Evaluation of water quality monitoring on urban streams in Fortuna, California from 1997-2003

Submitted to:

Mr. Mike Sandler
Community Clean Water Institute

Prepared by:

Jennifer L. Cole
Humboldt State University

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PURPOSE

To analyze water quality data collected by the Fortuna Creeks Project, provide background on water quality issues in the Fortuna area, briefly summarize other water quality monitoring efforts in the Fortuna area, provide suggestions to enhance quality control and assurance of future data collection, and present additional water quality monitoring procedures that could be adopted by the Fortuna Creeks Project.

INTRODUCTION

The Fortuna Creeks Project (FCP) began in 1989 at Fortuna High School as a high school club. Pam Halstead, a chemistry and biology teacher, and her class started the FCP during a brainstorming session about ways they could improve the water quality of local creeks. Some of the main objectives of the FCP were to improve educational programs and increase students' awareness about their local watersheds. Students are given the opportunity to work with community members to address urban water quality problems.

Currently, the FCP is working to restore many of the local creek habitats through planting and maintaining riparian vegetation, building in-stream structures for fish, cleaning up trash, and by installing nesting boxes for birds that nest along stream sides. Additionally, the FCP has and will in the future take advantage of local habitat improvement groups located in the Fortuna area. Specifically, FCP would like to become more involved with California Conservation Corps, Americorps Watershed Stewardship Project, and other local organizations that would like to partner with FCP in improving fish passage and habitat quality in local streams.

Fortuna Creeks Project is supported by a number of sources including the California Department of Education, California Department of Water Resources, Anheuser Busch Corporation, and the Community Clean Water Institute. The Community Clean Water Institute will use the results from this report to inform the public in Fortuna on the status of their watershed and to identify problems and prevent future degradation.

This report focused on physical water quality monitoring efforts collected by FCP. The FCP is the first and only group to my knowledge, to provide water quality baseline data for any creeks in the Fortuna area. Since 1997, FCP has been collecting water quality data in Fortuna, California on Mill, Strongs, and Rohner creeks. After the FCP partnered with the Community Clean Water Institute the FCP began to sample two Eel River sites in April 2002. Because the amount of monitoring in the Fortuna area is very limited to date, the FCP's continued efforts are critical for determining water quality and ensuring that native habitats are able to support both riparian and aquatic species.

Based on Oregon's Water Quality Monitoring Guidebook, Oregon plan for salmon and watersheds (Anonymous 1999), there are three levels of data quality. The levels of data quality are categorized based on data collection procedures, methods, and level of training. The level of data quality assigned to a set of data will determine what the data should be used for. Additionally, how data are going to be used can also determine how data should be collected and at what level of data quality. Level A is the highest data quality and could be used for regulatory and permitting purposes because of the intense training and scientifically approved testing procedures used in this data collection. Level B data quality is characterized as less expensive and easier to conduct than level A. Level B data quality could be used to identify potential problems before they become hazardous to a system, as screening procedures, and to signal warnings. Level C is the easiest to conduct, does not involve any quality assurance and control measures, and it is generally used for educational purposes.

Based on the descriptions of each level of data quality, data used in this report are level B. The FCP incorporated a significant amount of training on collection and testing procedures for each water quality parameter and employed quality assurance and control. Some United States Environmental Protection Agency (EPA) approved methods were used for testing water quality parameters and sophisticated equipment was used during sample analysis. The six years of data collected by the FCP can be useful to local managers in the Fortuna area if their goal is to protect aquatic habitat. These data can provide managers with useful information on water quality in Mill, Strongs, and Rohner creeks. Therefore, results from FCP monitoring can help them in identifying areas where better management practices need to be installed, how activities within the watersheds are affecting quality of aquatic habitats, critical areas for habitat improvement and restoration, and any necessary guidelines for urban development.

WATER QUALITY HISTORY

There are several other groups participating in water quality monitoring in the Fortuna area and these include Pacific Lumber Company, Fortuna Wastewater Treatment Plant, and Fortuna's office of California Department of Fish and Game. Pacific lumber company currently has a monitoring station on Strongs Creek just above the North fork. They are monitoring sediment and temperature changes over time on an annual basis from June to the end of October. Each station is visited about five times over the monitoring period. Habitat assessments, pebble counts and bulk sediments are a few of the parameters that Pacific Lumber is measuring at their station (Oliver 2003).

In 2002 and 2003 the Fortuna Wastewater Treatment Plant conducted a Priority Pollutant analysis in which approximately 124 tests were performed (James 2003). Dioxin testing still needs to be completed. The two sites sampled for the Priority Pollutant analysis were on the Eel River upstream of where Strongs Creek enters the Eel River and the same tests were ran on effluent from the treatment plant. The wastewater treatment facility is a concern to water quality in the Fortuna area because of flooding by the Eel River during high winter flows. When the Eel River reaches its full capacity it inundates the percolation ponds of the Fortuna Wastewater Treatment Plant. In order to remediate the effects on water quality caused by filling of the percolation ponds, managers at the treatment facility have attempted to forecast large rain events in order to stop discharging to percolation ponds before saturation occurs. Treated wastewater is discharged into Strongs Creek instead of percolation ponds during saturation events. Operating costs increase because the appropriate pH level discharge is costly. Regulations set by the California Regional Water Quality Control Board also requires the Fortuna Wastewater Treatment Plant to discharge into Strongs Creek from September 15th through May 15th. The remainder of the year they are required to discharge into the percolation ponds. Currently, upgrades to the facility are occurring to eliminate odors produced by wastewater treatment (Gehrky 2003).

SITE DESCRIPTIONS

Site Locations (Appendix A): A 1 is used to designate upstream sampling sites and a 2 designates downstream sampling sites. The confluence site is designated by RSM, Rohner, Strongs, and Mill, respectively, where all creeks converge into Strongs Creek. Refer to Table 1 for the geographic coordinates of each of the monitoring sites.

E1: before mouth of Strongs Creek (@50 (feet))

E2: after mouth of Strongs Creek (@50 (feet))

S1: below the intersection of Rohnerville Road and North Loop Road

S2: underneath River Walk Drive bridge, just off of Highway 101

R1: at the dead end on Carson Woods road

R2: next to Dinsmore Drive, at the sewage treatment plant

M1: on Mountain View Road approximately 75 (feet) up the road

M2: corner of Kenmar Road and Ross Hill road

Table 1: Geographic coordinates of monitoring sites

Site #	Creek	Geographic Coordinates
S1	Strongs	W: 124 8' 3.48" N: 40 35' 22.5"
S2	Strongs	W: 124 9' 16.14" N: 40 35' 7.14"
M1	Mill	W: 124 7' 16.79" N: 40 34' 8.72"
M2	Mill	W: 124 8' 45.28" N: 40 34' 37.78"
R1	Rohner	W: 124 8' 46.09" N: 40 36' 36.14"
R2	Rohner	W: 124 9' 27.31' N: 40 35' 23.44'
RSM	Confluence	W: 124 9'29.66" N: 40 35' 21.44'
E1& E2	Eel River	W: 124 9' 42.07" N: 40 35' 22.83"

Rohner, Strongs, and Mill creeks are all class B streams. A class B stream is defined by the EPA as a stream with "water quality (that)… shall exceed requirements for all uses. Uses include water supply (industrial, agricultural), stock watering, fish and shellfish, wildlife habitat, secondary contact recreation, sport fishing, boating, and aesthetic enjoyment, commerce and navigation (Anonymous May 26, 2003a)." All of the streams have steelhead trout *(Oncorhynchus mykiss)* present and are influenced at some point by urban runoff and development. Rohner Creek is unique in that it has resident coastal cutthroat trout *(Oncorhynchus clarki clarki)* beyond a passage barrier (falls), and below the barrier, which could mean that those below the barrier are anadromous or residents (Downie 2003). The Fortuna Creeks Project also identified coho salmon in Rohner Creek. Rohner and Strongs creeks are influenced by major timber management activities occurring near the upper reaches of the creeks. Pacific Lumber owns approximately 2000 (acres) within the Strongs Creek watershed and has harvested lumber from it over the last six years. Under the Headwaters agreement Pacific Lumber does not harvest any unstable areas thereby, decreasing the potential sediment loads to Strongs Creek (Sneed 2003). Timber management activities, cows in the stream and ranches within the watershed heavily influence Strongs Creek. These activities cause erosion and sediment loads in the stream. Therefore. Strongs Creek should be closely monitored because coho salmon *(Oncorhynchus kisutch)*, chinook salmon *(Oncorhynchus tschawytscha)*, coastal cutthroat trout and steelhead trout populations are all present in Strongs Creek (Downie 2003; Halstead 2003).

Cattle are also present in and around Mill Creek. Some private timber activities occur within the watershed. Mill Creek has spawning habitat sufficient to meet salmonid spawning requirements. However, it is the smallest creek and thus has limited fish rearing capacity. Mill Creek has been identified as the southern most range for coastal cutthroat trout. Coho and chinook salmon are found less frequently in Mill Creek than in Strongs Creek. However, Coho salmon are not found in large numbers in any of the creeks (Downie 2003;Halstead 2003). Several reasons for the decline in coho salmon populations exist. In order to reverse this trend, additional water quality monitoring and habitat restoration must be enacted.

METHODS

Water samples are collected and analyzed once a month at nine different sites. Parameters measured at each site include pH, ambient and water temperature (^{o}C), dissolved oxygen (mg/L), turbidity (NTU), and conductivity (µS/cm). Pam Halstead, along with two other club advisors separate into three groups to conduct the sampling. Each group receives a toolbox with all of the necessary equipment, and protocols to follow for each of the tests performed. All of the tests are performed *in situ* except for turbidity. A FCP officer or advisor trains each student before they conduct any of the water quality tests.

Turbidity is measured using a LaMotte 2020 Turbidimeter^{TM} in nephelometric turbidity units (NTU). NTU measurements below100 NTU have an accuracy of +/- 0.05 NTU or +/- 2% depending on which one is greater. For samples above100 NTU the accuracy is +/- 3%. The turbidity sensor is calibrated each time water samples are analyzed using 0, 10, and 100 NTU calibration solutions. Turbidity analysis is performed at Fortuna High School using a 60ml Nalgene^{TM} bottle to transfer the grab sample from each site back to the classroom for analysis. Air and water temperatures are measured with a glass alcohol thermometer in degrees Celsius. The thermometer is held both in the air and under the water for 30 seconds to obtain temperature readings. The pH is measured using an OAKTON Microprocessor based pH tester with an accuracy of +/- 0.1 pH. The pH meter is calibrated at the first site using pH 7.0 and 4.0 buffer solutions. Conductivity is measured with an OAKTON Waterproof microprocessor based TDS tester with an accuracy of +/- 1%, which is calibrated with a 477µS/cm standard solution of 0.005 molarity potassium chloride before each use. Dissolved oxygen is measured using the LaMotte^{Tm} Winkler test kit, which uses a titration to measure dissolved oxygen in mg/L. The chemical procedure used in the dissolved oxygen test is EPA approved. However, a 300ml bottle is required for EPA approval of the testing procedure. The FCP uses a 60ml glass bottle for easier handling of water samples.

RESULTS

Analysis of water quality parameters for Mill, Rohner, and Strongs creeks and Eel River focused almost exclusively on water quality and habitat criteria for coho salmon.

Coho salmon have several life history characteristics that make them more vulnerable in the streams they utilize. Because they spawn closer to the sea and will not go above the floodplains, they are more susceptible to warmer temperatures experienced in these lower reaches (Downie 2003). Additionally, coho salmon fry are more susceptible to extreme conditions such as floods, drought, pollution, predation, and other hazards from densely populated areas because they remain in their spawning stream for a full year after emerging (Ball May 8, 2003). Coho salmon habitat requirements were used to ensure that the most conservative estimates of adequate water quality requirements for species using these lotic systems were being met.

Turbidity is a measure of how light is reflected by suspended particulate matter and is important to monitor because sedimentation decreases primary productivity, invertebrate biomass, fish egg survival, and availability of juvenile fish habitat (Baayens and Brewch 2002). Additionally, high concentrations of suspended sediments can pose a direct threat to invertebrates and fish when their gill structures are harmed. High suspended sediment concentrations also obstruct fish visibility when they are trying to locate food (Anonymous 2002a). California Regional Water Quality Board guidelines for turbidity state that levels are not to exceed 20% above background levels (Leland 2003). Fortuna creek's background levels to my knowledge have not been established. Therefore, criteria used to analyze turbidity levels in this study were based on the following turbidity requirements for fish habitat. Turbidity levels of 10 NTUs meet fish habitat requirements for class B streams, while chronic levels of 25 NTUs cause a decrease in growth of coho salmon and trout, and levels greater than 30 NTUs have shown to stress fish making them more prone to diseases (Anonymous May 26, 2003a;Baayens and Brewch 2002). Therefore, 30 NTUs was used for the threshold criteria during turbidity analysis.

A temperature range between 10^o and 14^o Celsius is optimal for salmonid habitat, temperatures greater than 15^o should be avoided, at18^o C for coho and 20^o C for other species fish become stressed and mortality can occur, and 24^o C is lethal. Chronic temperatures above the optimal range of 10^o to 14^oC can reduce fish survival and growth rates (Downie 2003;Anonymous 2002b).

Dissolved oxygen is analyzed in conjunction with temperature because they have an inverse relationship. Therefore, temperature affects the percentage of dissolved oxygen saturation. Determining minimum oxygen requirements for salmonids is difficult due to the different requirements for each stage in their life history. Therefore, in general optimum dissolved oxygen saturation for salmon is greater than 90% while the minimum optimum dissolved oxygen concentration is greater than 8 mg/L (Anonymous 2002a). The acute lethal limit for salmonids is less than or equal to 3.0 mg/L, which below this mortality or growth impairment is likely to occur (Stefan et. al 1992).

The pH is a measure of the concentration of hydrogen ions in a sample. Optimum pH levels for class B streams and salmonid habitats are between 6.5 and 8.5 (Anonymous May 26, 2003a; Anonymous 2002b). The pH is important to monitor because it is a strong determinant of solubility and availability of nutrients and pollutants in a water system (Lind 1984).

Conductivity requirements for coho salmon were not available due to the complex interaction of this parameter and several other water quality factors. The California Regional Water Quality Control Board has set the 50% and 90% upper limits for specific conductance at 225µS/cm to 375µS/cm, respectively to meet the Eel Rivers water quality objectives (James 2003). Measured in micro-Siemens per centimeter (µS/cm), conductivity is a measure of dissolved salt concentrations in water. Higher conductivity readings equate to higher salt concentrations.

Water quality data analyzed in this report was collected from August 1997 through April 2003. Because of inaccessible sites, dry or flooded sites, faulty equipment failures, and FCP not meeting over the summer, sampling was not consistent. To identify when each site was sampled refer to Appendix B for the raw data. Monthly averages from each year for all sites were analyzed. However, each monthly average represented a different number of data points due to inconsistent sampling. For example, samples were only collected once in June and once in August over the six year study. Therefore, monthly averages could not be calculated for these months. The pH monthly averages are given as an average of the measurements taken and not the hydrogen ion concentration average. Both Eel River sites were sampled twice in 2003. Upriver site was sampled three times and downriver site was sampled seven times in 2002. A two sample t-test assuming equal variances was used to perform statistical analyses between monthly averages of different sites. The alpha used in the analysis was 0.05.

Mill Creek

Both sites had average monthly temperatures within the optimum range for salmonid habitat for the majority of the year. The upstream site was significantly cooler than the downstream site ($p=0.020$; $\alpha=0.05$) (Figure1). The pH levels were within the optimum range of 6.5-8.5. Dissolved oxygen concentrations met the minimum optimum concentration of 8 mg/L criteria for salmonid habitat for the majority of the year. Turbidity was significantly higher in the upstream site ($p=0.049$;$\alpha=0.05$), which had monthly averages that exceeded the threshold four times during the year (Figure 2). The downstream site had average monthly turbidity below the threshold for the entire year. Conductivity was sporadic and generally low (Figure 3). Both sites had readings below the 225 µS/cm lower limit from December through September. Downstream site continued this trend into October. The upstream site was above the 375 µS/cm upper limit in October. Both sites were above the upper limit in November. Mill Creek had the highest readings for all of the sites in November 1997. The value for upstream was 1896µS/cm and downstream was 1784µS/cm.

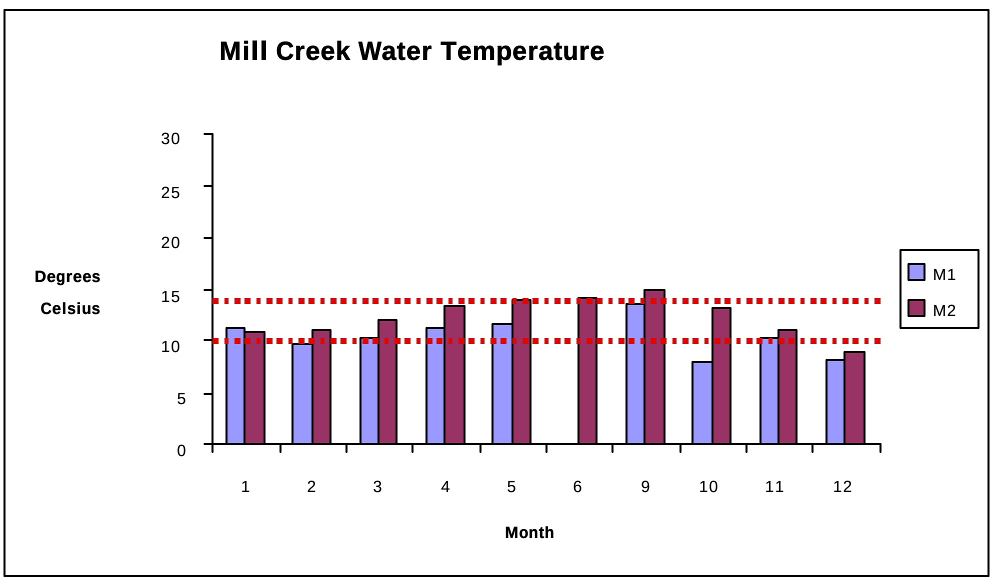

Figure 1: Monthly averages of Mill Creek water temperatures.

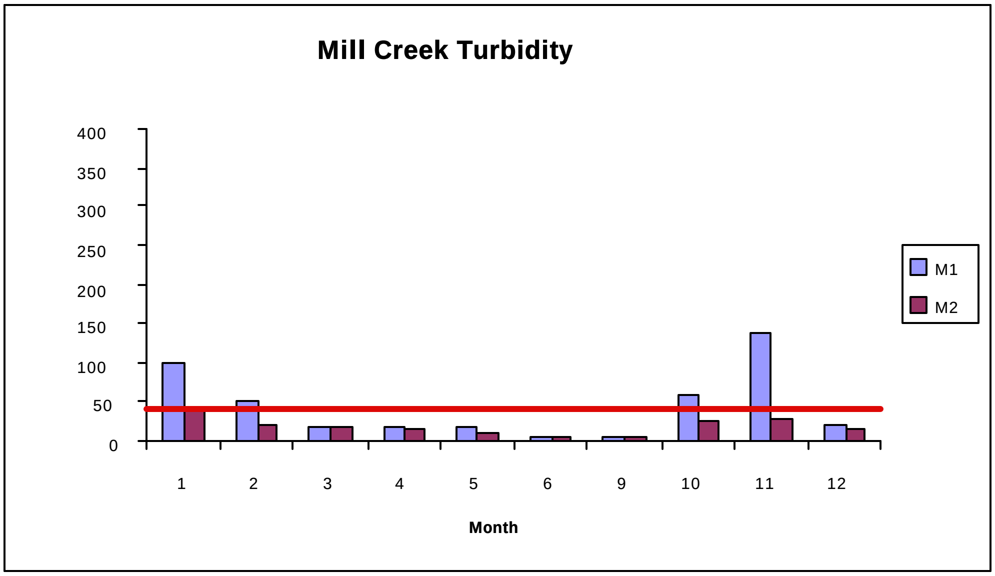

Figure 2: Monthly averages of Mill Creek turbidity measurements.

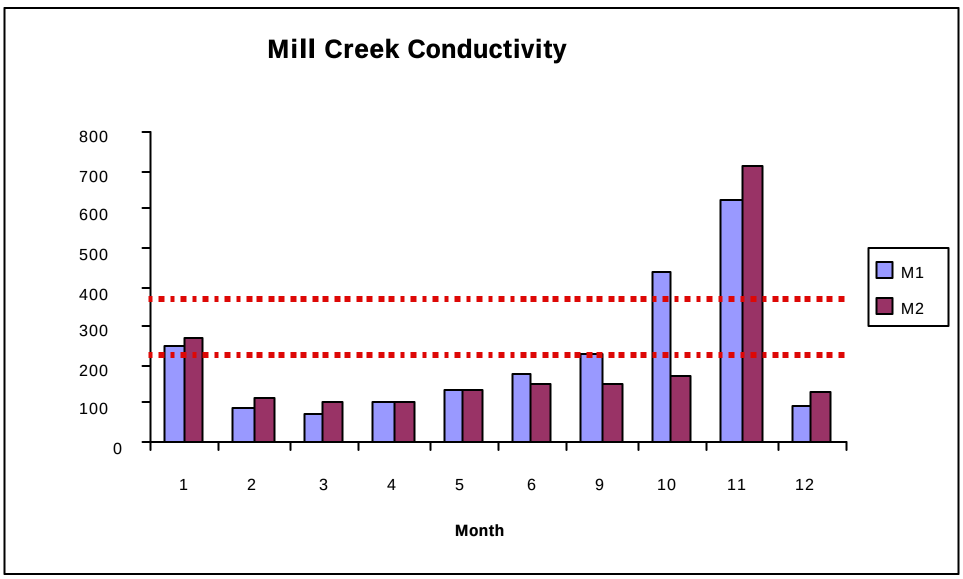

Figure 3: Monthly averages of Mill Creek conductivity readings.

Strongs Creek

Monthly averages for temperature fell within the optimum range for the majority of the year. However, they exceeded the optimum range during September at both sites, and in August at the downstream site. The pH levels were within normal range for salmonid habitat. Dissolved oxygen dropped below the minimum optimum concentration of 8 mg/L from June through September at both sites and in October at the downstream site. A drop in dissolved oxygen concentrations during the summer correlates with the rise in water temperatures during these months (Figure 4;Figure 5). Turbidity monthly averages were above the threshold for salmonid habitat for the majority of the year (Figure 6). Turbidity was below criteria level during summer months when flows were low. All flows characterized by high flows violated the threshold for salmonid habitat. Conductivity measurements taken from S1 were significantly higher than S2 ($p = 0.023$; $\alpha = 0.05$). Strongs Creek upstream site had monthly averages for conductivity above the 375µs/cm limit from May through November (Figure 7). The downstream site, S2, had monthly averages below the 225 µS/cm four times during the year.

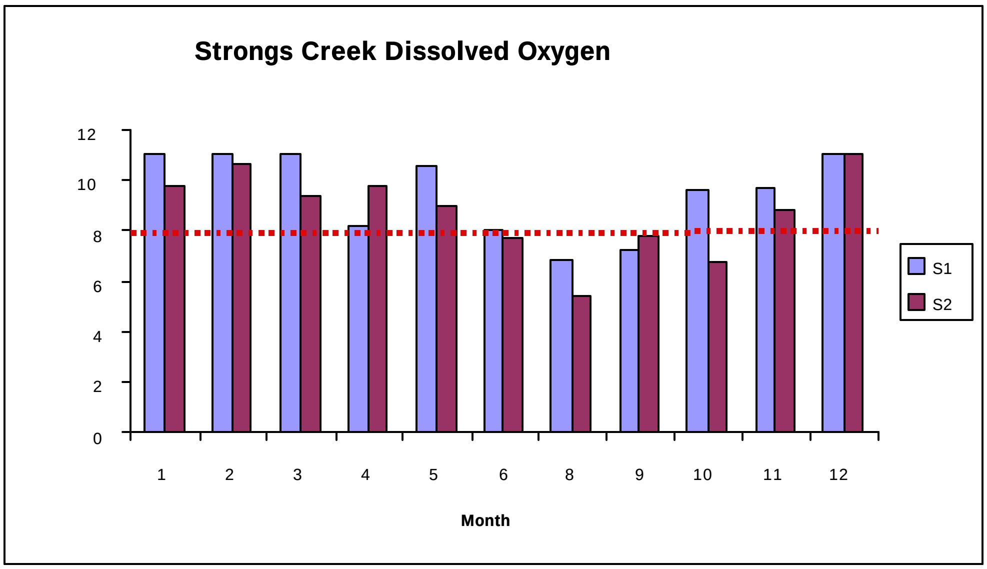

Figure 4: Monthly averages of Strongs Creek dissolved oxygen concentrations.

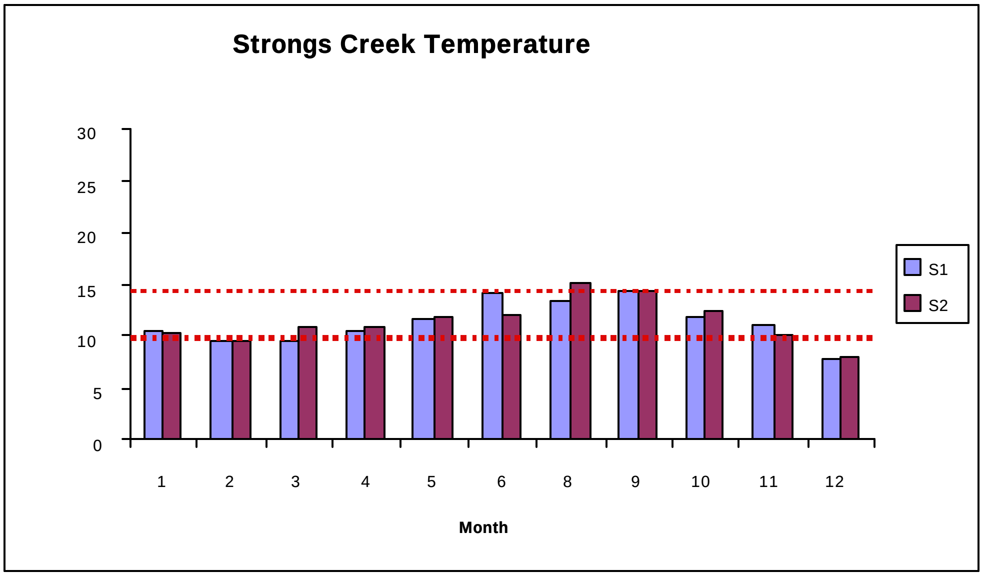

Figure 5: Monthly averages of Strongs Creek water temperatures.

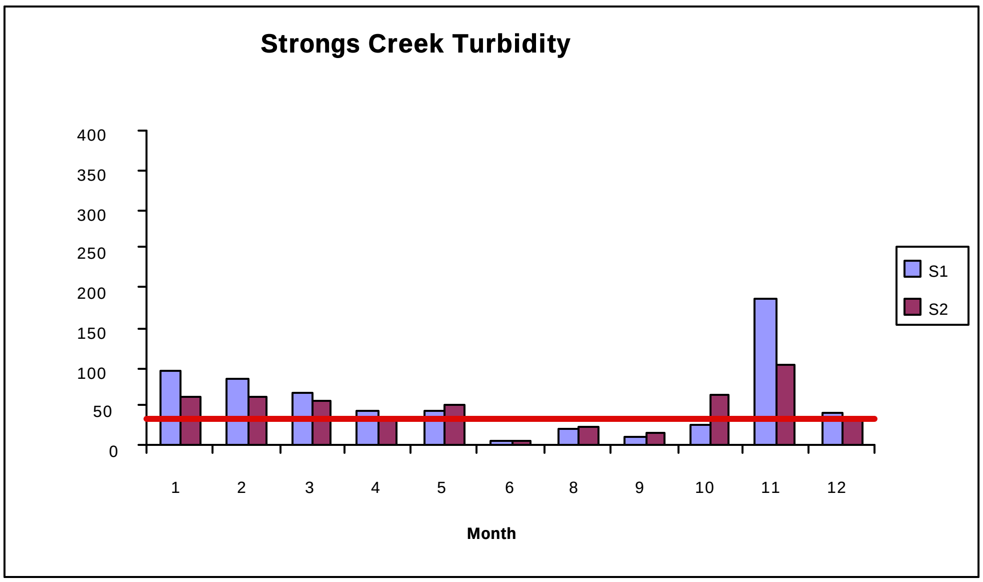

Figure 6: Monthly averages of Strongs Creek turbidity measurements.

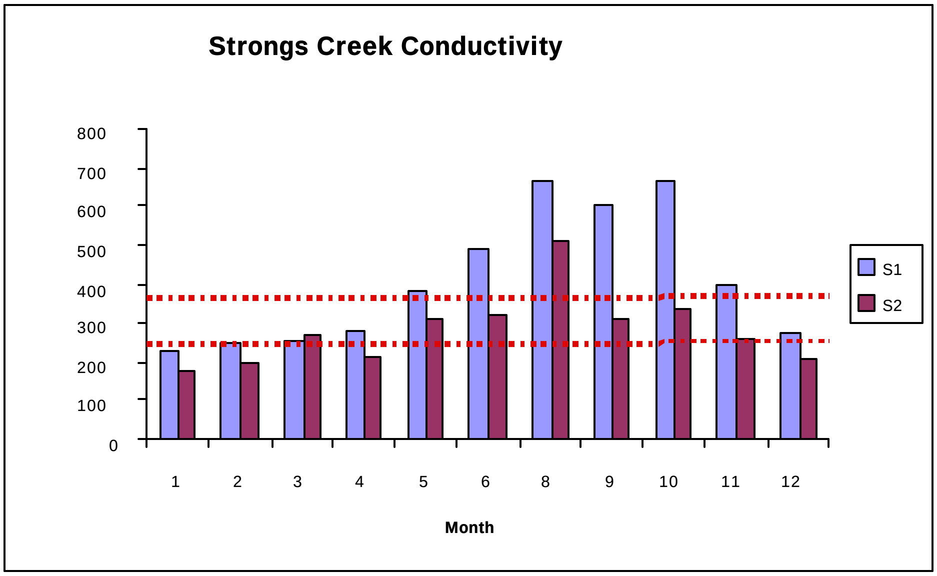

Figure 7: Monthly averages of Strongs Creek conductivity readings.

<u>Rohner Creek</u>

The highest individual temperature reading (26.25°C) occurred during the month of August at the upstream site. The downstream site was above the optimum range for salmonid habitat in September and below it in February and December (Figure 8). The upstream site was below the optimum temperature range from February through May, and in November and December. The pH levels were within the optimum range for salmonid habitat the majority of the year. However, the upstream site had a monthly average of 6.4 in March. Dissolved oxygen dropped below the minimum optimum concentration during the summer months and into October for the upstream site (Figure 9), which correlated with the increase in temperature for these months. The average turbidity level for November was the highest of all of the sites and November had the highest individual turbidity reading of 854 NTU at site R1 (Figure 10). Monthly averages for turbidity were below 30 NTUs for the downstream site during dry summer months, October and December. Upstream site did not exceed the threshold in June and September only. All of the conductivity readings taken at R1 from June to October were above the 375µS/cm upper criteria limit. Conductivity readings taken at R2 exceeded the upper criteria limit during June and August (Figure 11).

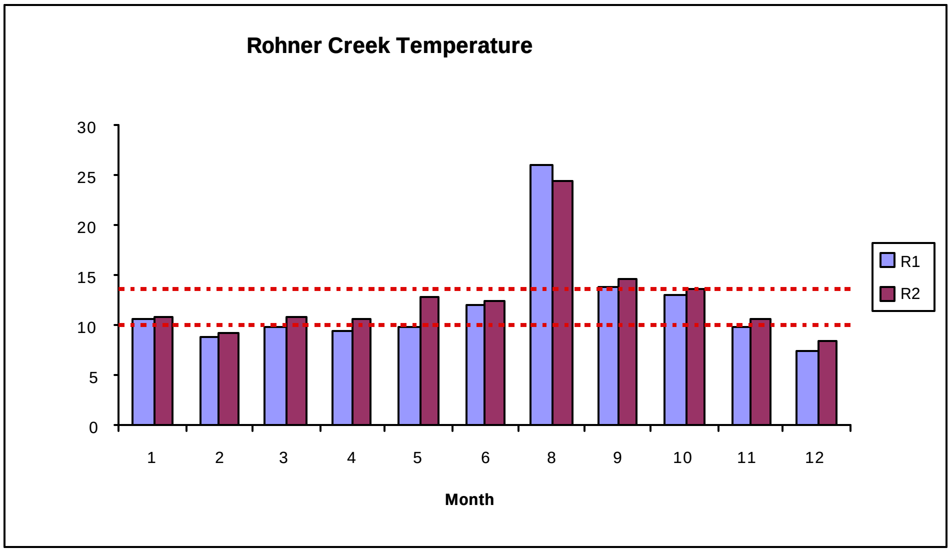

Figure 8: Monthly averages of Rohner Creek water temperatures.

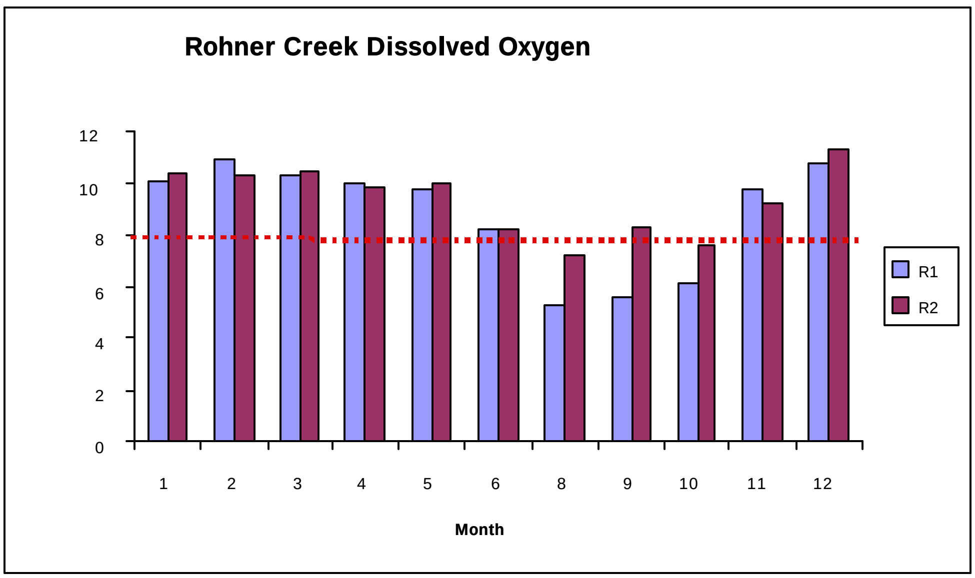

Figure 9: Monthly averages of Rohner Creek dissolved oxygen concentrations.

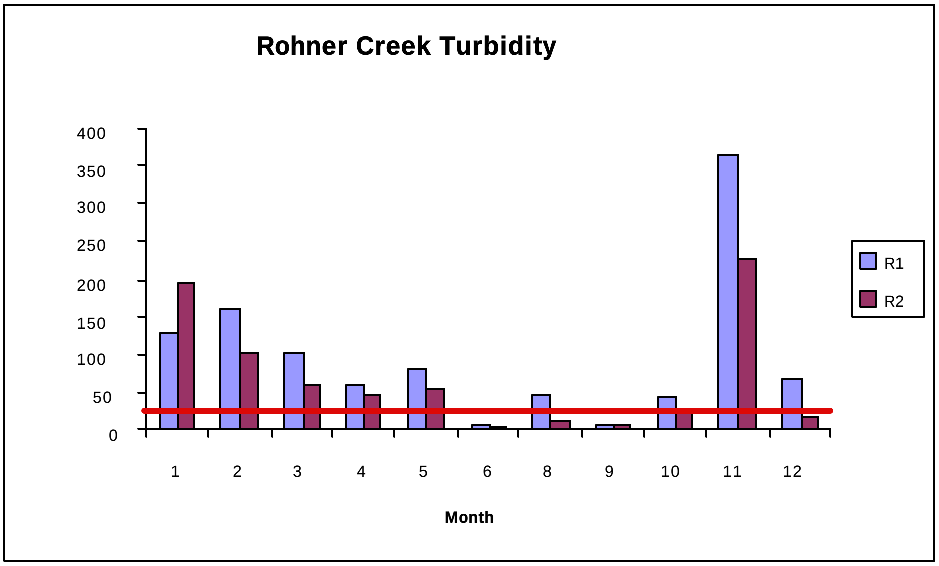

Figure 10: Monthly averages of Rohner Creek turbidity measurements.

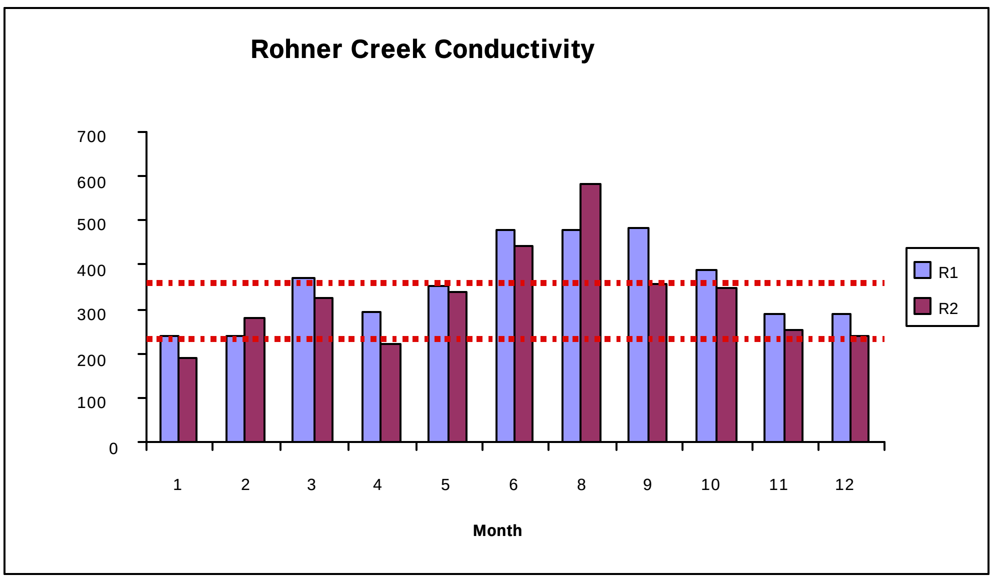

Figure 11: Monthly averages of Rohner Creek conductivity readings.

Confluence

Monthly temperature averages remained within the optimum range for salmonid habitat for the majority of the year. However, readings did drop below the optimum range in February and December and were above the optimum in September. The pH and dissolved oxygen concentration remained within the optimum ranges for salmonid habitat. Turbidity levels were below the threshold of 30 NTUs during the months of June and October only. Turbidity levels for RSM and R2, and RSM and E1 were statistically compared to assess whether there was a significant difference between turbidity levels either at RSM and R2 or at RSM and E1. There was not a significant difference in turbidity between RSM and R2. However, there was a significant difference between RSM and E1 ($p=0.026;\alpha=0.05$) (Figure 12). Turbidity levels at the confluence were significantly greater than E1.

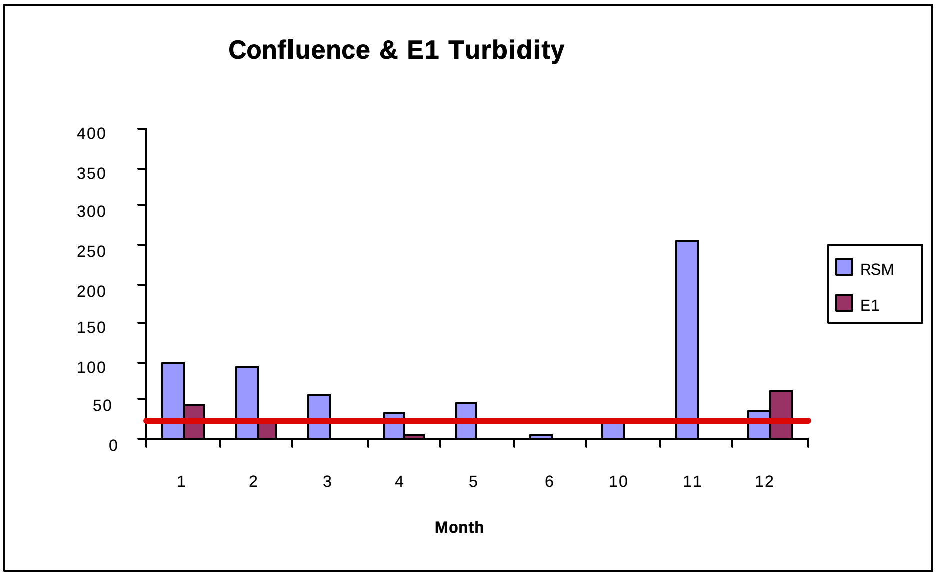

Figure 12: Comparison of Confluence site monthly averages of turbidity and Eel River upriver site turbidity measurements.

<u>Eel River</u>

Based on a limited amount of data collected, temperatures were outside the optimum range for salmonid habitat between May and October (Figure 13). In September, a temperature of 24.5^{o} C was recorded, which is considered to be the lethal level for coho salmon. Dissolved oxygen remained above the minimum optimum concentration for a majority of the months. The pH exceeded the optimum range three times in the sampling period at E1. Turbidity levels at upriver site were above the threshold in December and January. The downriver site was below the threshold twice out of four data points. Conductivity readings for Eel River sites fell below the optimum range set by the California Water Quality Control Board in their optimum water quality criteria for the Eel River guidelines (James 2003).

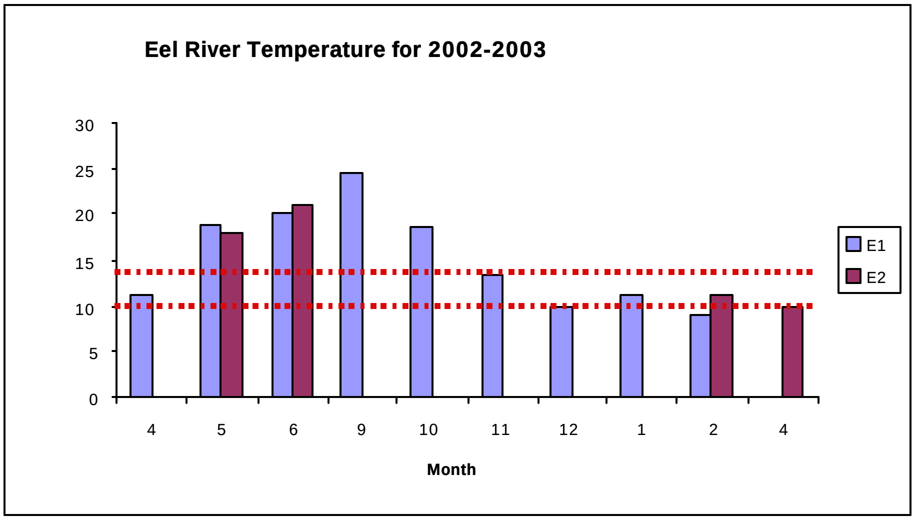

Figure 13: Eel River recorded water temperatures from 4/2002 through 4/2003.

DISCUSSION

The Mill Creek upstream site is characteristic of riparian habitat, which could cause the upstream site to be significantly cooler than the downstream site. Mill Creek had significantly lower turbidity than Rohner Creek. A more thorough analysis of the effects of cattle and major timber harvests on Fortuna watersheds should be conducted to see if these activities are causing the higher levels of turbidity found in Strongs and Rohner Creek.

High temperatures in Strongs Creek may pose a threat to salmonids spawning. Combinations of high temperatures and low dissolved oxygen concentrations have the potential to threaten fish health. An increase in temperature of the water may be a result of streambed siltation in concert with low flows. Consequently, metabolic rates are increased causing fish to be stressed and thus more prone to disease. Evidence for the effects of erosion caused by the presence of cattle and major logging operations can be seen in the turbidity results from sites on upper and lower Strongs Creek. The significant difference in conductivity levels between S1 and S2 could be explained by several theories, but both need more data to conclude either is occurring at Strongs creek. One theory could suggest that upstream had higher conductivity readings due to timber and ranching activities. These activities are causing sediment loading into the streams along with nutrients thereby, increasing conductivity. The low conductivity results from S2 could be due to the influence of substances such as oils and solvents, found in urban runoff (Lind 1984). These substances are not good electrical conductors and can decrease conductivity levels.

Rohner Creek exhibited temperatures significantly above the upper limit of the optimum temperature range of 10^{o}C to14^{o}C. The temperature reading of 26.25^{o} C from Rohner Creek is considered lethal for coho salmon. The increase in temperature coupled by a drop in dissolved oxygen during the summer months exemplifies the need for increased monitoring during these months. An increase in monitoring efforts will benefit any attempts to create an optimum fish habitat for fish returning to their home streams during summer months. Because Rohner Creek is also influenced by major logging activities it can also be assumed that activities in this watershed are causing high levels of turbidity consistently above the threshold. Rohner Creek also had significantly higher turbidity measurements than Mill Creek, which is the least impacted by timber harvesting activities. Significantly high levels of turbidity in November is also a concern in terms of fish habitat because some salmonid species will be spawning in November, and therefore there is an evident need for gravel free from fine sediments during this period to allow oxygenated water to reach eggs and embryos within the gravel.

Turbidity levels at RSM were significantly higher than E1, which could support the conclusion that activities occurring within the Fortuna watersheds are having an effect on turbidity levels in the Eel River. Studies should be conducted for a longer period of time in order to have a valid representation of measurements. At least a full years worth of sampling is needed to draw any conclusions from the water quality data collected on the Eel River, therefore no conclusions can be made at this time. Sample collection is hard to perform at E1 during high flows and E2 can go dry during part of the year. Alternative sampling sites could be considered to ensure that data collected is correctly analyzed.

CONCLUSIONS

Turbidity levels were significantly higher during the month of November for all of the sites. High turbidity exhibited in the month of November could be a result of the annual first peak flush. According to the Eureka National Weather Service office, November is generally when this first peak flush will occur in the Fortuna area (Colby 2003). The first peak flush is associated with a washing out of accumulated sediments along with other things like nutrients and bacteria into the water system. This occurrence of peak flows in November could explain why turbidity levels are consistently the highest for the month of November.

Evidence of the effects from low and high precipitation events on turbidity can be seen by comparing levels of turbidity throughout the year to monthly rainfall averages for Eureka (Figure 14 & 15) (Colby 2003).

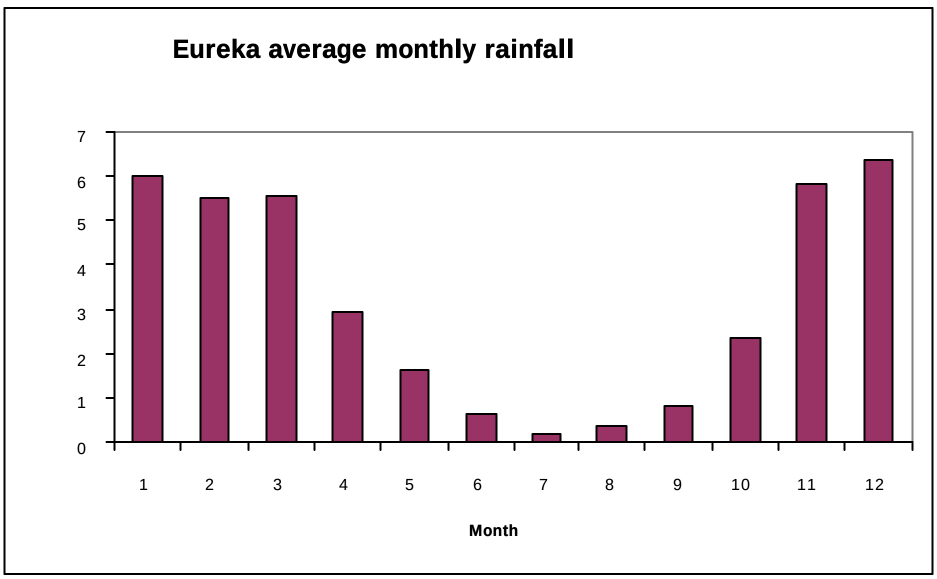

Figure 14: Average monthly rainfall in Eureka, California (Colby 2003).

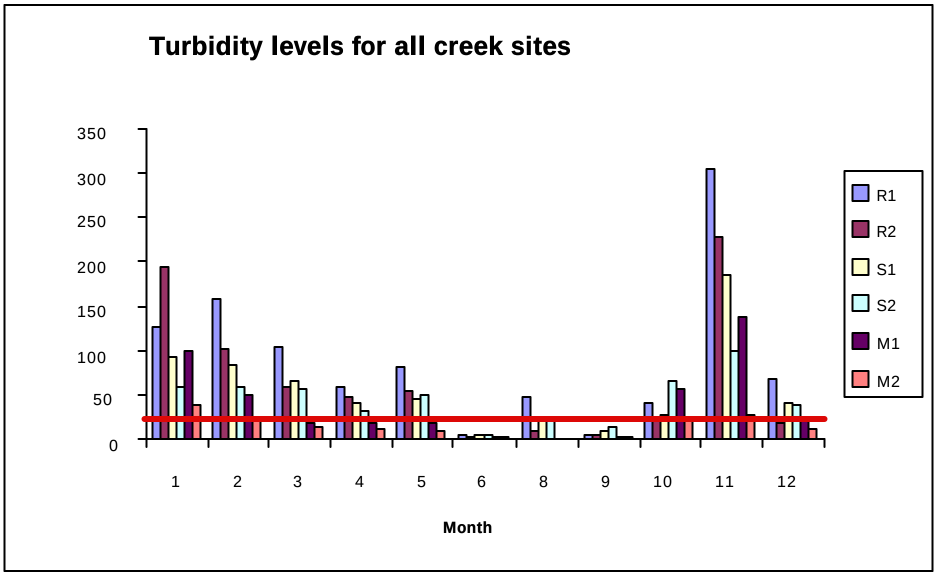

Figure 15: Monthly averages of turbidity measurements for all of the creek sites.

Temperatures appear to only be a threat to salmonids species during the summer months when they are exceeding the optimum range for salmonid habitat. Winter temperatures do not exceed the optimum range. However, winter turbidity levels are posing a problem to fish species trying to spawn in silt filled gravel beds. Fish survival at higher temperatures could be attributed to pockets of cooler water to escape. While temperatures in Fortuna rarely reach extreme highs and stay there, it is important to document the frequency and duration that these high temperatures are occurring at because of the accumulated stress factor.

The general trend for conductivity readings to be below the minimum 225µS/cm criteria limit during the wet months and above the 375µS/cm criteria limit during the warmer and dryer summer months is a predictable trend considering that as more storm water enters these streams ions will become diluted thereby, lowering conductivity and in the warmer and dryer months as water evaporates out ions will become more concentrated thereby increasing conductivity (Anonymous 2002b).

QUALITY ASSURANCE AND CONTROL

To improve the accuracy and precision of data being collected by the FCP, the following recommendations are being made for quality assurance and control.

- The pH meter should be calibrated with buffer solutions of ph 7.0 and 10.0 instead of pH 7.0 and 4.0.
- The glass alcohol thermometer used by the FCP should have a built in accuracy. It could be calibrated using ice water (0^{o} Celsius).
- A continued effort to conduct data collection during the same time of day for each sampling event is highly recommended.
- For each parameter being measured the standard deviation should be known for each month and each site. Therefore, data points can be compared to the month's mean and standard deviation during collection to identify whether the collected points are falling within two standard deviations of the mean (Appendix C).
- Duplicate measurements for a parameter should be taken. Two duplicates are sufficient if the measured values are similar. However, if they are not, a third measurement should be taken and an average of the two similar readings should be recorded.
- The downstream sites should be sampled before the upstream sites to eliminate contamination of downstream samples from disturbance created while sampling the upstream sites.
- Grab samples should be taken from at least six centimeters below the surface of the water (Standard Methods 19th Edition).
- Material Safety Data Sheets for the Winkler test should be reviewed before each student performs the test to ensure proper handling and disposal of potentially hazardous chemicals.

FUTURE WATER QUALITY MONITORING RECOMMENDATIONS

Additional tests or surveys that could be performed by the FCP if funding permitted include the following, listed in descending order of necessity.

- Scheduled sampling once a month for 12 consequent months
- Additional habitat assessment and fish surveys
- Flow/discharge measurements
- Additional aquatic macroinvertebrate surveys
- Documentation of potential sediment inputs.

Consistently sampling the streams on a regular schedule will greatly enhance the validity of data collected. Regular sampling was listed as the most important recommendation to the FCP because it is essential for valid data collection and this would allow the FCP to focus on refining the parameters they are already testing for without any additional financial obligations. The importance of including water quality analysis during the summer is emphasized because conditions are more likely to be extreme.

A habitat assessment does not have to include all of the measurable parameters, but instead could include just substrate typing using pebble counts, which is fairly simplistic and inexpensive. This would allow the FCP to draw some conclusions about how the substrate is changing over time and whether the streams are experiencing an increase in fine sediments throughout the year. Fish surveys require scientific collection permits and therefore would have to be performed after consultation with the local Fish and Game office. Additionally, they require a significant amount of training to handle and identify different juvenile fish species. Along with measuring flow and discharge at each site, gages could be installed to measure peak flows. Measuring peak flows and discharge will provide estimates of high and low flows throughout the sampling period and additional evidence of water quality in each stream. The aquatic macroinvertebrate surveys are time and labor intensive and therefore could be performed only four times a year to provide data on the macroinvertebrate populations during each season. Documenting potential sediment inputs could be done by measuring the dimensions of rills and gullies and documenting any mass wasting events in the watershed.

An additional suggestion for the FCP is to use a dissolved oxygen meter instead of the Winkler test to measure dissolved oxygen concentrations. The advantages of using a meter include elimination of generating hazardous waste, exclusion of exposure to hazardous waste, minimal maintenance cost involved, less time required to perform the test, and offsetting the low amount of precision obtained from many different high school students performing the test through out a sampling period. The meter will also provide the needed temperature data thereby eliminating the need to bring a glass thermometer into the field. However, the LaMotte™ Winkler test is more accurate than using a meter to obtain dissolved oxygen concentrations.

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