62.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Uvas Road, October 2005.

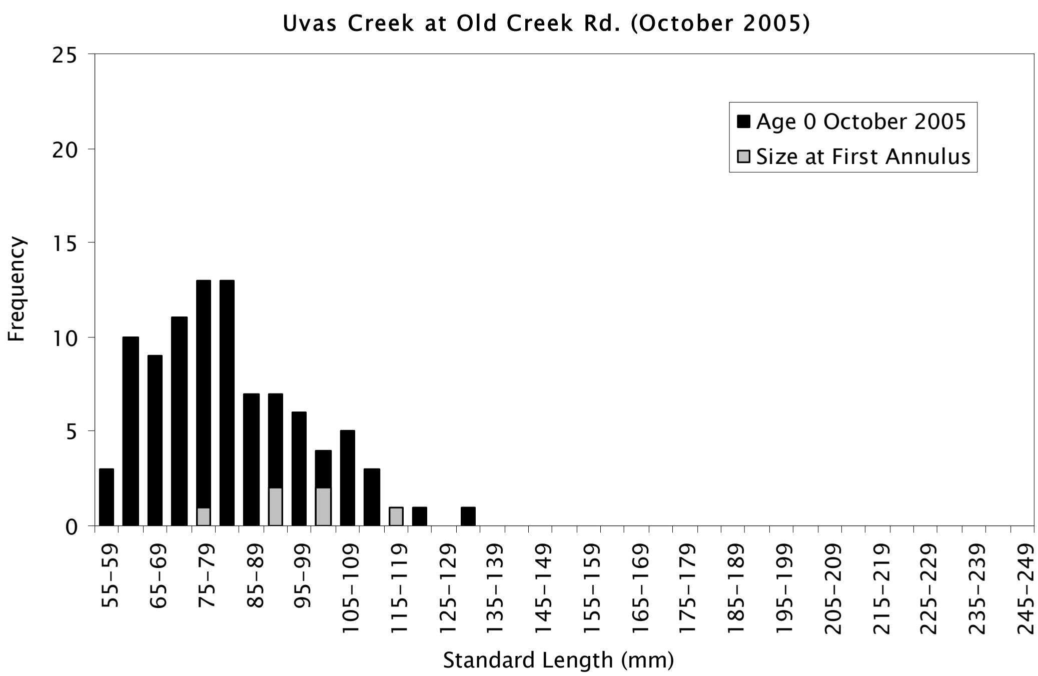


FIGURE D-63.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Old Creek Road, October 2005.

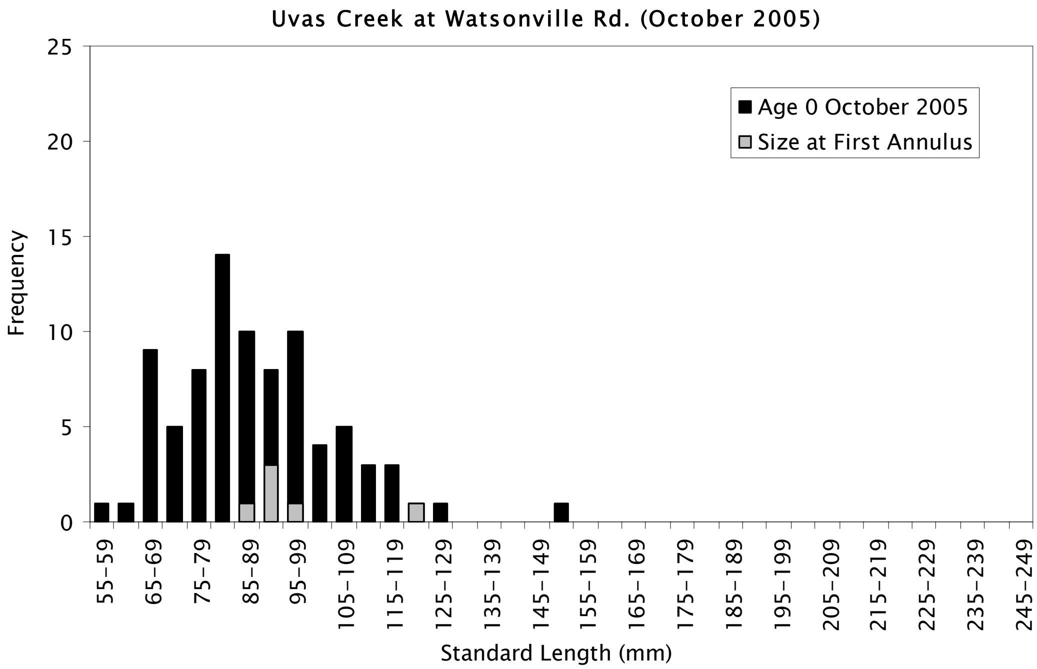


FIGURE D-64.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Watsonville Road, October 2005.

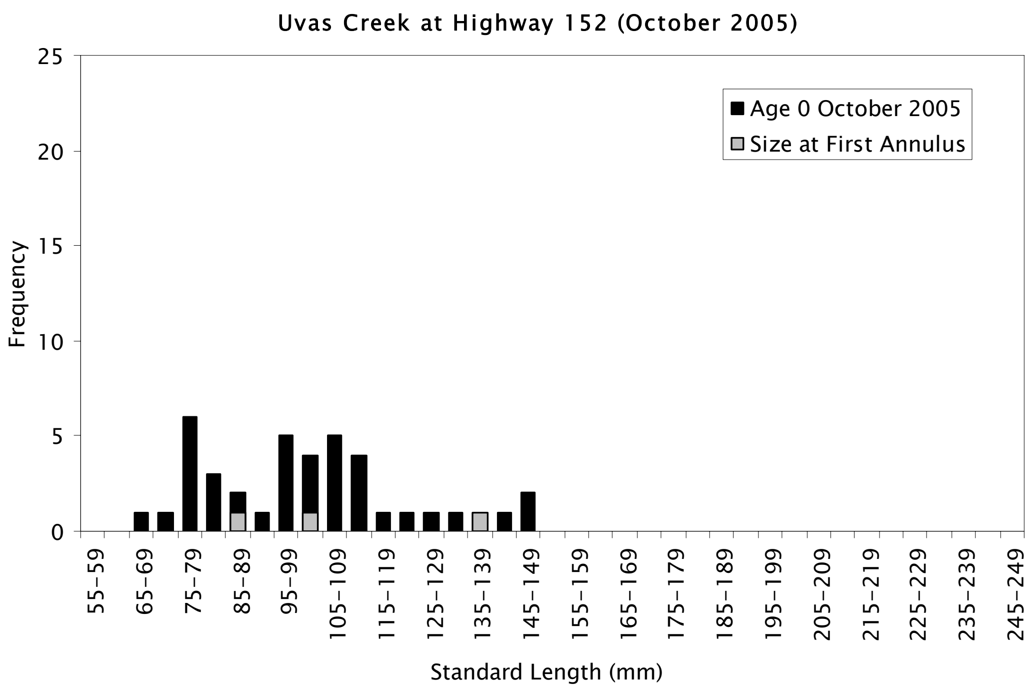


FIGURE D-65.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Highway 152, October 2005.

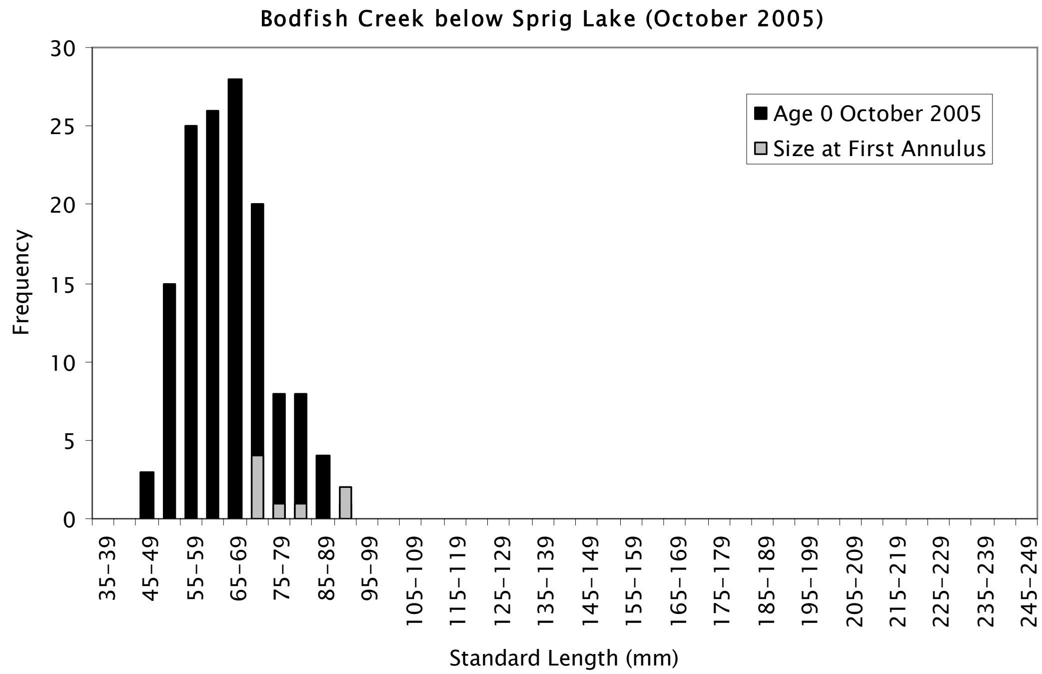


FIGURE D-66.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Bodfish Creek below Sprig Lake, October 2005.

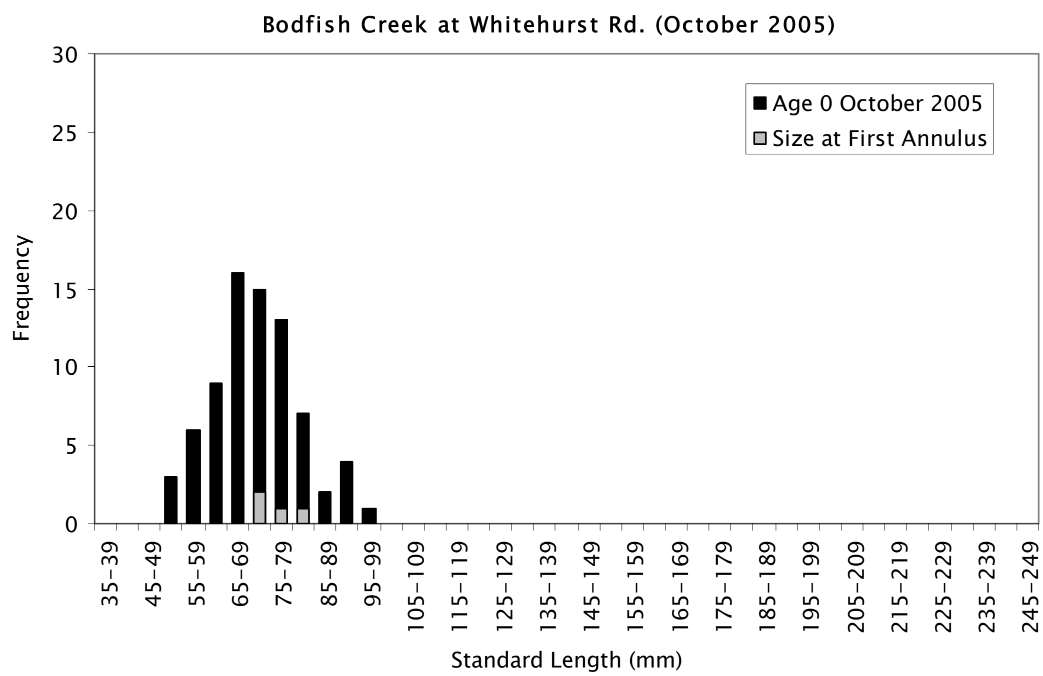


FIGURE D-67.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Bodfish Creek at Whitehurst Rd, October 2005.

Appendix E: July/August 2006 steelhead standard lengths (mm) for sites in the Uvas Creek watershed.

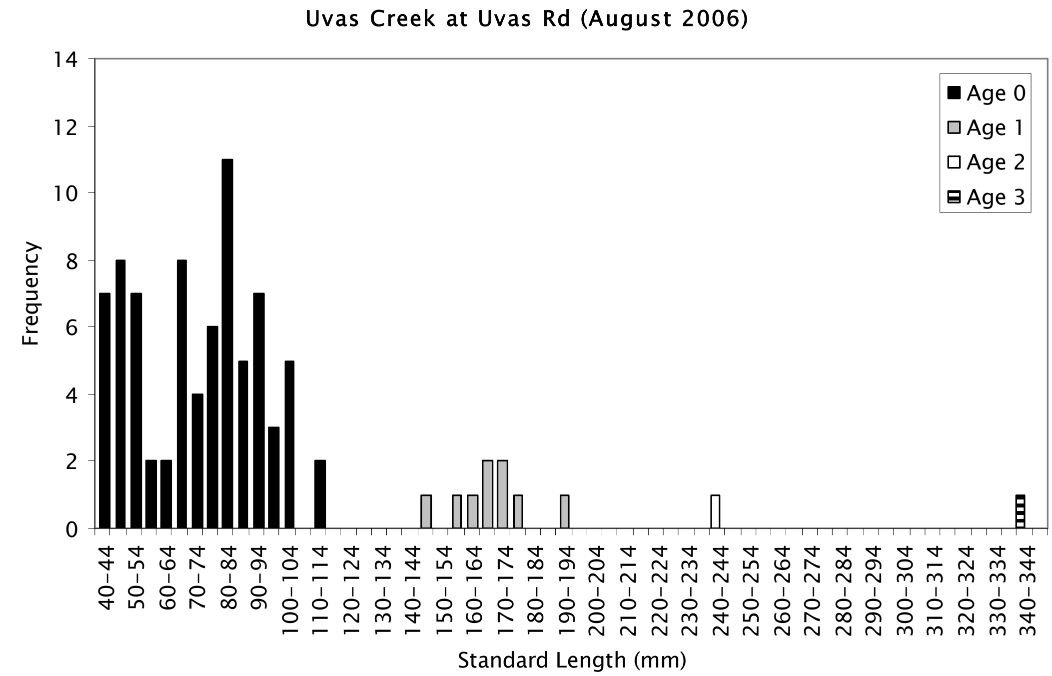


FIGURE E-68.—Steelhead standard lengths (mm) for Uvas Creek at Uvas Road, August 2006.

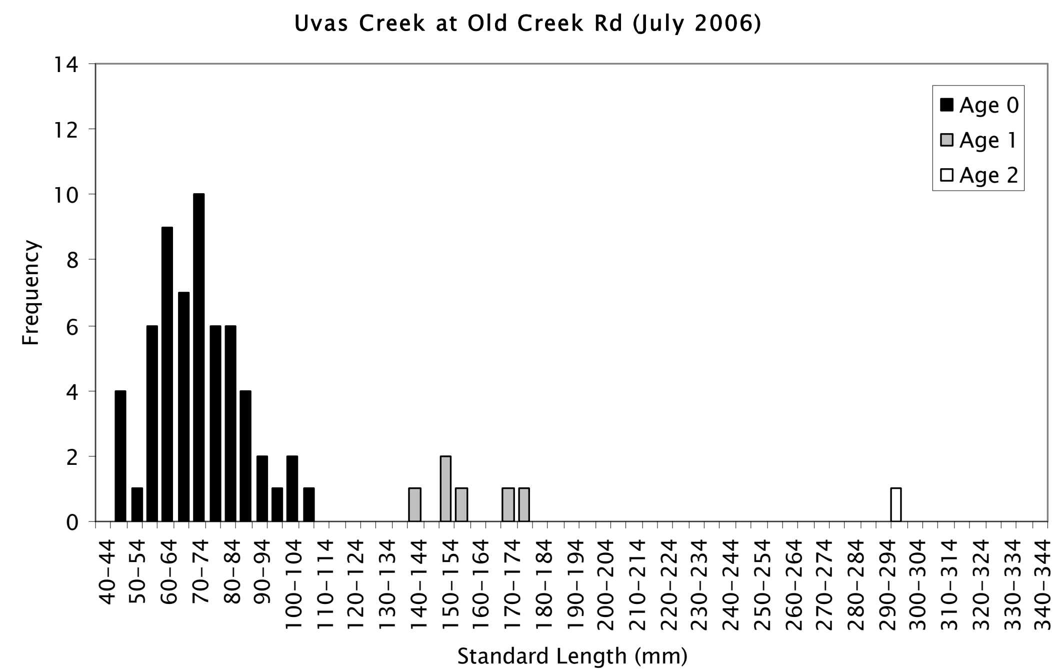


FIGURE E-69.—Steelhead standard lengths (mm) for Uvas Creek at Old Creek Road, July 2006.

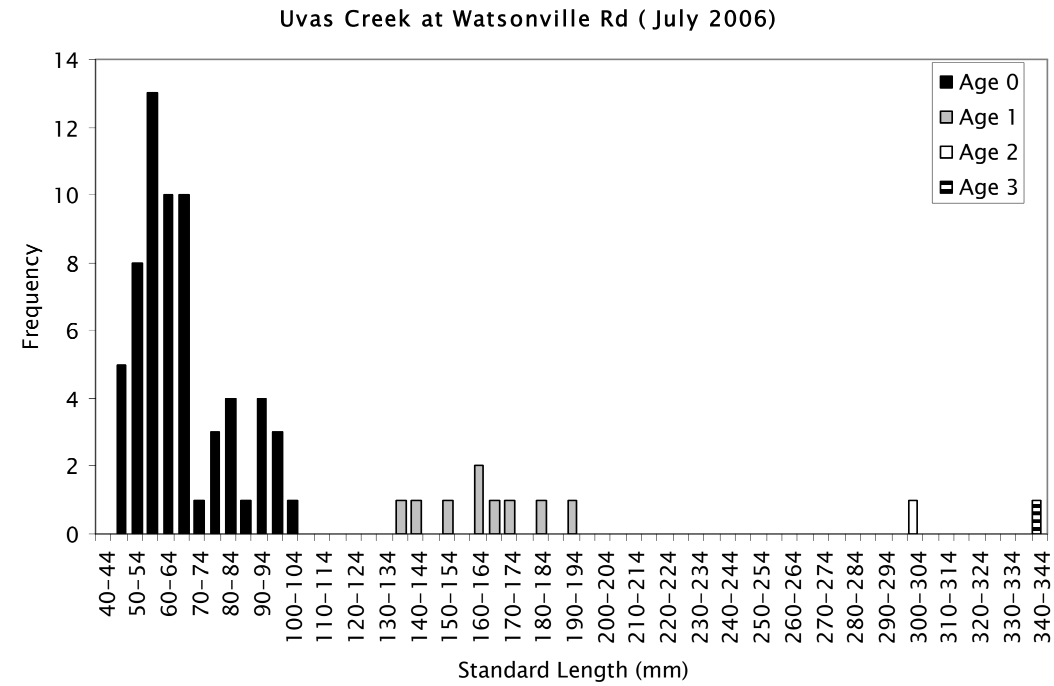


FIGURE E-70.—Steelhead standard lengths (mm) for Uvas Creek at Watsonville Road, July 2006.

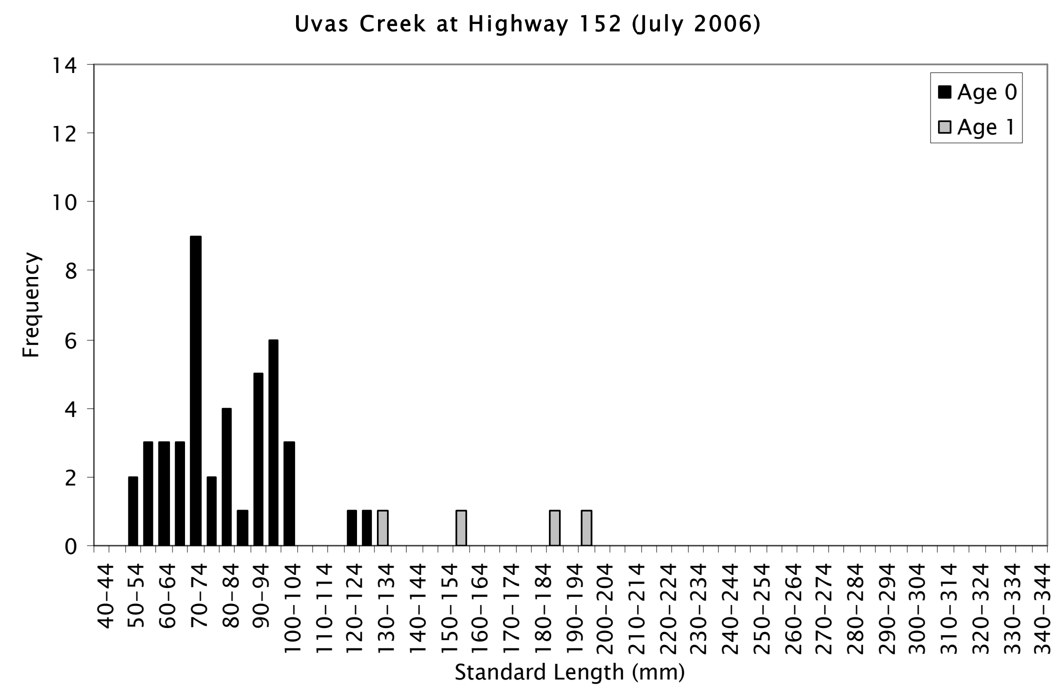


FIGURE E-71.—Steelhead standard lengths (mm) for Uvas Creek at Highway 152, July 2006.

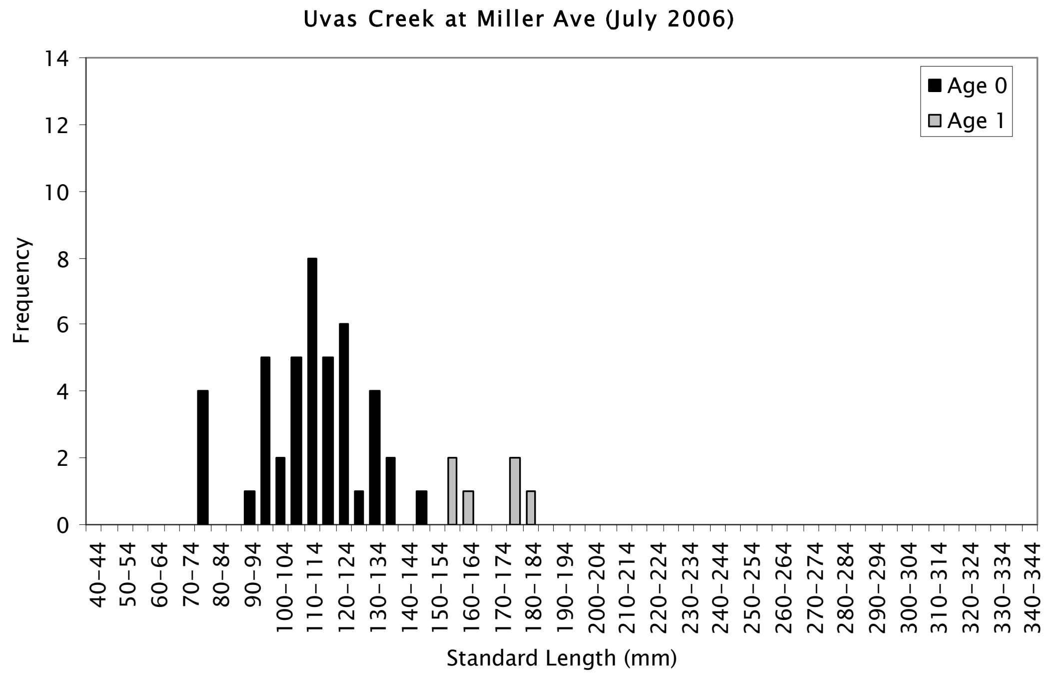


FIGURE E-72.—Steelhead standard lengths (mm) for Uvas Creek at Miller Avenue, July 2006.

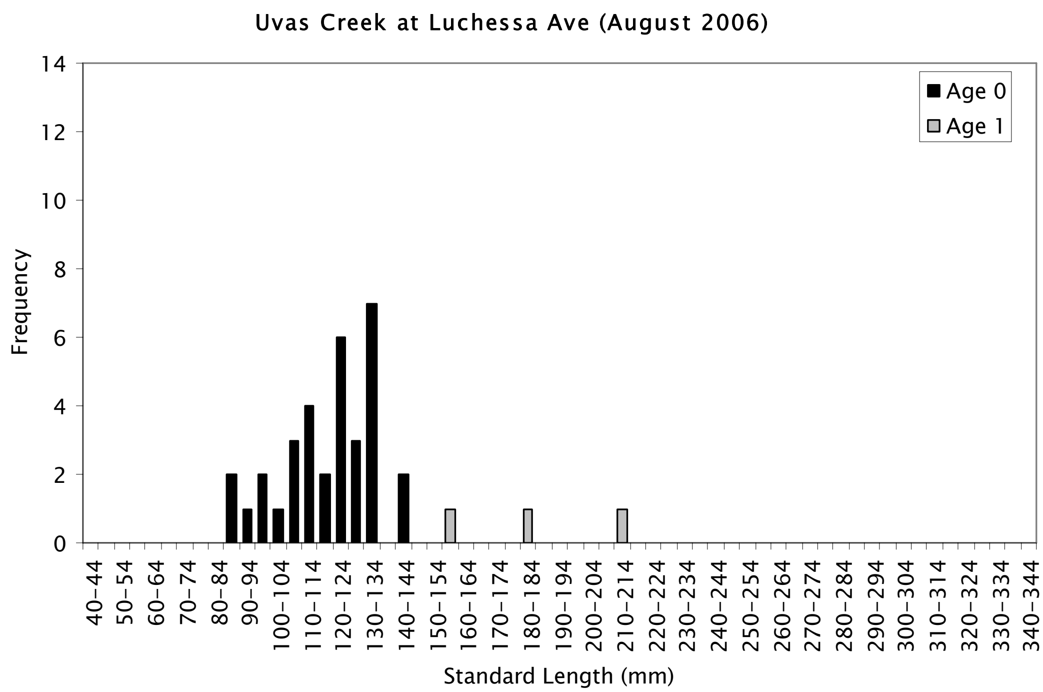


FIGURE E-73.—Steelhead standard lengths (mm) for Uvas Creek at Luchessa Avenue, August 2006.

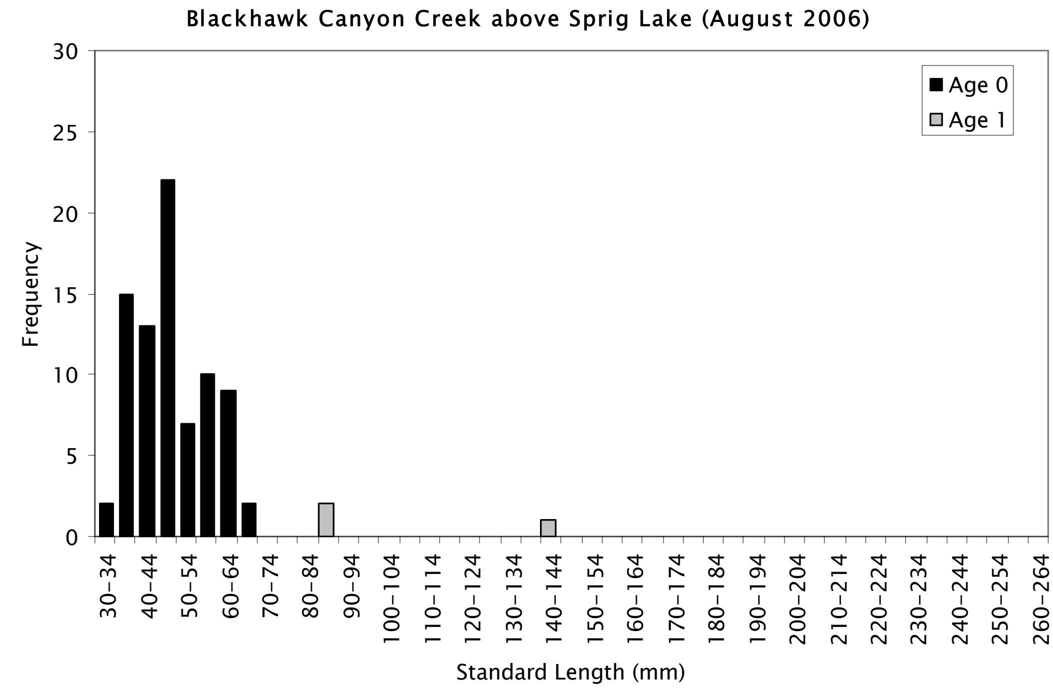


FIGURE E-74.—Steelhead standard lengths (mm) for Blackhawk Canyon Creek above Sprig Lake, August 2006.

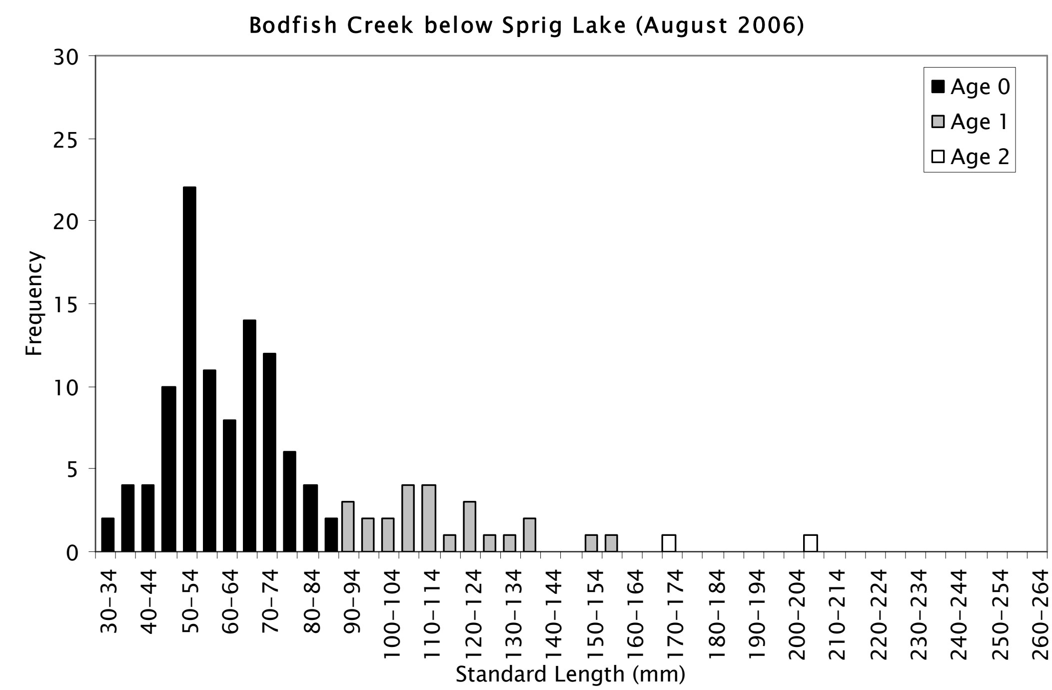


FIGURE E-75.—Steelhead standard lengths (mm) for Bodfish Creek below Sprig Lake, August 2006.

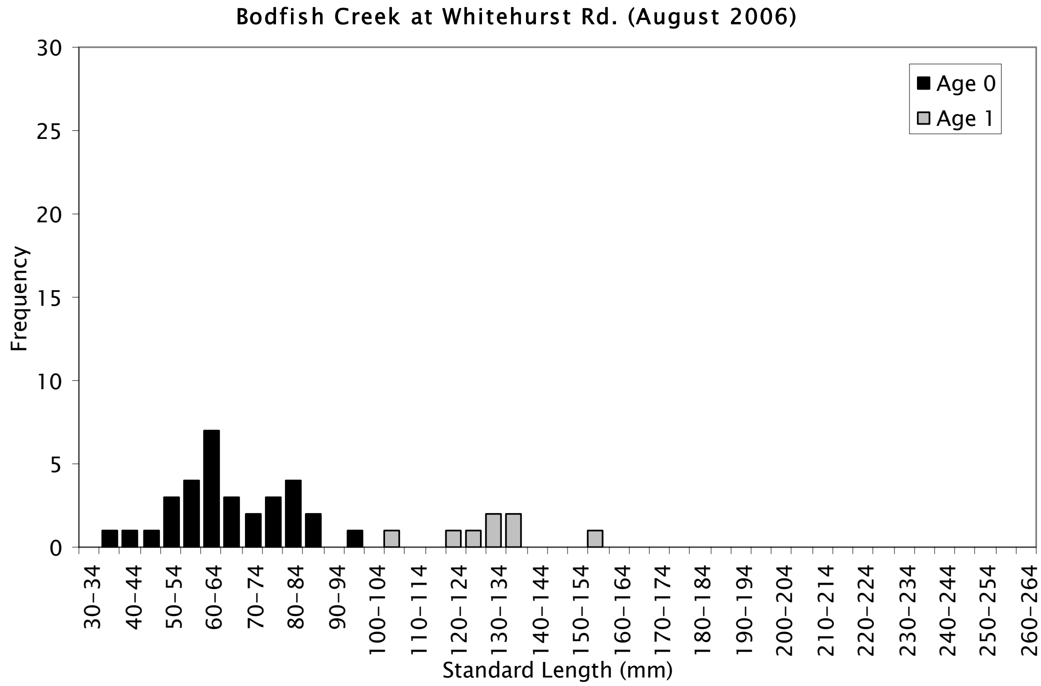


FIGURE E-76.—Steelhead standard lengths (mm) for Bodfish Creek at Whitehurst Road, August 2006.

Appendix F: October 2006 steelhead standard lengths (mm) for sites in the Uvas Creek watershed.

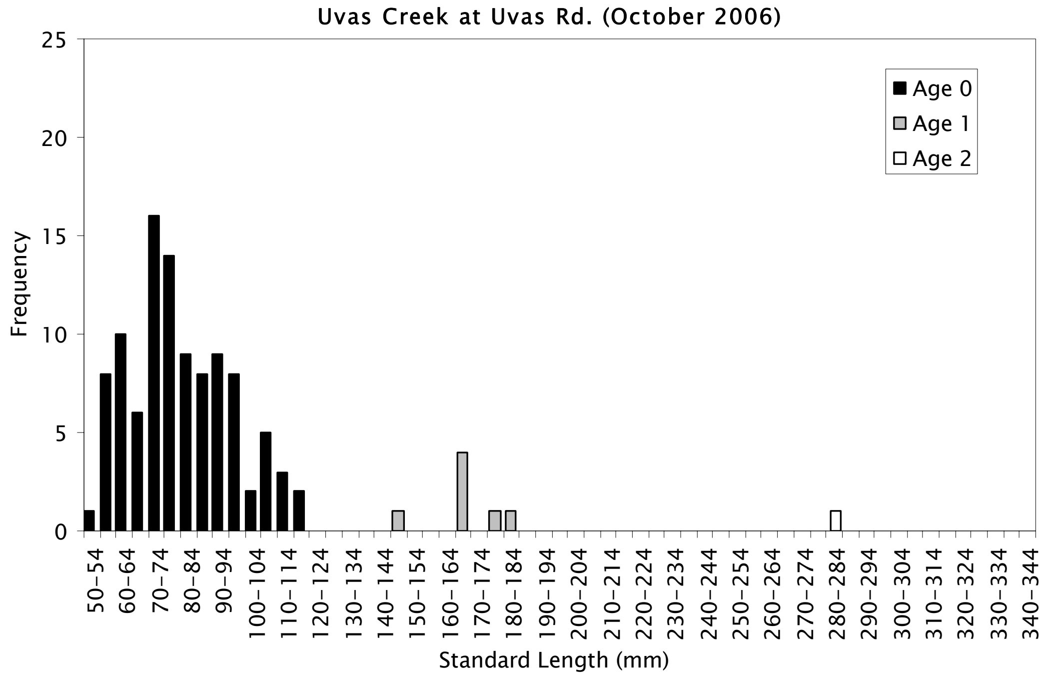


FIGURE F-77.—Steelhead standard lengths (mm) for Uvas Creek at Uvas Road, October 2006.

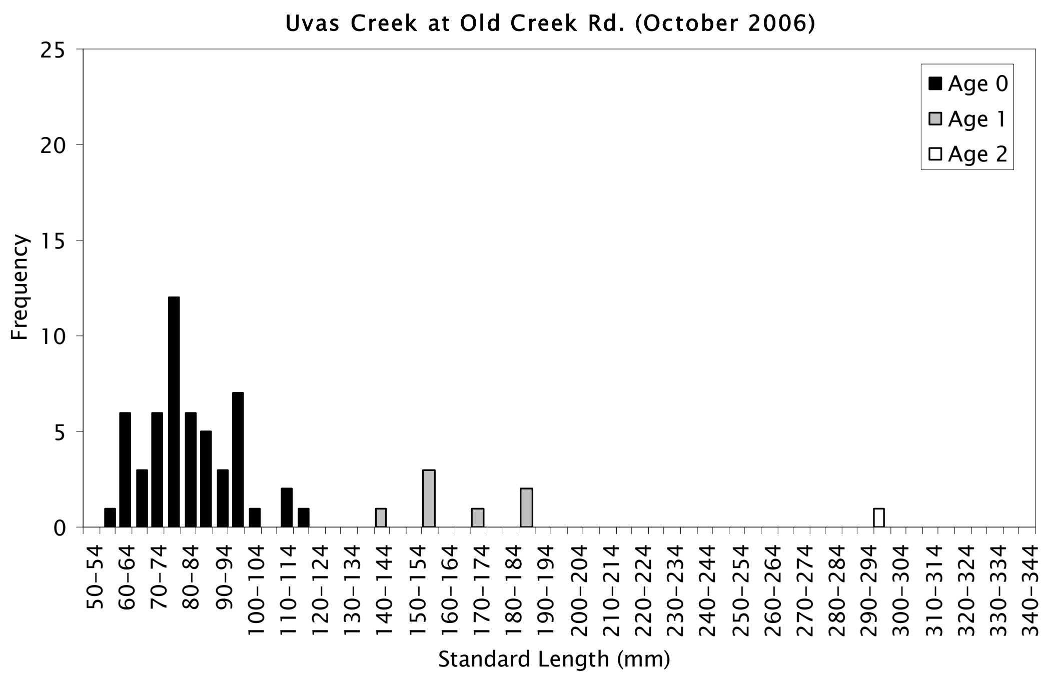


FIGURE F-78.—Steelhead standard lengths (mm) for Uvas Creek at Old Creek Road, October 2006.

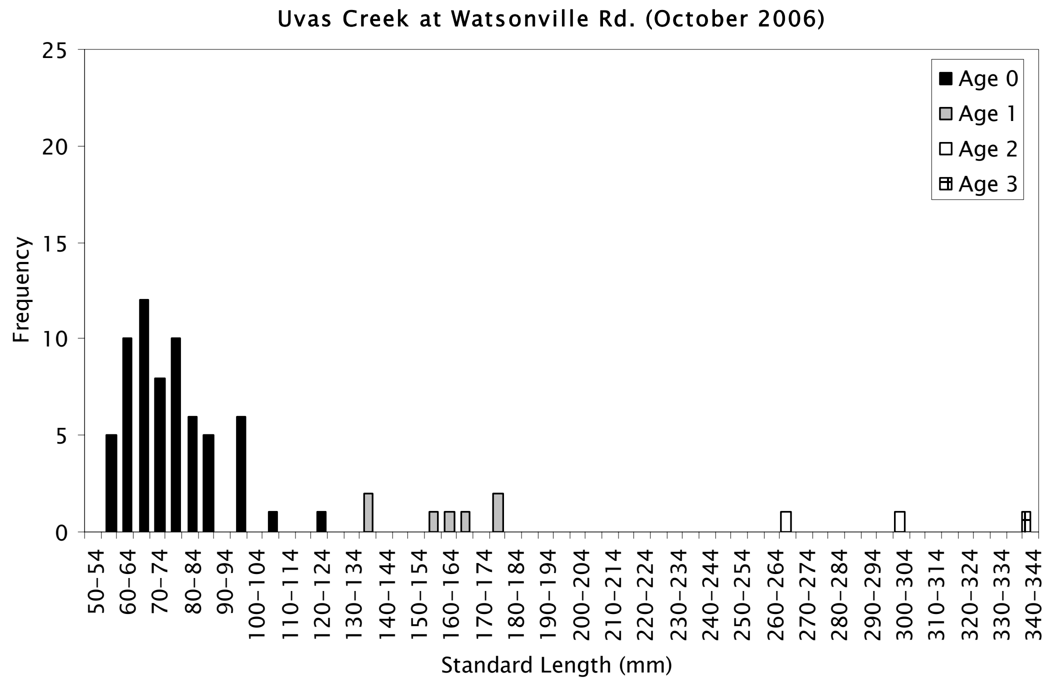


FIGURE F-79.—Steelhead standard lengths (mm) for Uvas Creek at Watsonville Road, October 2006.

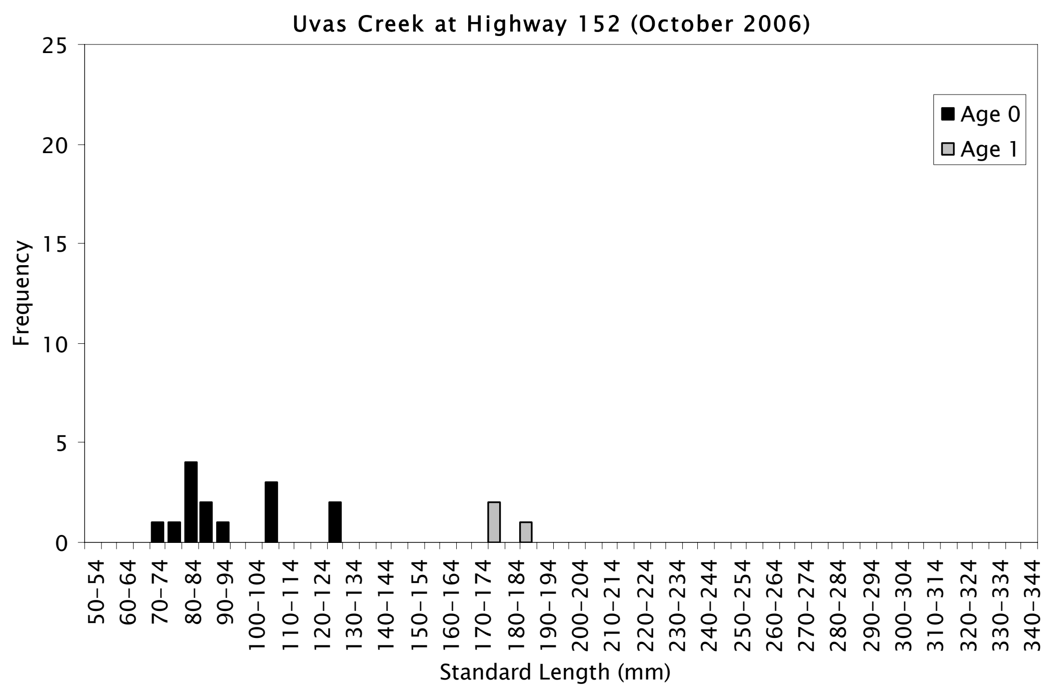


FIGURE F-80.—Steelhead standard lengths (mm) for Uvas Creek at Highway 152, October 2006.

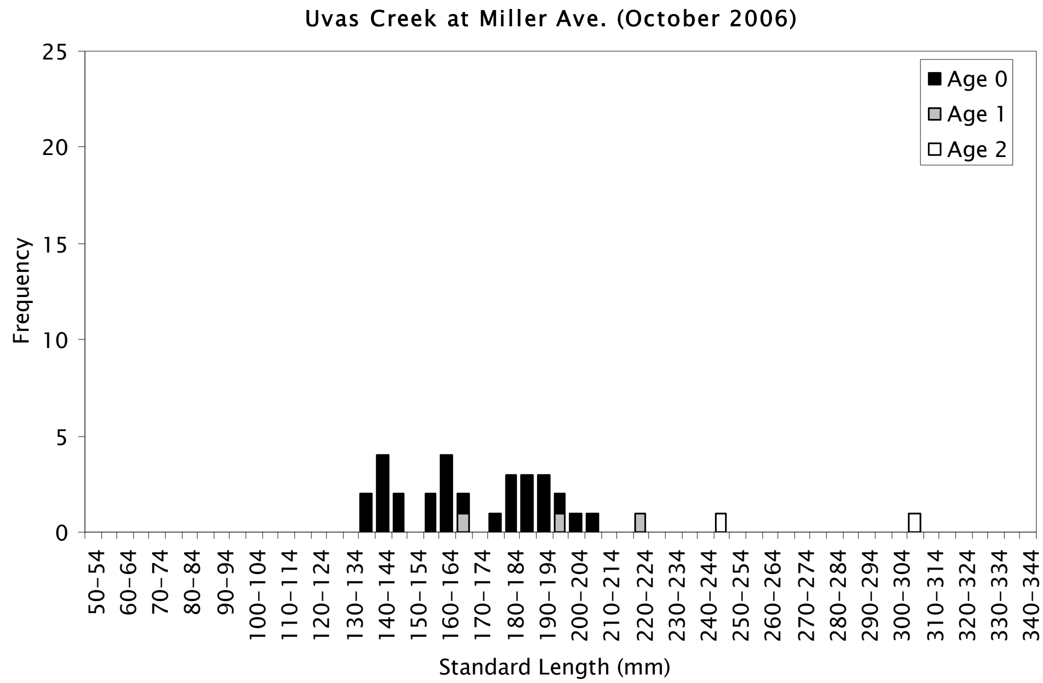


FIGURE F-81.—Steelhead standard lengths (mm) for Uvas Creek at Miller Avenue, October 2006.

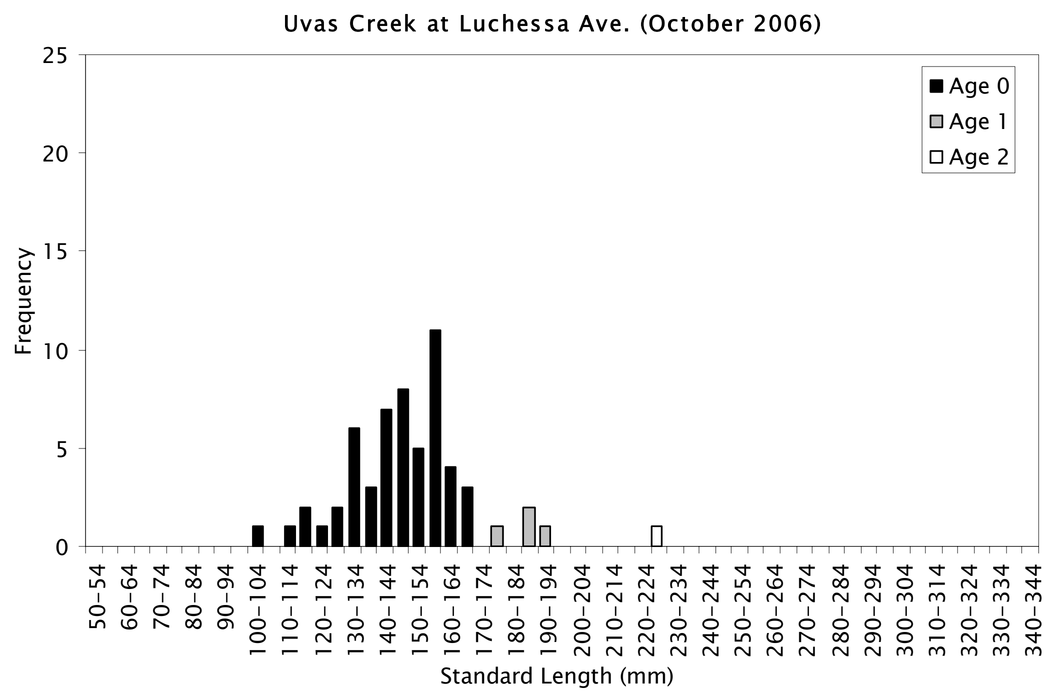


FIGURE F-82.—Steelhead standard lengths (mm) for Uvas Creek at Luchessa Avenue, October 2006.

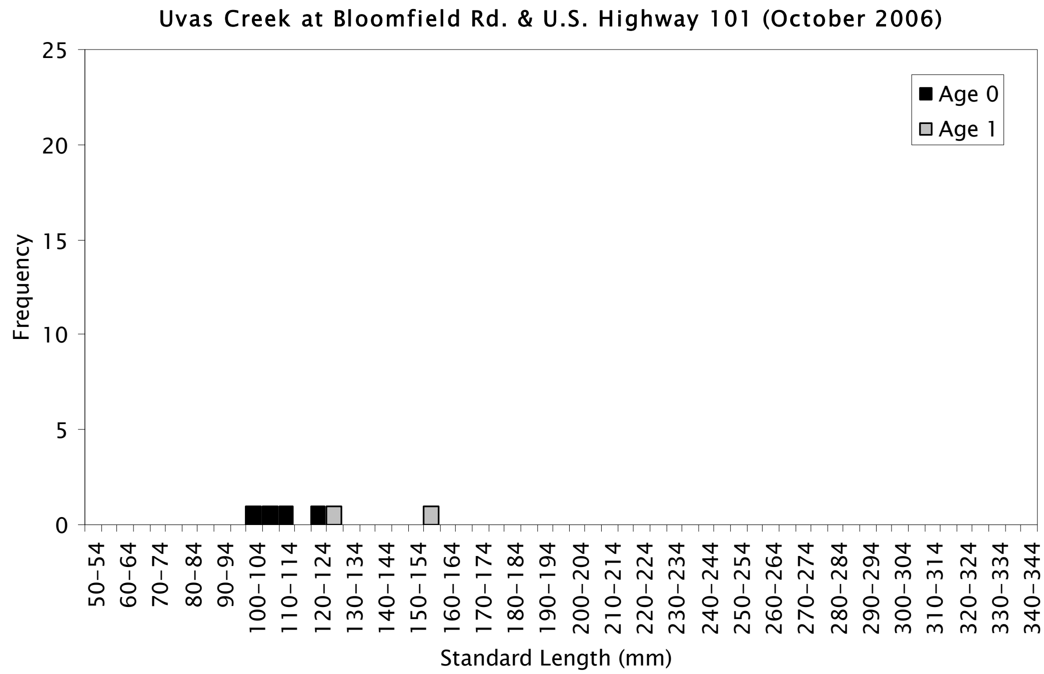


FIGURE F-83.—Steelhead standard lengths (mm) for Uvas Creek at Bloomfield Road and U.S. Highway 101, October 2006.

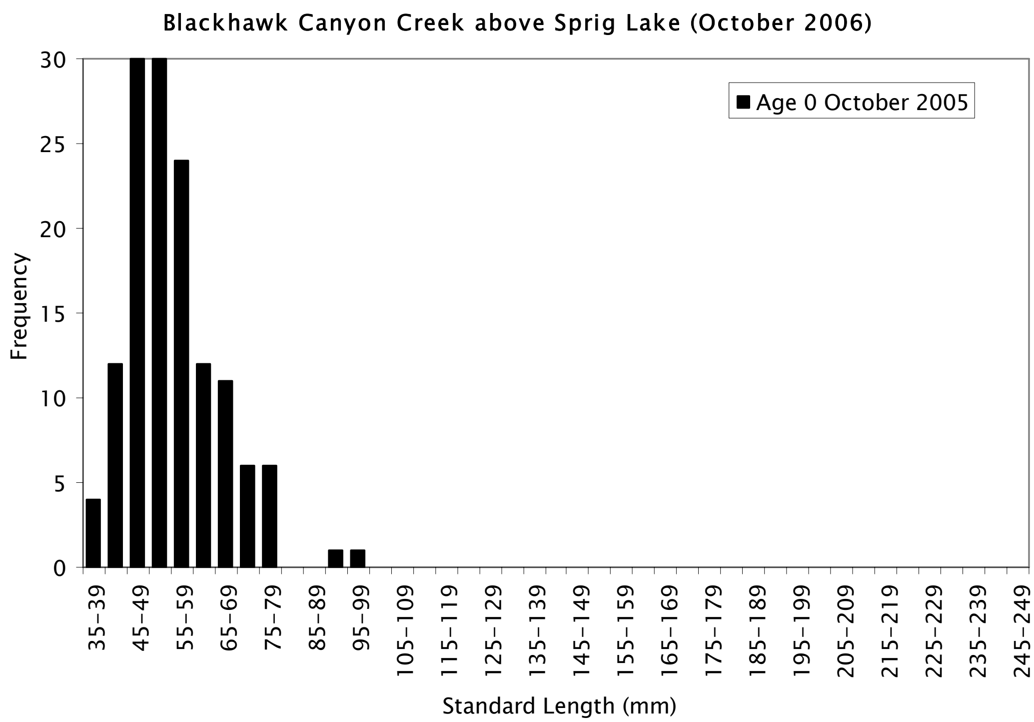


FIGURE F-84.—Steelhead standard lengths (mm) for Blackhawk Canyon Creek above Sprig Lake, October 2006.

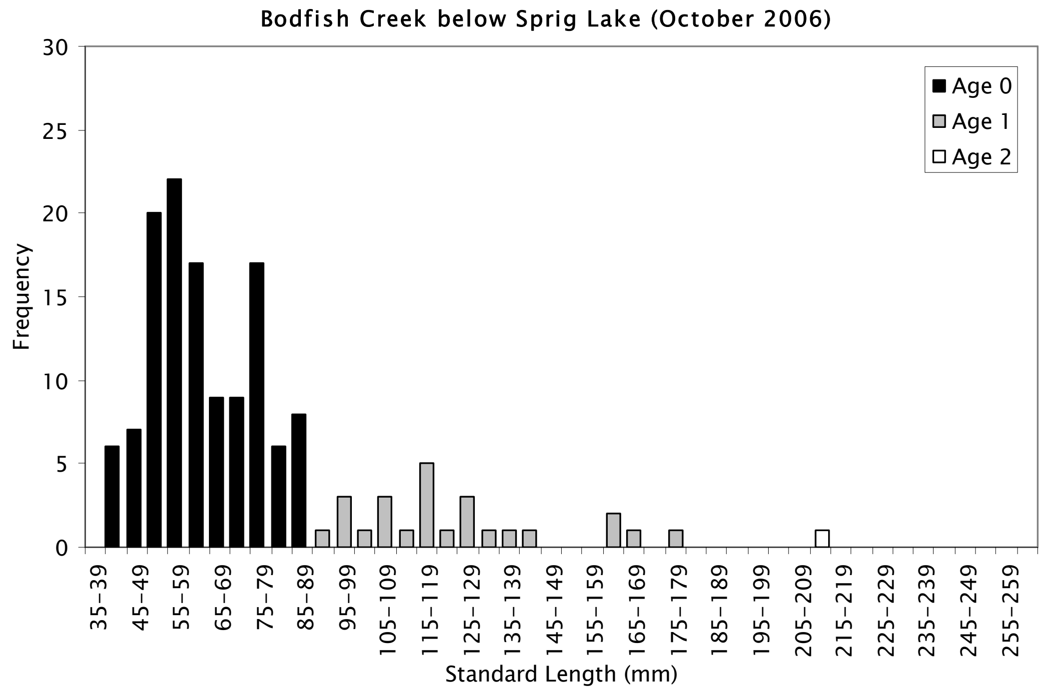


FIGURE F-85.—Steelhead standard lengths (mm) for Bodfish Creek below Sprig Lake, October 2006.

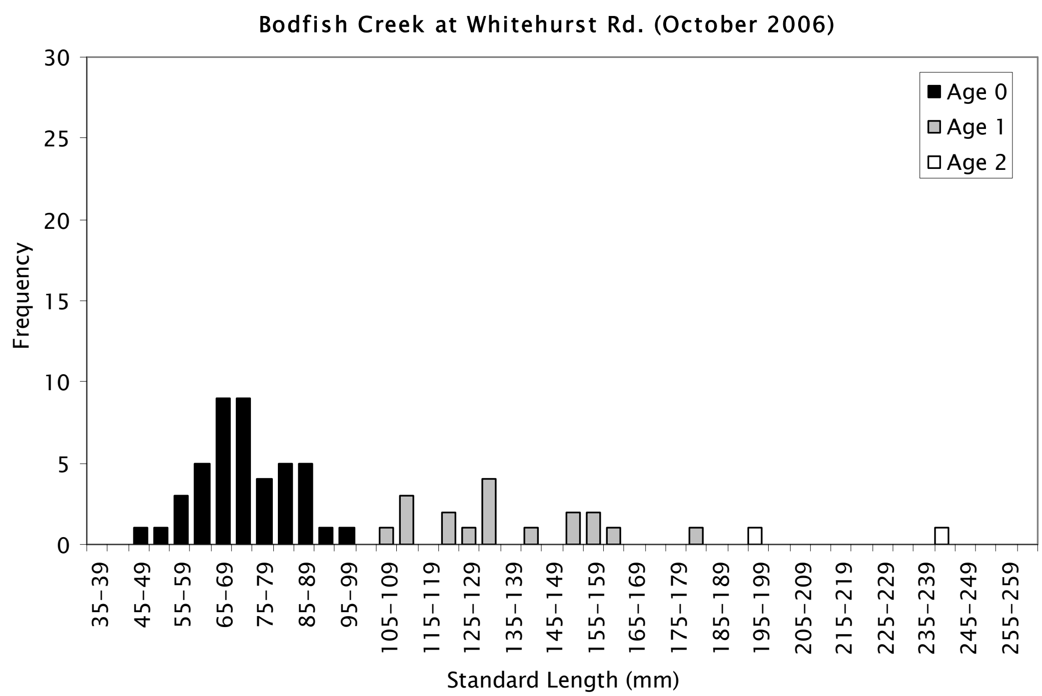


FIGURE F-86.—Steelhead standard lengths (mm) for Bodfish Creek at Whitehurst Road, October 2006.

Appendix G: 2006 yearling and older fish size (mm SL) at first annulus formation for sites in the Uvas Creek watershed.

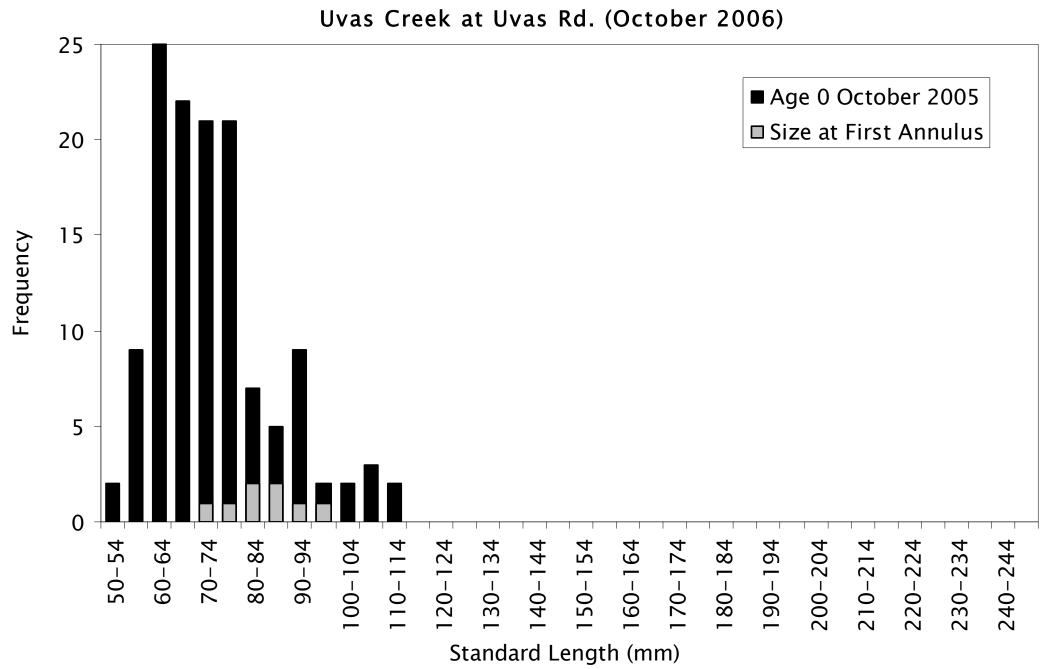


FIGURE G-87.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Uvas Road, October 2006.

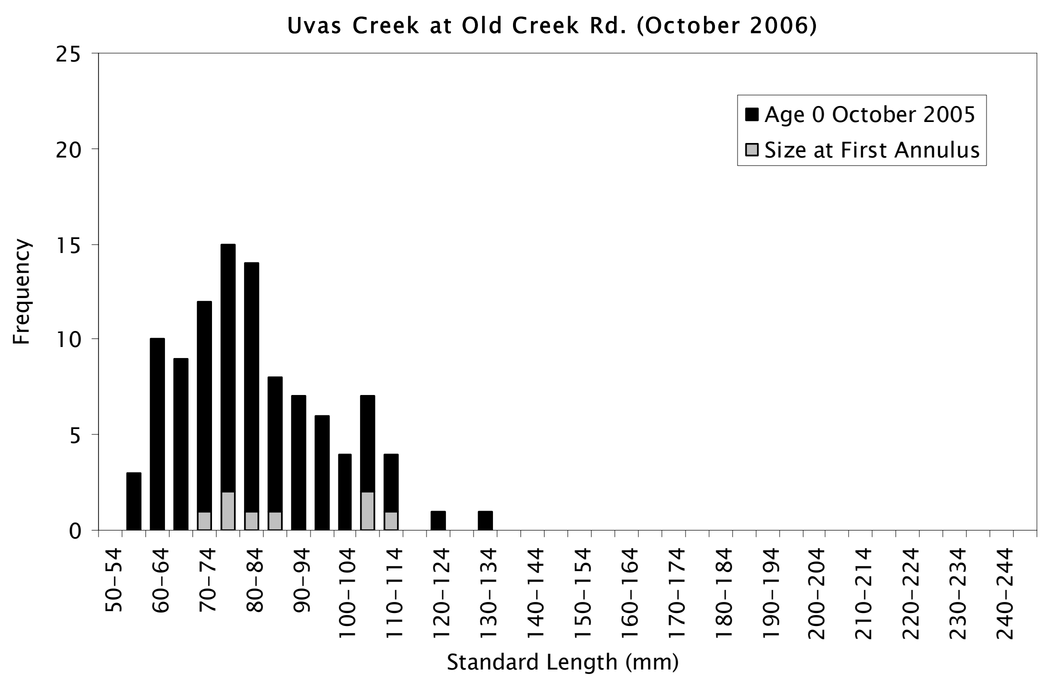


FIGURE G-88.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Old Creek Road, October 2006.

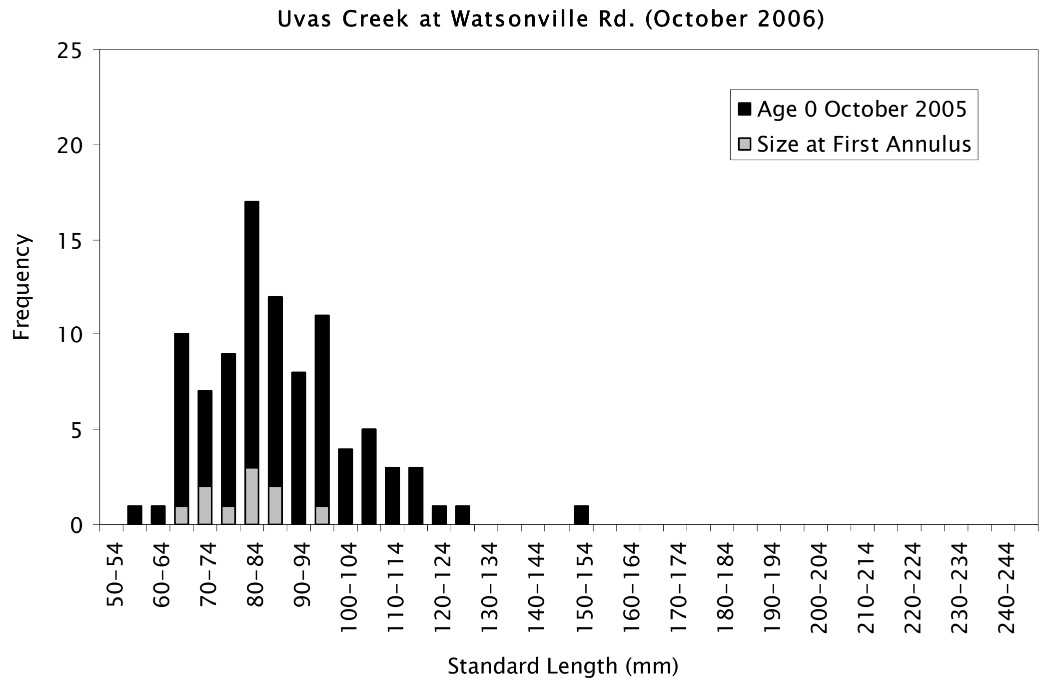


FIGURE G-89.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Watsonville Road, October 2006.

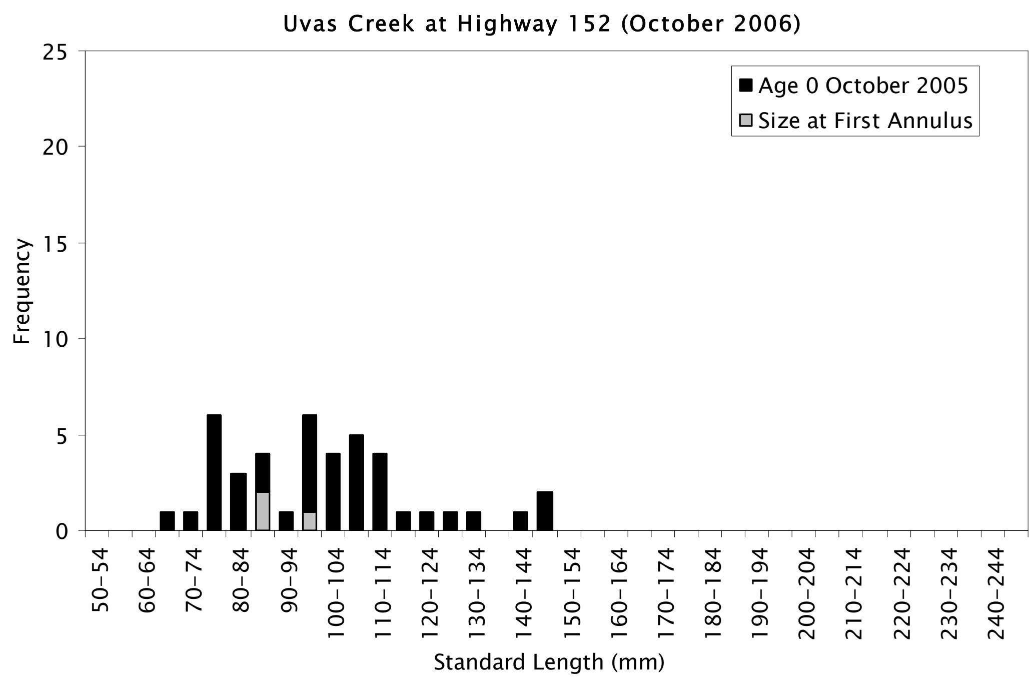


FIGURE G-90.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Highway 152, October 2006.

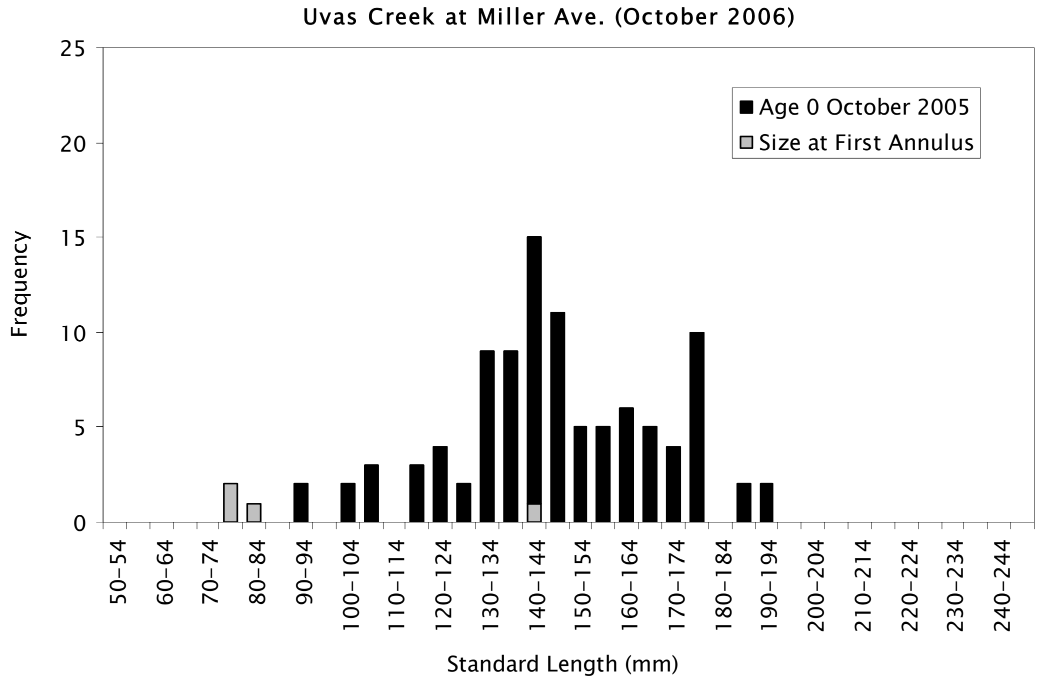


FIGURE G-91.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Miller Avenue, October 2006.

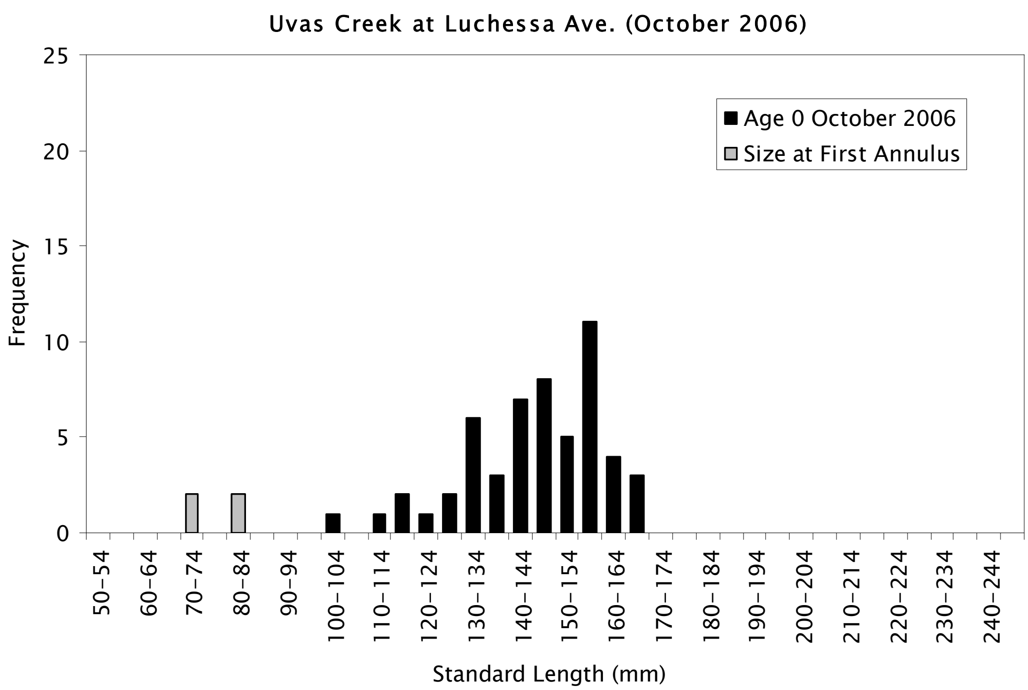


FIGURE G-92.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Uvas Creek at Luchessa Avenue, October 2006. Site not sampled in 2005.

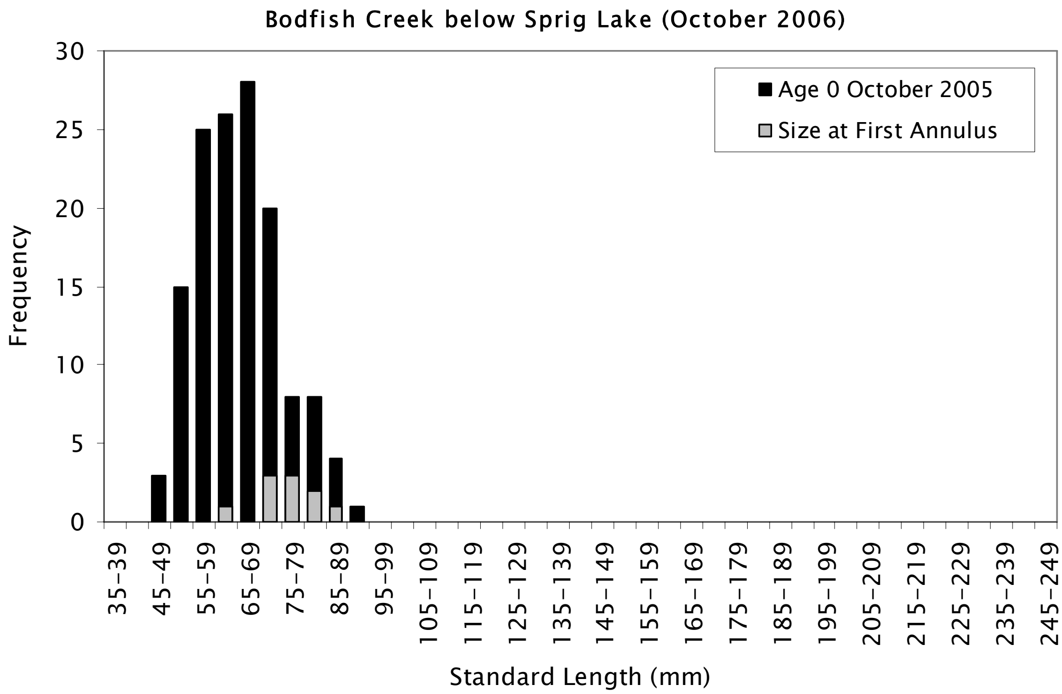


FIGURE G-93.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Bodfish Creek below Sprig Lake, October 2006.

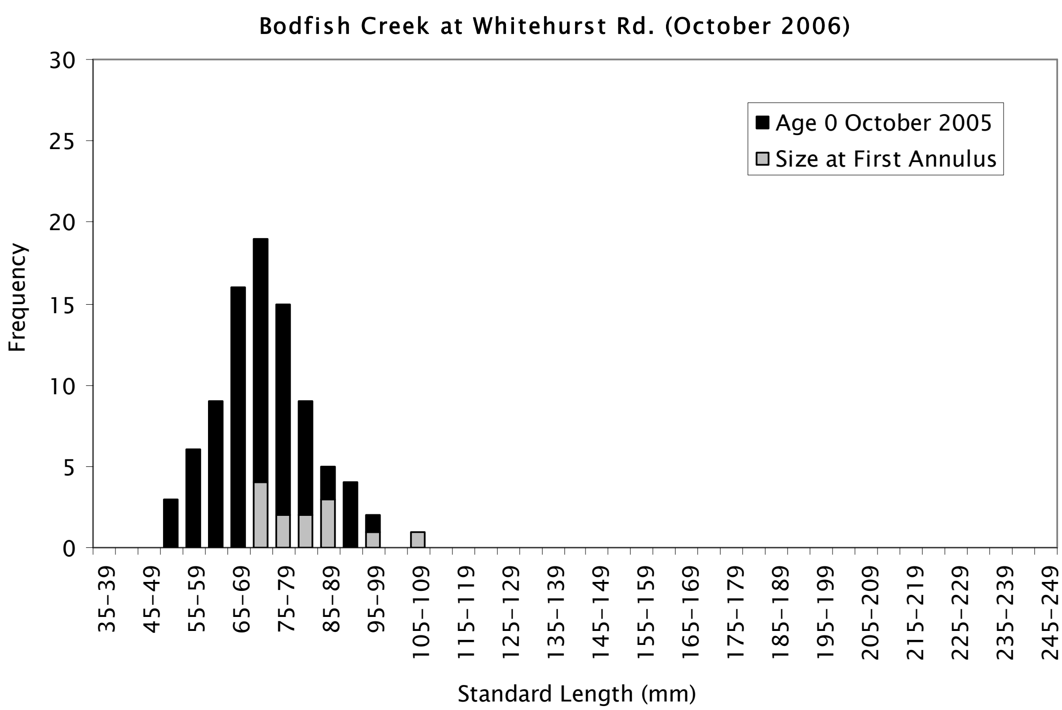


FIGURE G-94.—A comparison of yearling and older fish size (mm SL) at first annulus formation with Age 0 collected from Bodfish Creek at Whitehurst Road, October 2006.