The Effect of Chemical and Physical Parameters on Populations of Three-spine Stickleback in Strawberry Creek

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Abstract The population of three-spined stickleback, *Gasterosteus aculeatus*, has fluctuated greatly during the past century in Strawberry Creek on the UC Berkeley campus. After the restoration of Strawberry Creek in 1989, efforts have been made to reintroduce stickleback into the creek. To determine how the stickleback were influenced by stream water quality and habitat quality, weekly stickleback counts were compared to water quality parameters and physical stream parameters. From late January to mid-March 2005, samples for chemical parameters (pH, electrical conductivity, turbidity, water temperature, and salinity) and nutrient levels (nitrate and phosphate) were made at four sites on the North Fork, three sites on the South Fork and one site at the Mainstem where both Forks meet. Physical stream parameters (epifaunal substrate, pool substrate, sediment deposition, channel flow status, bank stability, vegetative protection, and riparian vegetative zone) measurements and stickleback counts were also made once a week at each site. Correlations between parameters and stickleback population were made using regression analysis. Areas with higher measurements of habitat quality had higher densities of sticklebacks. Phosphate had a negative relationship with stickleback abundance yielding a p-value of 0.0368 while nitrate had a positive relationship with a p-value of 0.0035. Overall this study shows that physical habitat parameters need improvement in order to establish more areas in which sticklebacks can live because habitat parameters had more correlation with fish abundance.

Introduction

The three-spine stickleback (*Gasterosteus aculeatus*), a polymorphic species, is found in estuarine habitats in shallow vegetated areas, usually over mud or sand (Leidy 2000). It can live in water with oxygen levels as low as 0.25 to 0.5 ppm, and tolerate a wide range of salinity (0 to 40ppt), and pH range (5.8 to 11.4) (Wooton 1984). In May 1989, 100 three-spined stickleback were reintroduced into Strawberry Creek as a part of a restocking project (Charbonneau et al. 1990). This restocking project was done after sewer rehabilitation projects, the building of check dams, and other restoration efforts on the creek took place… Prior to 1989, Strawberry Creek was affected by urbanization (construction of the campus) which led to turbid, foamy, discolored, and oily water (Charbonneau and Resh 1992). The stickleback was chosen to be evaluated due to its ability to tolerate frequently disturbed habitats and because they are native to the creeks in the Bay Area (Charbonneau and Resh 1992). As of 1989, stickleback and other native fish were transferred from other nearby creeks that have been restored for a longer period of time to the north and south fork of Strawberry Creek. This was all part of an effort to promote larger populations of the fish in the creek (Hans 2004 pers. comm.).

The purpose of this research is to determine how physical stream parameters relate to chemical stream parameters and to the presence of stickleback in Strawberry Creek. Nitrate and phosphate tend to cause excessive algal growth if leached into a stream. When there are excessive amounts of surface-associated algae, dissolved oxygen concentrations tend to be reduced (Erler et al. 2004) which may in turn affect the fish living in the stream. Riparian vegetation generally prevents nutrient runoff which helps reduce inputs into streams (Wilcock et al 1995). It is also shown that riparian buffers can be an effective way to reduce nitrate concentrations to improve water quality in streams (Spruill 2000). Therefore, my hypothesis is that areas with low vegetation will have high nitrate and phosphate levels and yield low numbers of stickleback.

A past study by Yung (1992) found no significant correlation between water quality parameters and the distribution of stickleback in Strawberry Creek. Since Yung's study, which showed an even distribution of the stickleback in Strawberry Creek, the locations of the stickleback have shifted to the lower areas of the creek. Singh (2002) also measured water quality to attempt to explain the difference between fish population in the north and south fork of the creek. This study showed that even though the south fork was found to have slightly better water quality than the north fork, the difference was not statistically significant. Though water quality parameters have not elucidated compelling data in the past, the parameters were never measured with fish counts and so further analysis should be made to determine if a correlation exists. Populations of stickleback tend to decline during the winter and increase after the rain which could be due to winter floods caused by the rain (Gillooly and Barlow 1995). Therefore data in the winter may provide some insight. Conducting a biological assessment to see if the physical habitat parameters of stickleback are met is also necessary to provide a better understanding on what parameters may affect it. This study will help determine suitable habitats for the stickleback so they may flourish in the creek and potentially indicate the possibility of other native species to live in the creek.

Methods

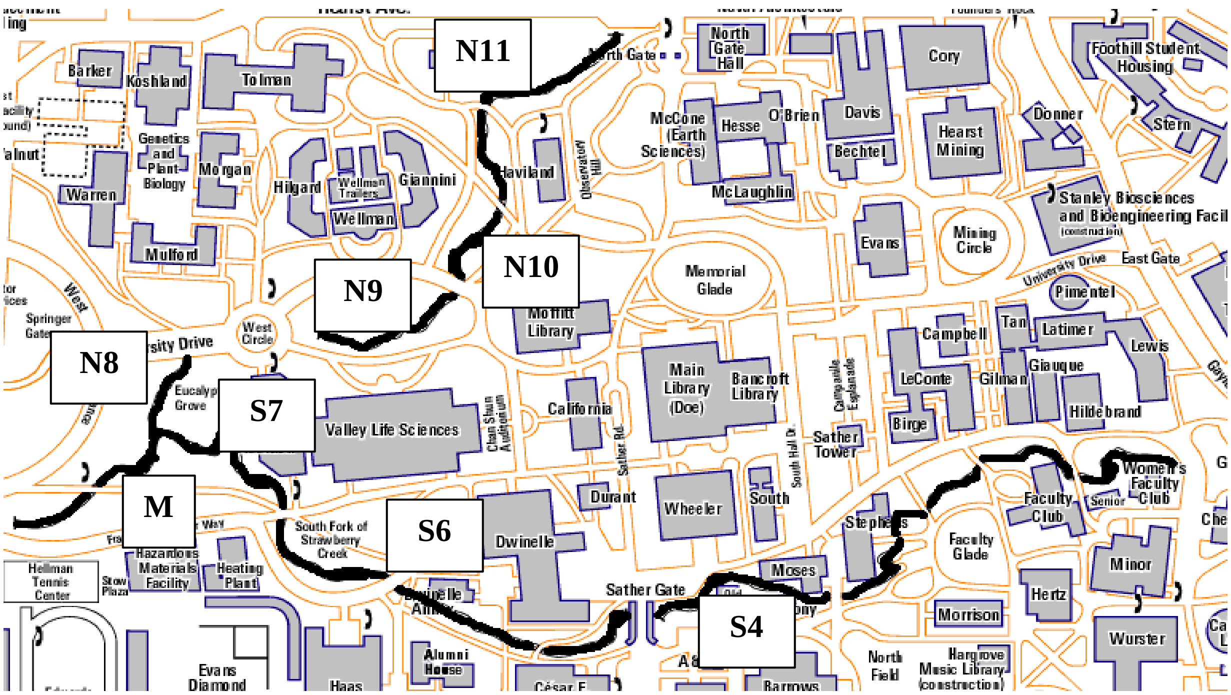

Figure 1. Map of Strawberry Creek and study sites. The N stands for the North Fork, S stands for the South Fork, and M stands for the Mainstem. The sites are labeled the way Charbonneau (2000) labeled these sites.
Source: Charbonneau 2000

The sites for this study were selected based on the presence of a pool or riffle. There are eight sights total with four on the North Fork, three on the South Fork, and one on the Mainstem (where the north fork joins with south fork) of Strawberry Creek (Fig. 1). All parameters and measurements were made once a week. At each site three categories of parameters were assessed: water quality parameters, nutrient levels, and physical habitat assessment. A U-10 Water Quality Checker (Horiba Ltd., Irvine, California) was used to measure pH, turbidity, conductivity, dissolved oxygen levels, temperature, and salinity. A DR/850 Portable Datalogging Colorimeter (Hach, Loveland, Colorado) was used to measure nitrate and phosphate levels. For each nitrate and phosphate assay, three 25mL test tubes filled with 10mL of creek water was mixed with a nitrate or phosphate packet from the Hach kit and the rest of the procedures can be followed through the Hach manual. For the physical stream parameter evaluation, a Habitat Assessment Data Sheet from the EPA was used. The parameters on the data sheet include: epifaunal substrate cover, pool substrate, sediment deposition, channel flow status, bank stability, vegetative protection, and riparian vegetative zone. Each of these seven parameters was measured on a scale of 1 to 20 (with 140 being the optimal score for the habitat).

At each site, fish counts were made along about 10 meters of creek. Using methods described by Vredenburg (2004 pers. comm.) I walked along the shore to search for as many sticklebacks as I could see while timing myself, allowing me to calculate the number of individuals/meter shoreline/time. I used polarized sunglasses, which cut down surface shine, enabling me to see more clearly into the water. Fish counts were made once a week at each site. A separate fish count was also made to determine the likelihood of a fish traveling across transects of a site using methods describe by Biging (2005 pers. comm.). One site was divided into transects with a width of two meters. A fish was then observed for a period of time to see how far across a site it would travel. This test was used to calculate the likelihood of recounting fish.

Linear regression analysis and logistic regression were used to test for the relationship between parameters using JMP IN® software.

Results

Table 1. Mean and range of water quality parameters

Water Quality	Mean	Range
Air Temp (C)	16.2	11.4-22.3
Avg Windspeed (m/s)	0.3	0.0-1.6
Humidity (%)	55%	27%-96%
pH	7.42	7.1-8.1
EC (mS/cm)	0.457	0.3-0.63
Turbidity (NTU)	20.5	1.8-164
DO (mg/l)	9.79	4.3-13.5
Water temp (C)	13.3	11.7-20.9
Salinity (%)	0.03%	0.00%-0.03%

Table 2. Mean and range of nutrient levels and fish counts

Nutrient and Fish Counts	Mean	Range
Nitrate (mg/l)	1.62	0.0-12.2
Phosphate (mg/l)	0.82	0.14-3.55
Chlorine total (mg/l)	0.1	0.0-0.45
# of fish	1.23	0.0-7.0
#fish/meter	0.2	0.0-1.2

Table 3. Mean and range of habitat assessment parameters.

Habitat Assessment	Mean	Range
Epifaunal Substrate	11.89	7.0-19.0
Pool Substrate	13.05	7.0-19.0
Sediment Deposition	11.82	8.0-18.0
Channel Flow Status	12.2	9.0-18.0
Bank Stability (Right)	7.8	5.0-10.0
Bank Stability (Left)	7.77	3.0-10.0
Vegetative Protection (Right)	5.77	1.0-10.0
Vegetative Protection (Left)	2.08	0.0-5.0
Riparian Vegetative Zone (Right)	5.17	1.0-10.0
Riparian Vegetative Zone (Left)	4.07	0.0-9.0
Habitat Score	82.54	57-122

Data was collected from late-January to late March totaling eight sampling sessions at each site. Stickleback was found in the lower reaches of the creek (at sites: M, S7, N8 and N9). The means and ranges for water quality parameters are shown in Table 1; however water quality parameters showed no correlation with the amount of fish counted. Turbidity did show some correlation with precipitation in the past 24hrs (Fig. 2) (R-square=0.1361, p-value= 0.0149).

Linear regression was also performed on turbidity and it showed a relationship with nitrate (Fig. 7) (R-square=0.1987, p-value=0.0024).

The relationships between nitrate and phosphate levels with the presence of fish at all sites are shown in Figure 3 and Figure 4. Figure 3 shows that nitrate has a positive relationship with the abundance of fish(R-square=0.1358, p-value of .0035). When a logistic regression fit was done for nitrate, it indicated a decreasing likelihood of seeing fish as nitrate levels increase. The logistic fit also showed that increasing levels of phosphate would lead to a smaller chance of seeing fish, but the linear regression for phosphate and the abundance of fish shows a negative relationship (R-square= 0.0718, p-value=0.0368).

When the nutrient levels were measured with the habitat assessment parameters, more relationships were found with phosphate than nitrate. The linear regression analysis (Fig. 6) indicates a negative relationship between phosphate and the habitat assessment scores (R-square=0.1429, p-value= 0.0024).

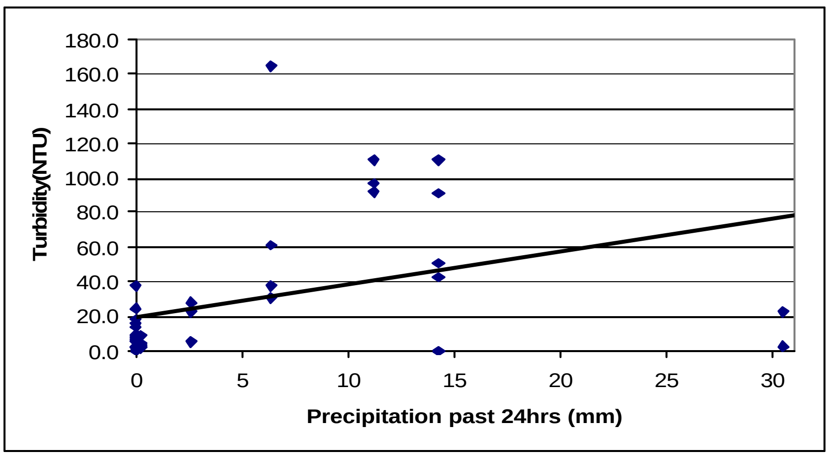

Figure 2. The effect of precipitation occurring in the past 24 hours on turbidity.

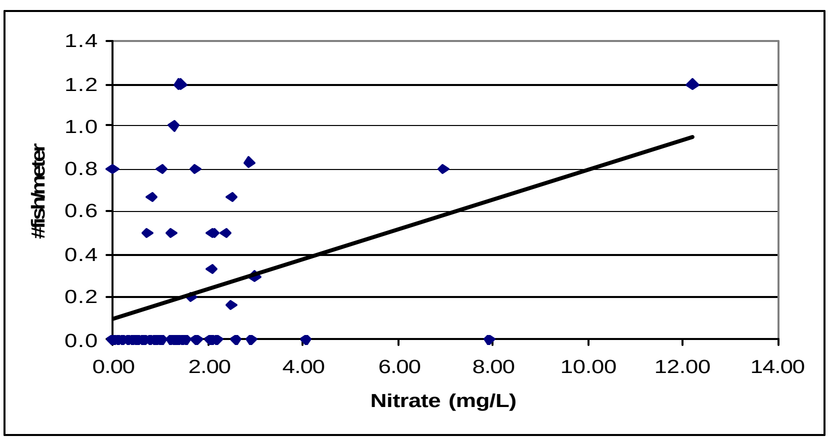

Figure 3. The relationship between nitrate levels and fish abundance

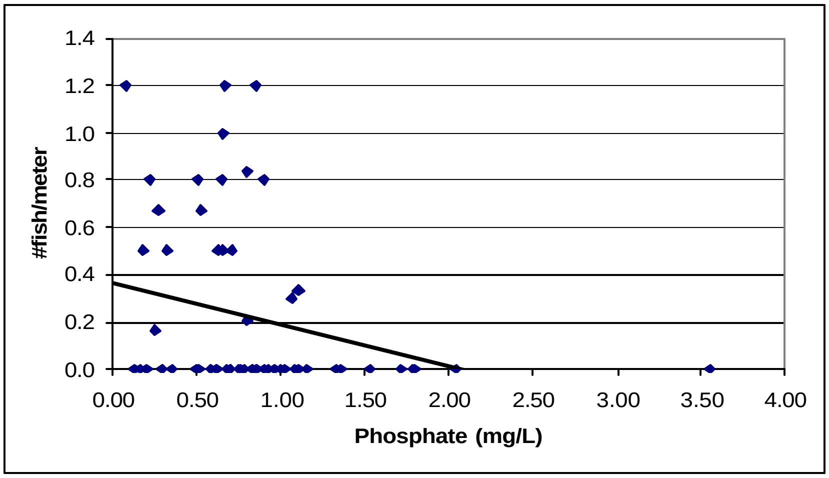

Figure 4. The relationship between phosphate levels and fish abundance.

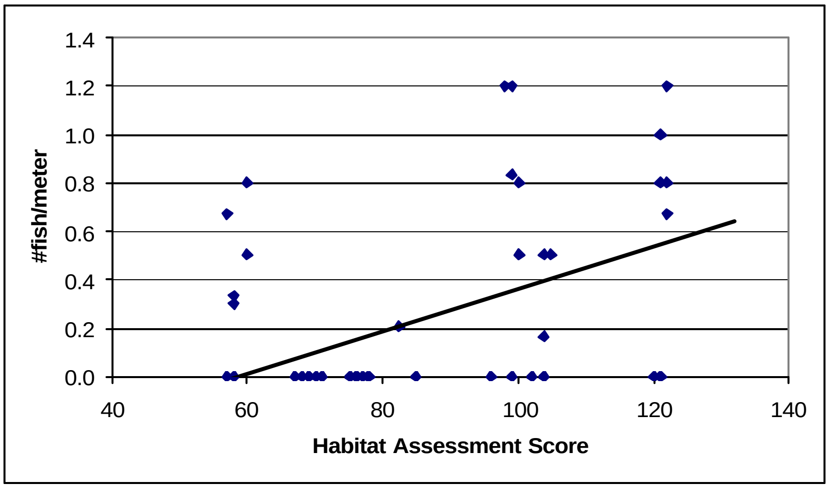

Figure 5. The relationship between the habitat assessment score and fish abundance

Table 4. Linear regression results of other habitat parameters.

Parameters	R-square	p-value
Epifaunal Substrate	0.4699	0.0001
Pool Substrate	0.2578	0.0001
Sediment Deposition	0.1777	0.0007
Channel Flow	0.2045	0.0003
Vegetative Protection (Right)	0.1088	0.0088
Vegetative Protection (Left)	0.2929	0.0001

Table 3 lists all the means and ranges of the habitat assessment parameters (the first four parameters are out of 20 points while the rest are out of 10 points and total habitat score is out of 140 points) while Table 4 list the parameters that had a positive relationship with the abundance of fish. Overall, the habitat assessment indicated a positive relationship with fish abundance (R-square=0.2224, p-value =0.0001). When phosphate was measured with riparian vegetation, a p-value of 0.069 was calculated and a negative relationship was shown.

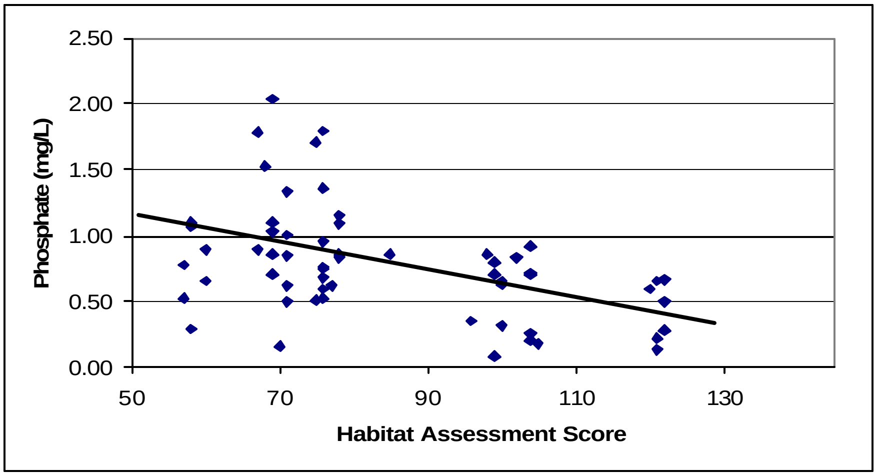

Figure 6. The relationship between Habitat Assessment Score and phosphate.

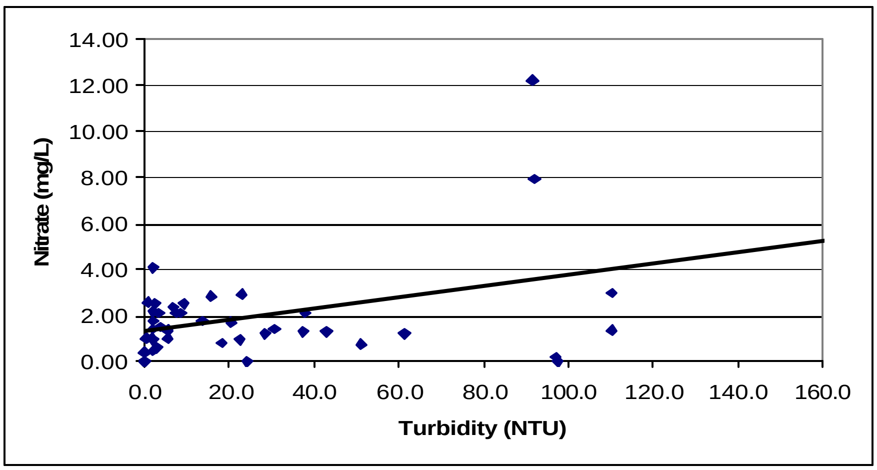

Figure 7. The relationship between turbidity and nitrate.

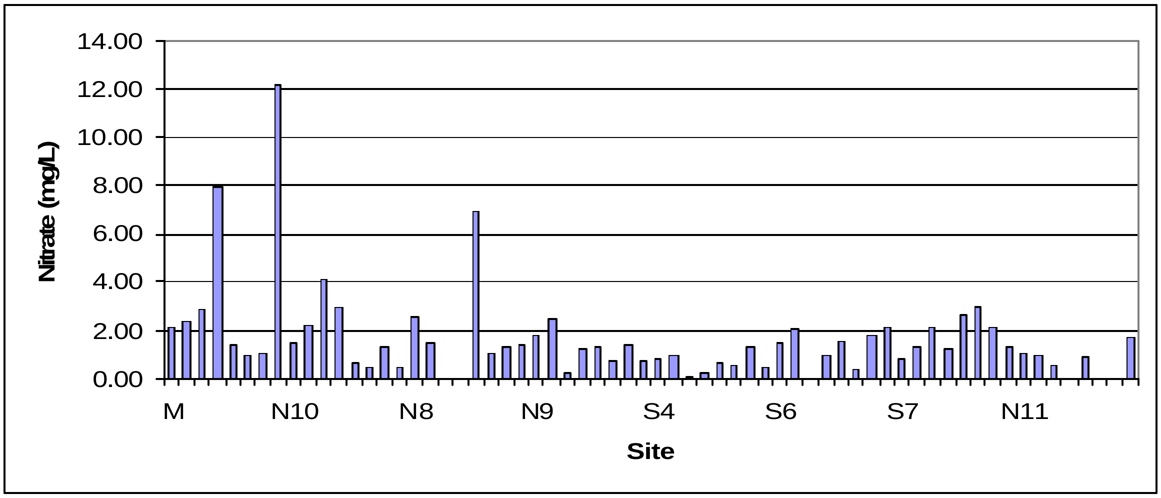

Figure 8. The variability of nitrate by site.

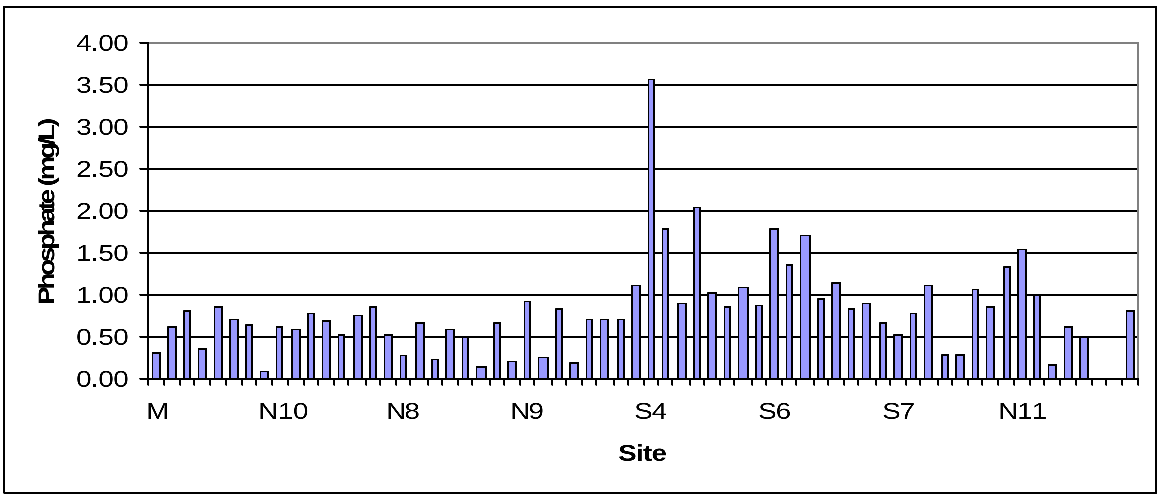

Figure 9. The variability of phosphate by site.

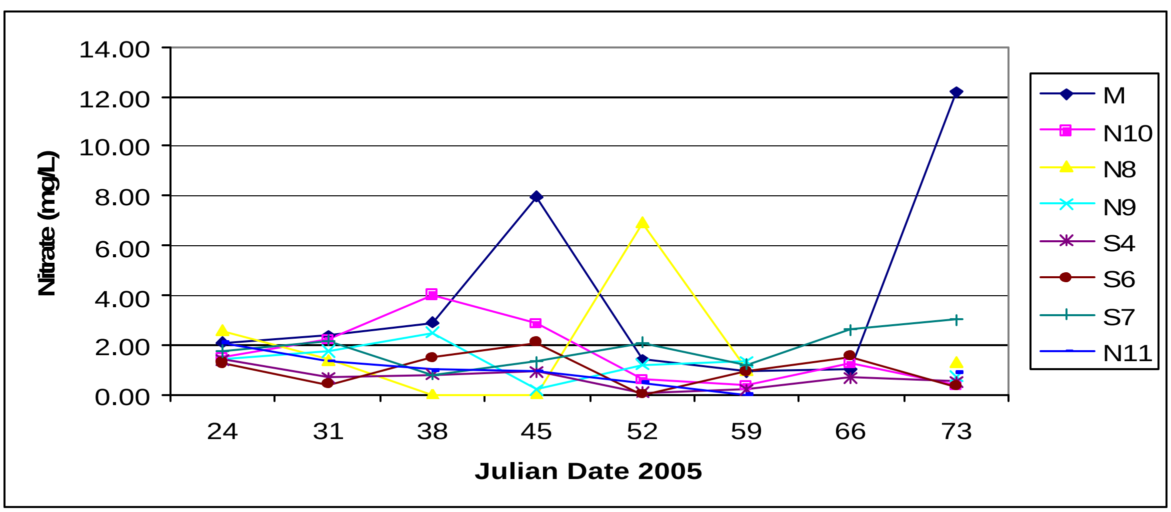

Figure 10. The variability of nitrate over time by site.

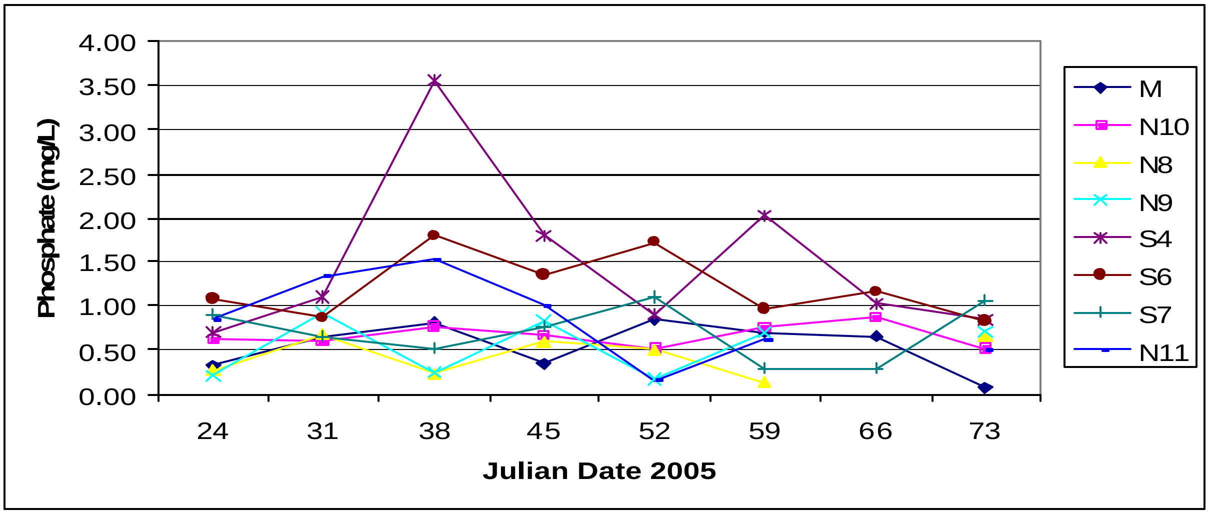

Figure 11. The variability of phosphate over time by site.

Discussion

This study show that water quality parameters do not correlate with the abundance of stickleback found at the sites. From Table 1, the mean of the parameters were within the right range for the stickleback. The ranges for the parameters tend not to vary a lot, except for turbidity which is affected by rain (Fig. 2). Though turbidity did not seem to affect the abundance of fish, it did affect the level of nitrate present. As turbidity increased, it caused nitrate levels to increase (Fig. 7). This is because of extra sediment in the water sample affecting the colorimeter's reading of nitrate which may also have cause the appearance of a positive relationship between nitrate and fish abundance. Phosphate did show a negative relationship with fish abundance (Fig. 4) because it is not as affected by sediment as nitrate when used with a colorimeter. For the distribution of nitrate by site (Fig. 8), the Mainstem had the highest values overall while phosphate (Fig. 9) congregated in the S4 and S6 region. The trend seems to be that phosphate is present in the areas where the stickleback is not found while nitrate is present where stickleback is found. This could be another reason for the positive relationship between nitrate and stickleback. Nitrate may not actually affect the fish, but its distribution may be affecting the results. The distribution of phosphate does show that it may influence fish abundance since all the areas where stickleback was present do have lower values of phosphate.

The results for the mean and ranges of the habitat parameters are shown in Table 2. There is a wide range for each of these parameters, but the sites with higher scores for each tend to be in the lower reaches of both forks (S7, N8 and N9) and at the Mainstem. This is because the areas around those sites are not as developed or as heavily culverted. When habitat assessment parameters were measured with stickleback counts, six parameters showed significance (Table 4). Epifaunal substrate has the highest R-square value and this may be because bank undercuts and logs are crucial for the stickleback in times of high flow since it gives them a place to take shelter. Of all the other parameters, epifaunal substrate is the one that can help in really sustaining the abundance of stickleback at a site. A point that was emphasized earlier on whether creek side vegetation played a factor into the amount of nutrient leeching into the creek is shown in Figure 6. As the habitat assessment score improved, the phosphate level starts to drop showing a negative relationship between the two. When phosphate was specifically measured with riparian vegetation, it yielded a p-value of 0.0696 and the slope of the line shows that phosphate levels declined as there is more riparian vegetation around a site. This helps in supporting the idea that vegetation around a creek helps reduce the amount of nutrients going into a creek.

For fish count data, the numbers are accurate for visual estimates made because from the separate observation of fish experiment, it was seen that the stickleback tended to stay in one region of the creek. Even if they do swim away, they did not swim very far because the sites are not that big. So the chances of double counting a fish are small since not that many fish were seen.

Past studies were unable to indicate why stickleback populations varied throughout Strawberry Creek. Through my study, I was able to support Singh's (2002) and Yung's (1992) idea that water quality may not have an effect the fish. However, I was able to find that habitat parameters did affect the fish. Further analysis still needs to be made in order to see if nutrient levels do play a factor and to see if other habitat parameters may play a role. For example, vegetative protection and riparian vegetative zone was shown to be more significant for one bank, but not the other. Also a more accurate way to account for the stickleback present at a site is needed because the counts I made are visual estimates and so the chances of not seeing a fish is higher than miscounting since I cannot count the fish that may be hiding under banks. Time is also a factor because this project and past projects were only conducted over a three month period at most and may miss variations and trends that could be found if the testing was done over a longer period of time.

Through this study, a better understanding on how to improve habitat for the stickleback should be achieved. If there are hopes for stickleback or other fish populations to expand across

Strawberry Creek, the areas around the creek need to be modified so there will be as little human impact on the creek as possible. Though the creek is better off than it was before the restoration (Charbonneau 1992), improvements can still be made and further testing on different parameters will give a better idea on what needs to be done.

Acknowledgements

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