Water Quality as an influence of fish populations in Strawberry Creek, Berkeley, CA

Navraj Singh Padda

Abstract Strawberry Creek has been very important to the Berkeley campus and the Berkeley community as a whole. Strawberry Creek has two major forks, north and south, which run through the campus and the city. Fish populations in the creek began disappearing after the turn of the 20th century due to poor water conditions and poor creek management. Since 1987 many efforts have been made to introduce fish into the creek. Currently, the south fork has an abundance of fish while the north fork has been unable to maintain a fish population. This project aims to look at whether water quality is the answer to why fish are present in one fork and not the other. Form February thru mid-April, 2002 weekly samples of pH, conductivity, turbidity, chlorine, copper, phenols and detergents were taken at five sites in each of the two forks. Weekly samples were also taken at two sites past the junction of the two forks simply known as the main branch. A Tukey-Kramer honestly significant difference test was used to detect for the difference between the sites. Data collected for all parameters was shown to not be significantly different and therefore the conclusion that water quality with respect to the collected parameters is not the reason for fish presence in the south fork and the lack of fish in the north fork in Strawberry Creek.

Introduction

Strawberry Creek has had a very important role in the history of the Berkeley campus of the University of California. The current site of the campus was originally chosen because of the presence of Strawberry Creek (Willey 1887). The creek represents an irreplaceable natural resource that is highly valued by both the university and the community at large (Hsieh 2001, Charbonneau 1987). The riparian corridors along the creek provide essential places for educational, recreational, social and individual activities (Charbonneau 1987). However, by turn of the 20^{th} century, urbanization had already begun to affect the creek. Sewage and silt polluted the water (Charbonneau 1987), and the creek's course was redirected and confined by retaining walls (Charbonneau & Resh 1999). In places, the creek was diverted into culverts (Charbonneau & Resh 1999). Strawberry Creek has two major branches, the north and south forks, and it also has a main branch that is located below the confluence of the two forks (Charbonneau 1987).

Many papers in the past have focused in on Strawberry Creek and measured different variables in the water. Carlson (1971) noted high pH measurements in the creek. Frazier (1983) measured for dissolved oxygen in the water and noted that it was within the limits set by the Regional Water Quality Control Board (RWQCB). Frazier (1983) also noted that the mercury levels in the water were high and there was also a large coliform concentration. Cheung (1986) concluded that not all of the water quality parameters tested in Strawberry Creek met RWQCB standards. Cheung (1986) stated that levels of pH and dissolved oxygen met the standards but once again coliform levels were higher than allowed. Phillips (1986) noted abnormally high pH values (above 8.0) on occasion but stated that the overall chemical condition of Strawberry Creek was fairly good. Vrudhula (1988) found no build-up of heavy metals in the soil along Strawberry creek but a study by Morales (1988) found that a higher number of people or automobiles are correlated with a high concentration of heavy metals. Morales conducted his study to detect for a difference in water quality in the summer and fall sessions at campus.

A relatively new study by Tudd (2001) made some startling discoveries. Tudd (2001) noted that the north fork had a mercury level of 0.77μg/L while the south fork had a mercury level of 2.5μg/L. The Environmental Protection Agency (EPA) allows a mercury level of 2μg/L for drinking water. This would suggest that Strawberry Creek is unsafe for people to use. Some studies have focused on other aspects of Strawberry Creek. Lee (2001) concluded that there were very few high flow refuges for fish in both forks. Of the six sites (in north and south forks) studied by Lee (2001), none were found to be favorable in terms of creek habitat (Lee 2001). Yoon (2001) viewed the competition between the introduced species of fish to the crayfish (*Pacifastacus leniusculus*) and discovered that the crayfish prey on the young benthic fish of the creek (Yoon 2001).

After the publishing of the Strawberry Creek Management Plan (Charbonneau 1987), many restoration efforts have taken place or are under way (Maranzana 2002, pers. comm.). Restoration efforts have included sewer and sanitary system repairs, bank stabilization, check dam repairs and installation, regrading, slope stabilization and revegetation (Lee 2001). These efforts have led to improved water quality and the return of several biological communities (Charbonneau & Resh 1999). The next step in the restoration process is the reintroduction of several fish species (Lee 2001). There were once at least 13 species of fish in Strawberry Creek (Lutrick 2001) but now there are only four species left (Maranzana 2002, pers. comm., Dudley 2002, pers. comm.) These species were introduced over the last 13 years. The four species of fish are the three-spined stickleback (*Gasterosteus aculeatus*), California roach (*Hesperoleucus symmetricus*), Sacramento sucker (*Catostomus occidentalis*), and the prickly sculpin (*cottus asper*) (Dudley 2002, pers. comm.)

The south fork of the creek has been able to support fish while the north fork has been unable to support fish for unknown reasons (Lutrick 2001). Fish introductions to the creek have been ongoing since May 1989 when the first introductions were made (Lutrick 2001). The main branch has supported fish throughout the 1990s (Lutrick 2001). Fish survival depends upon several factors: food supply, water quality, temperature, suitable pool habitat for feeding and breeding, and cover from scouring winter flows (Charbonneau & Resh 1999). The goal of this paper is to investigate whether water quality may explain the lack of fish in the north fork by comparing water quality in the two forks and the main branch.

Methods

Strawberry Creek is located on the UC Berkeley campus in Alameda County, California, USA (37°52’ N; 122°15’W) (Figure 1). It runs from Strawberry canyon above the campus, down to San Francisco Bay (Charbonneau 1987). Much of the creek is culverted including all of it starting from the end of the campus until it enters the bay. This study focused on the portion of the creek that runs through the campus and is not culverted.

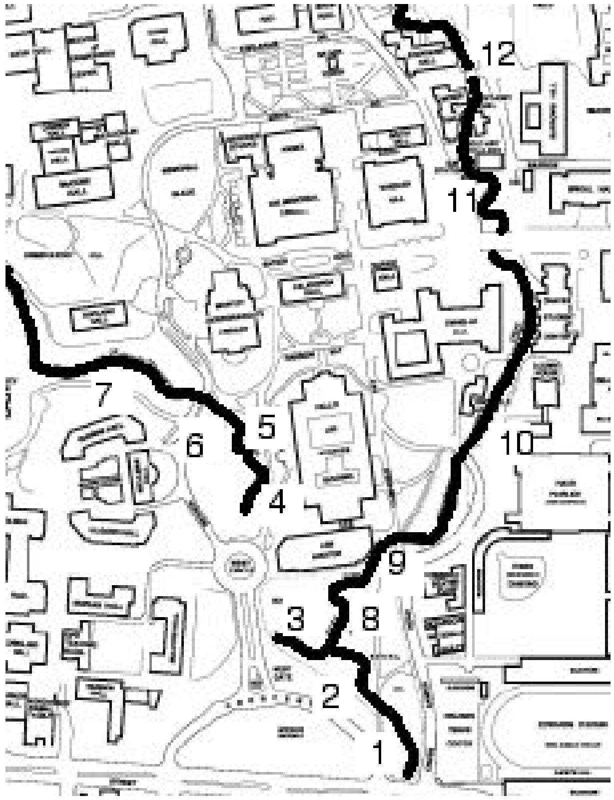

Figure 1 Map of Strawberry Creek and study sites (1-12)

Weekly water samples were taken from February thru mid-April, 2002. Samples were analyzed for pH, conductivity, turbidity, chlorine, copper, phenols and detergents. Electronic testers were used to measure for conductivity, turbidity and pH. A TDSTestr 40 by Cole Parmer was used to test for conductivity. Testing for turbidity was done by a 2100P turbidimeter by HACH. A pH-Testr 1 by LaMotte was used for testing pH. Data analysis for copper, chlorine, phenols and detergents was done using instructions in a model number SSDK Strom Darin Kit by LaMotte.

The creek was divided into a total of 12 sections. The divisions were made using areas where the numbers of fish introductions were about equal during the last 13 years. There were five sections in each of the two (north and South) forks and the main branch was divided into two sections. These separations were made so fewer samples could be taken throughout the creek since it was divided into 12 portions. Also, a method known as electro-fishing was used to compare numbers of fish in each of the sections. Fish were shocked, which caused them to float to the top. These fish were captured and counted, and their size and species were noted.

The means were calculated for each group and the Tukey-Kramer honestly significant difference (HSD) test was used to determine differences between the means (Zar 1999). JMP IN® software was used to calculate the statistical analyses.

Results

Between the months of February to mid-April 2002, 10 samples were taken at each of the 12 study sites for each parameter tested. The means of each variable were calculated and are listed in Table 1.

Site	Branch	pH	Conductivity (μS)	Turbidity (NTU)	Chlorine (ppm)	Copper (ppm)	Phenols (ppm)	Detergents (ppm)
1	Main	7.65	545	6.11	0	0	0.5	0.2
2	Main	7.75	552	6.61	0	0	0.5	0.1
3	North	7.95	525	8.64	0	0	0.5	0.1
4	North	7.7	544	3.36	0	0	0.5	0.1
5	North	7.7	549	2.37	0	0	0.5	0.1
6	North	7.75	671	1.99	0	0	0.5	0.1
7	North	7.75	730	2.22	0	0	0.5	0.1
8	South	8.5	572	3.33	0	0	0.5	0.1
9	South	8.6	580	4.13	0.2	0	0.5	0.1
10	South	7.8	579	5.98	0.2	0	0.5	0.1
11	South	7.6	642	3.61	0	0	0.5	0.1
12	South	7.6	655	4.17	0	0	0.5	0.1

Table 1 The means of each collected variable are listed by site number

The Tukey-Kramer HSD test was run on this data. In a Tukey-Kramer test all means from a selected variable are compared with each other (Zar 1999). Positive values show pairs of means that are significantly different (Sall & Lehman 1996). Figures 2-6 shows the distribution of the data and Tables 2-6 Shows the results of the Tukey-Kramer HSD test.

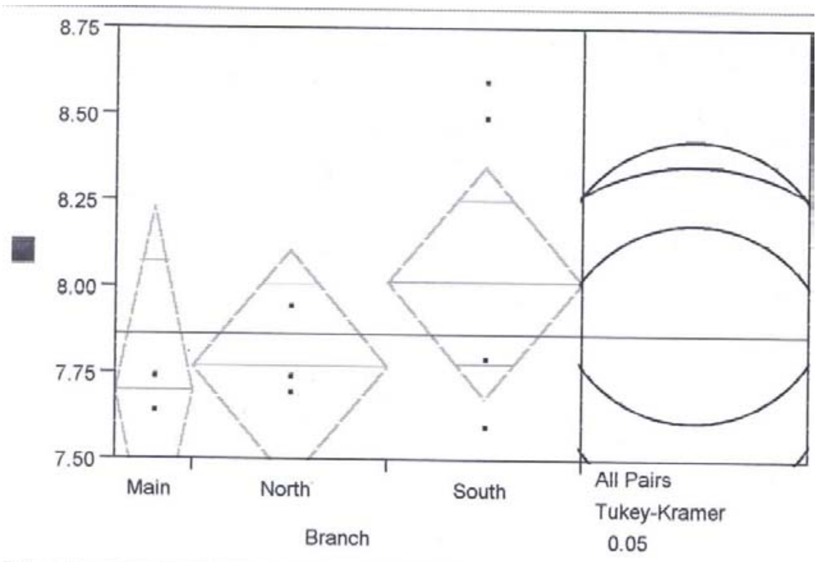

Figure 2 pH distributions shown by site. Tukey-Kramer comparison circles are shown on the right

	South	North	Main
South	-0.5933	-0.3433	-0.46486
North	-0.3433	-0.5933	-0.71486
Main	-0.46486	-0.71486	-0.93809

Table 2 Tukey-Kramer comparison pair values for pH data

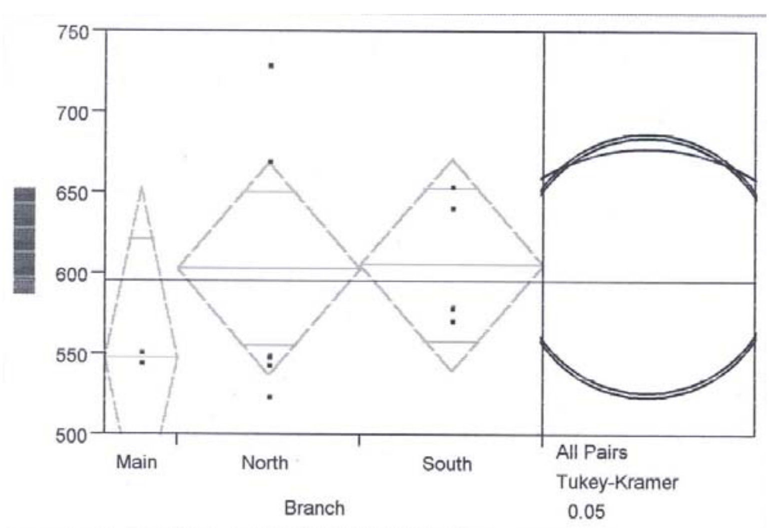

Figure 3 Conductivity distributions shown by site with Tukey-Kramer comparison circles on the right

	South	North	Main
South	-117.002	-115.202	-97.679
North	-115.202	-117.002	-99.479
Main	-97.679	-99.479	-184.996

Table 3 Tukey-Kramer comparison pair values for the conductivity data

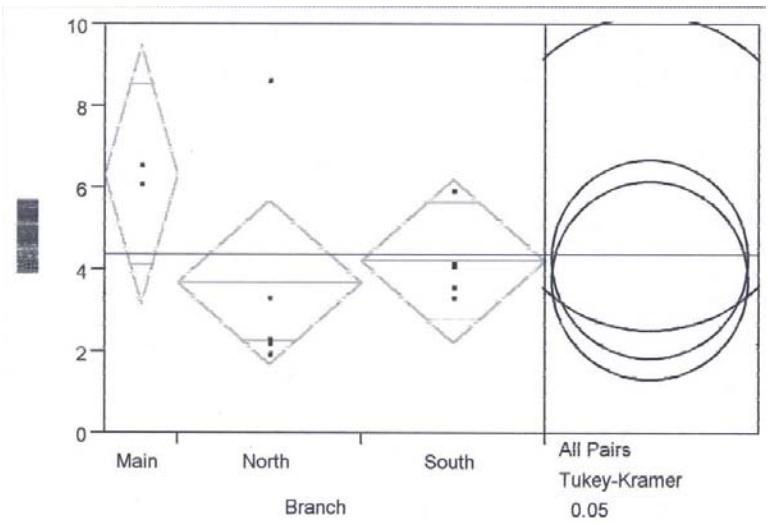

Figure 4 Turbidity distributions shown by site with Tukey-Kramer comparison circles on the right

	Main	South	North
Main	-5.56816	-2.54266	-2.01466
South	-2.54266	-3.52162	-2.99362
North	-2.01466	-2.99362	-3.52162

Table 4 Tukey-Kramer comparison pair values for the turbidity data

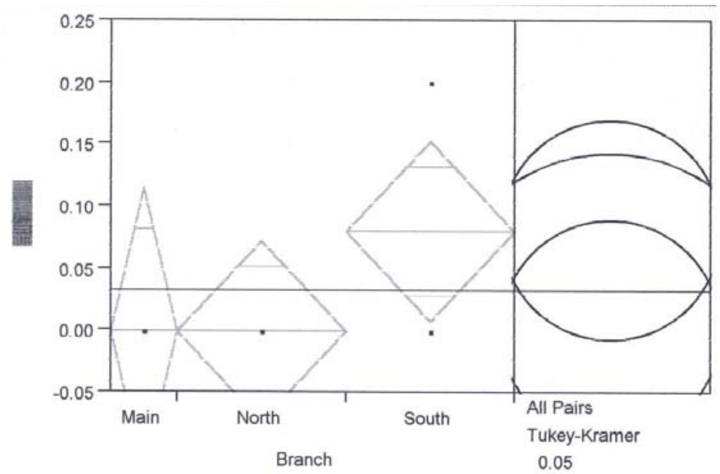

Figure 5 Chlorine distributions shown by site with Tukey-Kramer comparison circles on the right

	South	Main	North
South	-0.12896	-0.09059	-0.04896
Main	-0.09059	-0.2039	-0.17059
North	-0.044896	-0.17059	-0.12896

Table 5 Tukey-Kramer comparison pair values for the chlorine data

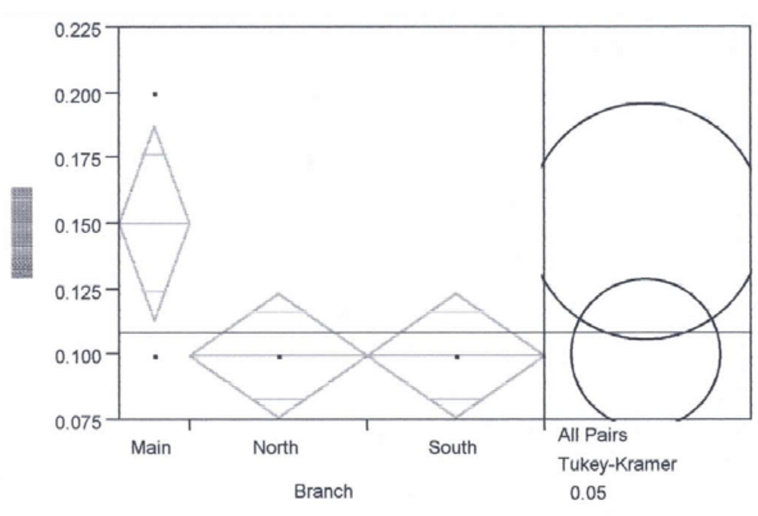

Figure 6 Detergent distributions shown by site with Tukey-Kramer comparison circles on the right

	Main	North	South
Main	-0.06581	-0.00506	-0.00506
North	-0.00506	-0.04162	-0.04162
South	-0.00506	-0.04162	-0.04162

Table 6 Tukey-Kramer comparison pair values for the Detergent data

Copper was not detected in the creek by the method used so no statistical analyses could be run on this data. Phenol data was identical in each site so statistical analyses could not be run on this data either.

Discussion

During the last 13 years, over 200 fish from the four species were introduced throughout the entire north fork (Lutrick 2001). After electro-fishing only ten fish were caught. The numbers of fish introduced into the south fork were 300 fish and with electro-fishing approximately 200 fish were caught. The main branch, for which no numbers on fish introductions are known, carries over 150 fish. Electro-fishing can catch about 50% of the total number fish in a creek (Dudley 2002, pers. Comm.). Comparing these numbers clearly shows that the south fork is healthier than the north fork because the fish are not surviving in the north fork.

The question that this paper is targeting is whether water quality may explain differences in fish populations between north and south forks. After looking at water quality data from the two forks and the main branch, it can be said that the water quality is not significantly different. The Tukey-Kramer HSD test did not yield any positive values in the comparisons of the two forks and the main branch. These numbers should not really be a surprise because the creek is monitored so closely (Maranzana 2002, pers. comm.). By looking at the results of this paper we can conclude that the water is not different in the two forks.

Other explanations for why fish are abundant in the main branch and the south fork and not the north fork include habitat, competition, and flow. While electro-fishing, it appeared that where more crayfish were present less benthic fish were seen. From the Yoon (2001) paper we know that crayfish prey on the young of the benthic fish, this causes fewer fish in the next generation to survive (Dudley 2002, pers. comm.). If less fish survive this will cause the population to decrease. The crayfish feed on almost anything they want including their own species (Dudley 2002, pers. comm.). The crayfish were once introduced to the creek but the exact reason of why they were introduced is still a mystery (Maranzana 2002, pers. comm.).

Lee (2001) noted that lack of refuges due to high flows leads to a decline in the fish population. Out of the six sites studied by Lee (2001), only two sites provided high flow refuges for the fish in the creek but at some of the larger winter flows these may not be present also leaving the fish with no refuge (Lee 2001). Lee's (2001) study sites were chosen because they were ideal sites for fish habitat but they did not have a refuge down stream for high flows. During high flows the younger fish get washed downstream more easily further leading to a decline in the population (Dudley 2002, pers. comm.).

Lee's (2001) creek habitat assessment found the creek to be undesirable for fish population establishment. In natural creeks, variations in depth in the form of pools and riffles are expected (Hunter 1991) but in Strawberry Creek there was little variation within the sites chosen by Lee (2001). Variations in depth are important in fish habitat because it affects water temperature (Lee 2001), but also deeper pools provide feeding areas as well as predator and flow refuges (Vehanen 2000).

Another reason for fish decline in the north fork could be the number of accidents that the north fork has suffered through over the years (Resh 2002, pers. comm.). The number of accidents is clearly greater in the north fork than in the south fork (Maranzana 2002, pers. comm.) which leads to loss of fish (Dudley 2002, pers. comm.). After the samples were collected for this project, another accident was reported at the north fork (Maranzana 2002, pers. comm.). A truck backed into a fire hydrant which caused water to be released into the creek at a very high rate and also caused steam pipe to burst releasing very hot water into the creek (Maranzana 2002, pers. comm.). The water reached 125 F for at least 90 minutes (Pine 2002, pers. comm.). Electro-fishing was conducted in the north fork but no benthic fish and very few crayfish were found after this accident. The north fork is susceptible to more accidents because there is plenty of construction done near that fork.

There are many other factors for fish survival in Strawberry Creek that were not mentioned in this paper. These factors include temperature, food supply, pool habitat for breeding, etc. and further testing will explain why fish have not become prevalent in the north fork. They creek may need further restoration on recommendation by Lutrick (2001) and others. The eventual goal is to return as many of the native species of fish to the creek as we can (Dudley 2002, pers.

comm.). The creek is much better off than it was when Charbonneau (1987) made initial attempts to clean up the creek (Maranzana 2002, pers. comm.) but further testing will allow us to learn more and return the creek to its original form.

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