SONOMA ECOLOGY CENTER

SONOMA CREEK WATERSHED ASSESSMENT

1998 WATER TEMPERATURE MONITORING

prepared by
Oona McKnight
Mitchell Katzel

Sonoma Valley Watershed Station

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205 First Street West, Sonoma, CA 95476 • (707) 996-9744 • fax (707) 996-1744
sec@vom.com • www.vom.com/sec • Sonoma Valley Watershed Station (707) 996-0712

Executive Summary

In recent decades, Sonoma Creek and its tributaries have reportedly seen a decline in the once abundant steelhead trout population. The main purpose of the SEC thermal monitoring program is to determine if water temperatures during the summer months are a critical factor limiting the steelhead fishery in the Sonoma Creek watershed. There are virtually no known studies related to temperature conditions prior to the water temperature monitoring and assessment program initiated by the Sonoma Ecology Center (SEC) in 1996.

The 1998 thermal monitoring program consisted of deploying automatic temperature data loggers at twelve locations in the upper half of the watershed from late June through October. Four thermal monitors were placed in mainstem Sonoma Creek above Madrone Road, and eight monitors were deployed in five tributaries (Asbury Creek, Carriger Creek and Graham Creek on the west side of Sonoma Valley, Calabazas Creek and Stuart Creek on the east side, and Nathanson Creek).

Analysis of the data indicate that water temperatures at all of the monitored locations are suitable for rearing steelhead and are not likely to be a significant factor limiting distribution in the watershed. This finding supports the conclusions of the 1997 SEC temperature study. However, water temperatures are not optimal at many locations. Higher water temperatures increase the metabolic rate of steelhead, which must be supported by an adequate food supply. If the food supply is not adequate, then warmer water temperatures could adversely affect steelhead growth.

To directly determine if steelhead growth and production is adequately supported by the food base, SEC is conducting two studies beginning in 2000. A fish population study will evaluate the size, condition, and age classes present, and the availability and abundance of the macroinvertebrate food base will be investigated. Riparian corridor extent and condition will also be assessed.

Since temperatures are not optimal, any opportunity to improve physical habitat conditions influencing temperature, including riparian shading and streamflow, should also be identified. The thermal monitoring program should be continued for the next several years to establish baseline conditions and account for variation between years. An ongoing monitoring program can serve as a warning system to detect water temperature changes that might occur due to changes in land use or land management.

Introduction

Historically, Sonoma Creek and its tributaries supported a large population of steelhead trout (*Oncorhynchus mykiss gairdneri*). Although no comprehensive studies have been carried out to quantify the numbers of steelhead present in the watershed, anecdotal evidence indicates the numbers have been declining in recent decades. Steelhead have been listed as a threatened species by the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG) under the federal and state Endangered Species Acts.

The SEC's Technical Advisory Committee (TAC) directs and supports activities which foster a comprehensive understanding of the historic and present condition of the Sonoma Valley watershed in order to facilitate wise stewardship. These activities include developing scientifically based plans for the restoration of salmonid fish populations, preservation and restoration of riparian corridors, and the preservation and protection of the quality and quantity of water. To assist in these activities, the Sonoma Valley Watershed Station (SVWS) was formed in June 1998 with the assistance of a grant from CalFed. The Watershed Station is an educational and research center dedicated to understanding the natural resources of the Sonoma Creek watershed and communicating that understanding to local citizens and other concerned parties (SEC, 2000).

Warmer water temperatures during the summer months may cause juvenile steelhead to seek refuge habitat in cooler waters such as deep, well-shaded pools. Data collected in1996 and 1997 by the SEC concluded that summer water temperatures, as preferentially measured in well-shaded pools, are not limiting steelhead production, although conditions were found not to be optimal (Katzel, 1997). The 1996-1997 study however, did not collect temperature data during the earlier part of the summer (June and early July) and did not cover all significant fish-bearing tributaries in the watershed. It was therefore recommended that additional temperature monitoring be conducted to expand the period during the summer when data was collected and assess additional stream reaches.

This Thermal Monitoring Program was conducted to assess the likelihood that summer water temperatures are limiting the steelhead population. The Thermal Monitoring Program was conducted by SVWS staff with the assistance of TAC members and volunteers. The specific objectives of the program were to:

(1) collect baseline summer water temperature data for Sonoma Creek and its tributaries;
(2) identify where summer water temperatures may be suitable for steelhead rearing;
(3) determine if water temperatures are limiting the steelhead fishery, and if so, where;
(4) in locations where water temperatures may be limiting, determine what the underlying causes may be (e.g., lack of surface flow, loss of riparian habitat, shallow pool depths, etc.), and recommend enhancement or restoration measures.

Methods

Twelve thermal monitoring sites in mainstem Sonoma Creek and several tributaries were chosen based on their potential to provide juvenile steelhead rearing habitat and on accessibility to the site (Figure 1). Table 1 describes the monitoring locations. The thermal monitors were installed in well-shaded 1½ to 4 ft deep pools where cooler water temperatures provide thermal refuge for juvenile steelhead. These sites represent the best habitat available in upper mainstem Sonoma Creek and tributaries arising from both sides of the watershed..

All sites on mainstem Sonoma Creek are upstream of Madrone Road, since rearing conditions downstream of this location were believed to be unsuitable for steelhead. However, since this study was conducted, other research has identified steelhead in the lower reaches of Sonoma Creek, near the city of Sonoma (Adams, 1998). In addition, Chinook salmon were observed and photographed while spawning in the lower reaches during the fall of 1998 (R. Dale, pers. comm.). Four monitors were placed in the upstream portion of mainstem Sonoma Creek. Five tributaries in the upper watershed in which steelhead had recently been observed were also selected for temperature evaluation: Graham Creek, Asbury Creek and Carriger Creek on the west side and Stuart Creek and Calabazas Creek on the east side. Nathanson Creek, which runs from the eastern hills through downtown Sonoma and joins Sonoma Creek in the slough area south of Sonoma near San Pablo Bay, was also selected for monitoring.

Table 1. Thermal monitoring locations.

Name	Location	Notes
Asbury1	Downstream of Jack London's Wolf House, on the Smith property	Dense shade, redwood grove area, medium depth pool
Calabazas1	Off Nunn's Canyon Road near Beltane Ranch quarry, in pool by pump house	Full shade, undercut bank in deep pool
Calabazas2	In shallow pool on upstream edge of Dunbar Road culvert	Mostly sunny, no flow by end of summer, rocky / sandy shallow pool
Carriger1	In deep pool under footbridge at Goode property on Grove Street	Partly sunny, very deep boulder-lined pool
Graham1	Approximately 0.2 miles upstream of confluence with Sonoma Creek, off Sonoma Mountain Road	Full shade, shallow pool in step-pool portion of stream
Nathanson1	At upper fenceline on Haywood property	Medium depth boulder-lined pool, dense shade
Nathanson2	At Sonoma Valley High School, near downstream edge of school grounds	Mostly sunny, sluggish flow, murky water, deep section
Sonoma1	Sonoma Creek at Sugarloaf State Park just upstream of park boundary	Shady pool, sandy bottom, medium depth
Sonoma2	Sonoma Creek in Kenwood at 986 Warm Springs Road	Undercut bank, shaded pool, medium depth
Sonoma3	Sonoma Creek in Glen Ellen, 100 yards upstream of Morgan property	Light shade, steep bank, medium depth pool with sandy bottom
Sonoma4	Sonoma Creek 100 yards downstream of Arnold Drive bridge at north end of Sonoma Developmental Center	Partial shade, large boulders in sand / gravel bottomed pool
Stuart1	At Bouverie Audobon Preserve, in large pool downstream from the Dottie's Path steps	Shaded, deep pool with large boulders

Six sites monitored in 1996 and 1997 were also selected for this study, to build a longer-term, integrated temperature record. This continuity provides a basis for comparison of annual variations in water temperatures at the same site over time. The sites monitored in 1996-1997 and in 1998 for this assessment include Sonoma Creek near Kenwood (Sonoma2), Sonoma Creek in Glen Ellen

(Sonoma3), Sonoma Creek at the Developmental Center (Sonoma4), Graham Creek (Graham1), Calabazas Creek near Beltane Ranch (Calabazas1), and Asbury Creek (Asbury1).

HOBO® Temp data loggers (Onset Corp.) in submersible cases were used for recording temperatures. The HOBO® Temp is a single channel temperature data logger capable of measuring and storing temperature data up to 1800 times at a set interval over a set period. When downloaded to a computer, the stored information can be exported to a spreadsheet program for compilation and analysis. Each HOBO® Temp is reusable and runs on a replaceable 1-year battery. The submersible case is a rugged, waterproof, polycarbonate screwtop enclosure that provides watertight protection for the HOBO® Temp down to 400 feet.

For this study, temperature readings were set to be taken automatically by the data loggers 12 to 18 times per day for the duration of the sampling period. The easily accessible loggers were retrieved, downloaded and replaced halfway through the program to store the data in case the loggers were lost or damaged later during the sampling period. All data loggers were retrieved and downloaded at the end of the sampling period, and the data was reduced and analyzed using Microsoft Excel.

The data loggers were deployed in late June and continuously recorded water temperature until October. These are the low-flow months when water temperatures are highest. Monitors were placed into the deepest or best-shaded portion of a pool (as feasible). The temperature and depth of the water above the monitor were recorded at the time of installation. Each monitor was attached to a brick weight to maintain its position, and care was taken to assure it was not readily visible to the public. The monitoring locations were documented by photos, maps, and descriptions in a field notebook, with flagging onsite to mark the location. At least two people were present for the installation of each monitor, for safety purposes.

Monitors were installed at some sites later than others, so not all sites show data for the month of June. The Carriger1 monitor was not working when retrieved mid-way through the monitoring period. The battery was replaced and the monitor reinstalled in early September.

Results

Monthly average temperatures and diurnal temperature ranges are presented in Table 2. The monthly averages of daily maximum and minimum temperatures at each site are plotted for June through September in Figures 2 and 3. Plots of average monthly temperature and average monthly diurnal range are shown in Figures 4 and 5. Typical plots of raw temperatures are shown from one of the cooler (Sonoma3, Figure 6) and warmer (Sonoma1, Figure 7) sites.

The highest average maximum temperature was about 72 °F recorded at Sonoma2 and Sonoma3 in July and August. For all other sites, the average maximum temperatures were below 66 °F. The highest instantaneous daily maximum temperature recorded at any site was about 77°F, at Sonoma4 (see Appendix A). Average minimum stream temperatures were typically below 61°F in July and August, although Nathanson2 and the two downstream-most Sonoma Creek sites were usually between 64 °F and 66 °F (see Figure 2).

Table 2: Average monthly temperatures and monthly average diurnal ranges for all thermal monitoring locations (all temperatures in °F).

	June		July		August		September		October	
Location	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**
Asbury1	-	-	59.9	3.2	61.0	3.6	59.7	2.7	55.2	2.4
Calabazas1	58.6	4.8	61.9	4.7	62.4	4.4	60.6	3.1	54.0	3.1
Calabazas2	62.2	6.3	62.8	3.2	62.5	2.1	62.4	2.0	54.9	2.0
Carriger1	-	-	-	-	-	-	62.2	3.4	55.6	2.9
Graham1	-	-	61.5	5.2	62.2	5.2	60.2	3.4	54.3	3.4
Nathanson1	58.4	3.7	60.2	2.4	60.9	1.4	60.0	0.8	54.3	1.3
Nathanson2	-	-	65.4	5.4	64.7	1.9	62.5	1.2	56.3	1.6
Sonoma1	57.5	4.6	60.8	5.3	61.9	5.3	60.0	3.6	54.2	3.0
Sonoma2	61.5	4.1	63.7	4.4	63.7	4.8	61.4	3.0	56.1	2.9
Sonoma3	63.1	7.0	67.0	7.5	66.8	5.5	63.4	2.9	55.7	3.6
Sonoma4	-	-	69.2	6.4	69.0	7.4	65.6	4.9	57.0	3.8
Stuart1	-	-	62.8	4.5	62.4	2.6	60.9	1.3	55.5	1.6

At all locations, average water temperatures were highest in the months of July and August. By late September, water temperatures at all sites exhibited a cooling trend which continued through October. Average water temperatures were consistently coolest on Asbury Creek (Asbury1), upper Sonoma Creek (Sonoma1) and upper Nathanson Creek (Nathanson1). Temperatures were consistently warmest at the two downstream-most sites on Sonoma Creek. The average temperature difference between the warmest site (Sonoma 4) and the coolest site (Asbury1) was 9 °F in July and 8 °F in August. Carriger Creek cannot be accurately compared with the other sites due to the lack of data in June, July, and August, but in September it was one of the warmest sites.

Other tributary streams had average monthly temperatures intermediate between the warmer downstream sites on Sonoma Creek and the relatively cooler Asbury, Sonoma, and Nathanson Creek sites. Excluding the warmest and coolest sites, the greatest average monthly temperature differences were typically 4-5 °F between monitoring locations. All tributaries had cooler temperatures than nearby reaches of mainstem Sonoma Creek.

Water temperatures on mainstem Sonoma Creek show a warming trend in the downstream direction with the highest temperatures measured the Sonoma Developmental Center (Sonoma4). There was an 8 °F difference in average July temperatures between Sugarloaf Ridge State Park (Sonoma1) and the Sonoma Developmental Center monitoring sites, a distance of approximately 7.5 miles. August and September had smaller average temperature differences between the upstream and downstream monitoring sites. This warming trend was weakly evident during the 1997 temperature monitoring. Nathanson Creek also shows a consistent warming trend between the upstream and downstream monitoring locations, with an average 5 °F temperature difference in July. Calabazas Creek also showed an increase in temperature in the downstream direction, although this increase was smaller than Nathanson Creek or Sonoma Creek.

The monthly average diurnal range did not follow a clear pattern at all sites. Sonoma3 and Sonoma4 had the largest diurnal range, about 6-7 °F in July. All other sites had smaller diurnal ranges, typically 2-5 °F. The smallest average monthly diurnal range was about 1-2 °F, at Nathanson1. The average monthly diurnal range was not necessarily well-correlated with average monthly temperatures. For example, in July Nathanson2 had an average temperature of 65.4 °F and Sonoma1 had an average temperature of 60.8 °F, but the diurnal range was almost identical for both, about 5.3 °F.

Discussion

Overall, summer water temperatures are probably suitable for rearing steelhead at all locations which were monitored in 1998. Preferred temperatures for juvenile steelhead range between 55?F and 61?F (Rich, 1987). Different optimal temperature ranges have been indicated by other researchers and agencies. For example, Department of Fish & Game (Flosi and Reynolds, 1994), indicate a preferred temperature range of 45-58?F for juvenile steelhead. The critical thermal maximum (CTM), the temperature at which a fish loses equilibrium and dies, is 84.9?F for steelhead (Lee and Rinne, 1980). Although many locations have average temperatures above the optimal range, water temperatures never approached the CTM. An electrofishing survey in the fall of 1995 (SSCRCD, 1996) revealed juvenile steelhead were present in Sonoma Creek in downtown Glen Ellen, not far upstream of the Sonoma4 monitoring location which had the warmest temperatures measured in 1998 and in 1996-1997 (Katzel, 1997). The data shows that juvenile steelhead have been able to occupy this warmest monitored reach of Sonoma Creek.

Most of the monitored sites are within the preferred temperature range of 55-61?F during the months of June, September, and October when considering the average temperature. Most sites are either just within or a few degrees above this preferred range in July and August. Using the average maximum temperature values, most sites are about 2 to 5 ?F above the preferred temperature range, except again for the downstream-most Sonoma Creek sites and the lower Nathanson Creek site which are about 8-10?F above the preferred range.

In-stream water temperatures may have indirect effects on the steelhead population. Warmer than optimal water temperatures and large diurnal temperature fluctuations require more abundant food resources for fish survival because of the resultant increase in their metabolic rate (Bret, 1971; Fausch, 1984). Increased metabolism also leads to a slower growth rate in salmonids, even when water temperatures are raised just a few degrees above ambient temperatures (Hughes et al, 1987). If the fish grow more slowly, they may not be able to survive as well later in life when size can be an important factor in competing for food and other resources. Additionally, warmer temperatures result in decreased numbers and a lower diversity of aquatic insects (Hughes et al, 1987).

Many factors can influence temperatures and diurnal ranges at a given site, including the relative contributions of groundwater and surface water, pool depth, condition and extent of riparian canopy, color and size of bed materials, aspect, elevation, topographic position (e.g., streams in narrow valleys receive less sunlight than streams in wide, open valleys) and water quantity. The more moderated the diurnal temperature range, the less metabolic energy is required to support the fishery. Relatively small temperature differences between sites may be more a function of micro-habitat conditions existing at the monitoring installation site rather than a trend in temperature conditions which are truly representative of differences between stream reaches. For example, the Carriger1 monitor was placed in a pool that is very deep, but both the pool and the shallow upstream portion of the stream receive high solar input.

The downstream warming trend seen in Sonoma Creek and Nathanson Creek is reasonable, given that the creeks flow in wider channels in the downstream reaches. Wider channels may have greater solar input due to less canopy cover, and therefore have relatively warmer water temperatures. For this reason, it is also reasonable that tributaries have cooler temperatures than mainstem Sonoma Creek where it reaches the valley floor and widens. On Nathanson Creek, the lower monitoring site (Nathanson2) is in an urban reach with sparse canopy and low discharge.

Overall differences between the natural states of different streams could also account for temperature variations, such as those between Nathanson1 and Stuart1. Both locations are fed by stream reaches in undisturbed areas of the upper watershed. In July and August, Stuart1 was several degrees warmer and had a larger diurnal range than Nathanson1. The differences could be due to higher groundwater contribution to the flow in Nathanson, or the Stuart Creek watershed could be naturally less wooded with lighter canopy over the stream, or Nathanson may have more water flowing down it in the summer, or any combination of these and other factors. There are so many different factors influencing water temperatures that the criteria for optimal rearing temperatures should not be considered as absolute values that must fall exactly into a range. Each stream environment is unique, with its own character, allowing for some natural variation.

Groundwater may have a major influence on stream temperatures during low flow periods. Calabazas2 and Stuart1 have similar temperatures and ranges from July to September, but Stuart1 is located in a deep, shaded pool in an undisturbed watershed, while Calabazas2 is in a shallower, sunny, almost stagnant pool where the creek does not flow during the later half of the summer. Calabazas2 had relatively high temperatures in June, with the average daily maximum of 66?F and a diurnal range of 6.3?F, but temperatures became slightly cooler and the diurnal range decreased as summer went on. The temperatures at Calabazas2 most likely became cooler due to the increased influence of groundwater contributions to streamflow.

In general, summer stream temperatures in the Sonoma Valley appear to be adequate, although not ideal, for juvenile steelhead. Due to higher than optimal temperatures in the warmer areas on the valley floor, habitat may be limited to the deepest pools and shaded areas of mainstem Sonoma Creek. The tributary streams had average temperatures that were only a few degrees higher than the preferred range, and no location had temperatures near the CTM. It is not likely that summer water temperature is a critical factor limiting the steelhead population here.

Recommendations for Future Monitoring and Restoration Activities

Since temperature does not appear to be a crucial limiting factor for steelhead in the Sonoma Creek watershed, restoration to improve temperatures is not likely to have a significant effect on the steelhead population. However, opportunities which may arise for re-vegetating or improving the riparian corridor should always be considered, since reducing water temperatures could improve habitat conditions. Opportunities to increase streamflows in the summer months should also be considered, especially considering the trend toward increasing groundwater withdrawals in the watershed. Well locations should be planned carefully, since groundwater withdrawals can influence surface flows.

Future monitoring efforts should focus on other possible limiting factors for steelhead. If food (benthic macroinvertebrate) availability were found to be a limiting factor, improvements in water temperatures might help to increase the available food supply. Habitat quality and availability should also be investigated as possible limiting factors.

It is important to continue the thermal monitoring program for at least several years to establish comprehensive baseline data and to see how temperatures may vary from year to year over the typical range of summer streamflow conditions (drought years, wet years, average years). In addition to placing some monitors in the same locations for continuity, new locations could be chosen to try to determine the downstream extent of suitable rearing habitat. If downstream temperatures are unsuitable, restoration efforts may improve habitat. Similarly, many tributaries that have not yet been monitored may provide opportunities for restoration or for conservation of existing conditions to protect steelhead habitat. Other tributaries should be selected for monitoring to determine the full range of temperature conditions throughout the watershed.

As land uses intensify in the Sonoma Valley, it becomes increasingly important to have baseline data indicating the normal range of temperatures in a stream. Extraction of surface water and groundwater influences not only water quantity but also temperatures. A continued thermal monitoring program can help to track the effects of these changes on temperature which may adversely affect the fishery.

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Data and map are all on Nathanson/sec/Limiting Factors. Bold type below are comments that were never resolved.

{brief description of 1997 deployment}

The downstream warming trend seen in Sonoma Creek and Nathanson Creek is reasonable, given that the creeks flow in wider channels in the downstream reaches. ***{I know that Sonoma Creek widens between Sugar Loaf and Glen Ellen, is this true for Nathanson Creek – its not very wide at the High School}*** Wider channels may have greater solar input due to less canopy cover, ***{I've never seen any study relating flow velocities and water temperature. Maybe you mean volume of flow, if there is in fact less total discharge in these downstream reaches which I don't think is true for either stream}*** and therefore have relatively warmer water temperatures. For this reason, it is also reasonable that tributaries have cooler temperatures than mainstem Sonoma Creek where it reaches the valley floor and widens. ***{***On Nathanson Creek, the lower monitoring site is in an urban reach with sparse canopy and low discharge.}

Groundwater may have a major influence on stream temperatures during low flow periods. Calabazas2 and Stuart1 have similar temperatures and ranges from July to September, but Stuart1 is located in a deep, shaded pool in an undisturbed watershed, while Calabazas2 is in a shallower, sunny, almost stagnant pool where the creek does not flow during the later half of the summer. Calabazas2 had relatively high temperatures in June, with the average daily maximum of 66?F and a diurnal range of 6.3?F, but temperatures became slightly cooler and the diurnal range decreased as summer went on. The temperatures at Calabazas2 most likely became cooler due to the increased influence of groundwater contributions to streamflow. ***{Could it be that there is another issue -- pumping from Calabzas in June accounting for increased temperatures? The raw data might help with this. sez MK. but temps were lower, not higher!}***

It is important to continue the thermal monitoring program for at least several years to establish comprehensive baseline data and to see how temperatures may vary from year to year over the typical range of summer streamflow conditions (drought years, wet years, average years). In addition to placing some monitors in the same locations for continuity, new locations could be chosen to try to determine the downstream extent of suitable rearing habitat. If downstream temperatures are unsuitable, restoration efforts may improve habitat. Similarly, many tributaries that have not yet been monitored may provide opportunities for restoration or for conservation of existing conditions to protect steelhead habitat. Other tributaries should be selected for monitoring to determine the full range of temperature conditions throughout the watershed. ***{I would also make more specific suggestions here about which streams should be added to the monitoring program – RD?}***. ***{we now have data from 1996 to 1998 and will be getting some temp data for 1999 – think about how many years are necessary to establish a "baseline". Do you think there will be any changes in the results and conclusions if we monitor another year? I believe we have a very good baseline already for the upper watershed and should consider placing greater emphasis in other areas. Consider reducing the frequency of sampling in the upper watershed – say every other year or maybe once every 2-5 yrs. Initiate monitoring in a few places, this could be starting next year or skip a yr. on an every other yr basis,where we have no or little data – what about the lower watershed where we had Chinook spawning in the fall? There are standards for spawning temps. Also, remember the paper Adams***

did (the high-schooler) identifying SH near downtown Sonoma. What about Carriger Creek since we did not get out there in the beginning of the summer. What do you think?)