Lake Merritt Nitrogen Project
Pinpointing Nitrate Contributions to Lake Merritt

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Abstract High-quality golf courses and cemetery landscapes require substantial pesticide and fertilizer applications, leading to concerns about their environmental impacts. Anthropogenic sources of nitrogen coming from highly fertilized lawns of the Claremont Country Club (golf course) and the Mountain View Cemetery, both located in the upper urban watersheds of Oakland, California, were hypothesized to be the major contributors of the nitrogen loading. A study was conducted to locate the origin of nitrogen loading into Lake Merritt from its contributing waterways. Runoff from the Claremont Country Club and the Mountain View Cemetery flows into Glen Echo Creek, the adjacent waterway that drains into Lake Merritt. This study includes monitoring nitrate levels above and below these sites in order to evaluate and locate the source of the nutrient load further downstream and in Lake Merritt. The golf course and cemetery management practices did not appear to be the main contributors of nutrient loading into Lake Merritt. High upstream concentrations of nitrate in Glen Echo Creek indicated contamination above these locations. However, monthly sampling also revealed increases in downstream nutrient concentration below these sites. Therefore, fertilizer applications and management practices at the Claremont Country Club and the Meadow Wood Cemetery appear to contribute some N loading, but much of the N loading above these two sites appear to contribute more to long-term stream and lake nutrient enrichment. Further research above the locations is needed to conclusively identify the major nutrient contributor to Lake Merritt.

Introduction

For as long as humans have lived near waterways, they have used them to wash away their wastes and pollutants. With the growing population and increased production and consumption, this tradition of flushing wastes downstream has overwhelmed the cleansing capacities of the Earth's water (Carpenter et al. 1998). As a result, water quality in rivers, lakes and coastal oceans has degraded over recent decades. This degradation is demonstrated by the disruption of aquatic ecosystems and the decimation of the various inhabiting species as well as the amenities that those ecosystems once provided to society (Carpenter et. al 1998).

The most common impairment of surface waters in the United States is eutrophication caused by excessive inputs of phosphorous and nitrogen (Caraco and Cole 1998). There are three forms of nitrogen: dissolved organic nitrogen, dissolved inorganic nitrogen, and particulate organic nitrogen. Dissolved inorganic nitrogen consists of ammonium (NH_4^+), nitrate (NO_3^-), or nitrite (NO_2^-), which fosters the growth of bacteria, algae and higher plants (Seitzinger and Kroeze, 1998).

Lake Merritt, known as the "Jewel of Oakland," suffers from excessive nutrient loading from urban runoff. Low oxygen levels within the lake have classified the lake as an impaired body of water by the Environmental Protection Agency. The amount of nutrients drained into lakes in general is significant when the rainfall flows over the creeks and into drainage lines that are discharged directly into the lake (Klessig et. al 2004). It is speculated that increased urban development and recreational usages in the upper regions of Lake Merritt's watersheds has increased the nitrogen and phosphorus load into the lake. The increased production and accumulation of these nutrients stimulates eutrophication of the lake and its waterways.

Unfortunately, water quality and general upkeep of the Lake has suffered in recent years due to Oakland's declining budget, and from the increasing pressures of an urban environment. As a result, the City of Oakland's Public Works Agency created a non-profit organization that now oversees upkeep of the lake; the Lake Merritt Institute (Plearn 2000). Since its inception in 1992, the Lake Merritt Institute has supported research funded by grants and public donations to improve the environment of the lake, and as a result aeration fountains, tidal gates, flood dams, and weekly clean-ups have contributed to a healthier lake and preserved the habitat for many migratory birds and aquatic species. The Lake Merritt Institute has continued to support several water quality studies to pinpoint sources of additional pollution. This particular study is focused on point sourcing nitrogen contributors to the lake.

Second only to phosphorous, nitrogen is a limiting nutrient for plant and algae growth and may enter the lake through an array of sources. Studies have shown that precipitation may be the main N source for seepage and some drainage lakes (Klessig et. al 2004). As excessive plant-algal growth dies, aerobic bacterial decomposers proliferate and break down the dead and decaying plant matter. In this decomposition process, the aerobic bacteria consume dissolved oxygen from the water, leaving oxygen shortages that causes fish kills (Carpenter and Ludwig 1999). Alterations to the natural environment may decrease species population size, growth rates, reproductive success and survival rates, while others sky-rocket, disturbing the fragile balance of ecosystem processes. Thus, overabundance of N loading plays a tremendous role in causing potential ecological destruction, and the subsequent loss of biodiversity (Vitousek et. al 1997).

The contribution of N from these watersheds into Lake Merritt has not been identified in the past. This study was designed to obtain this data. NO_3^- levels and turbidity levels were monitored for a full seasonal year, beginning in February 2004 through February 2005 from the Glen Echo and Trestle Glen Watersheds.

The main creek in focus for this project is Glen Echo Creek found in the Glen Echo Watershed, whose banks are parallel to both the golf course and cemetery. These two recreational areas are hypothesized to be the major nitrogen contributors to Lake Merritt because of the potential for fertilizers containing N compounds spilling over into the creek. By comparing the NO_3^- levels from the cemetery and golf course, both upstream and downstream, the primary focus of this study will identify the amount of N loading from these two locations to test our hypothesis that there is more N loading after the cemetery and golf course. Our secondary objective is to analyze Trestle Glen Creek, a creek without any major recreational areas and found on the Trestle Glen & Wildwood Creeks Watershed, in order to compare the difference of N loading with Glen Echo Creek.

Methods

Study Area Characteristics

In this study we examine the anthropogenic Nitrogen (N) inputs from two watersheds, 1) The Glen Echo Watershed and 2) The Trestle Glen & Wildwood Creeks Watershed. Both watersheds drain into Lake Merritt located in Downtown Oakland, California. Lake Merritt is a 150 year-old, 140 acre man-made lake that is surrounded by 4,670 acres of five urban watersheds. The human population of these watershed ranges from 210,000 to 390,000 individuals in the year 2000 (US Census 2000). Each of the lake's five watersheds is characterized by urban development extending from residential homes to recreational areas to commercial high-rises.

Glen Echo Creek, the major waterway draining the Glen Echo Watershed is a confluence of two streams that converge together as it empties into Lake Merritt. The northern fork banks are adjacent to the Claremont Country Club, while the southern fork banks are adjacent to the Meadow Wood Cemetery. Both forks of Glen Echo creek are surrounded by residential areas, however, because of potential abundance of fertilizer runoff from the golf course and cemetery, these two locations are believed to be the major NO_3^- contributors.

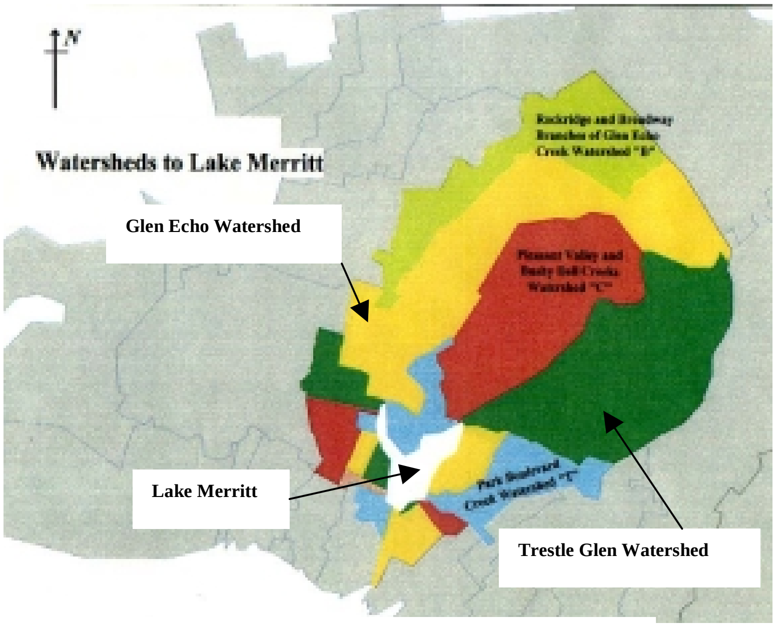

Figure 1 – Watersheds of Lake Merritt

The Trestle Glen Watershed is surrounded by similar residential areas as Glen Echo Creek, but this watershed is without a golf course and cemetery. Wildwood Creek and Bushy Dell Creek are the major waterways that flow within this watershed through the upper Piedmont area and finally empty into Lake Merritt. To test the assumption that fertilizer use at the Claremont Country Club and Meadow Wood Cemetery are the main contributors to Lake Merritt's N loading problem, we are comparing Glen Echo Creek from the Glen Echo Watershed, and Wildwood Creek and Bushy Dell Creek from the Trestle Glen watershed.

Sampling Design

Nine water sample sites were designated among these watersheds: six along the Glen Echo Watershed, and three within the Trestle Glen Watershed (Fig.1). Along the northern fork of Glen Echo Creek, sample sites were established above and below Claremont Country Club (respectively G1 and G2). A sample site (G3) was designated at the outlet of the creek into Lake Merritt after the forks converged to monitor the complete NO_3^- input from the Glen Echo Creek waterway.

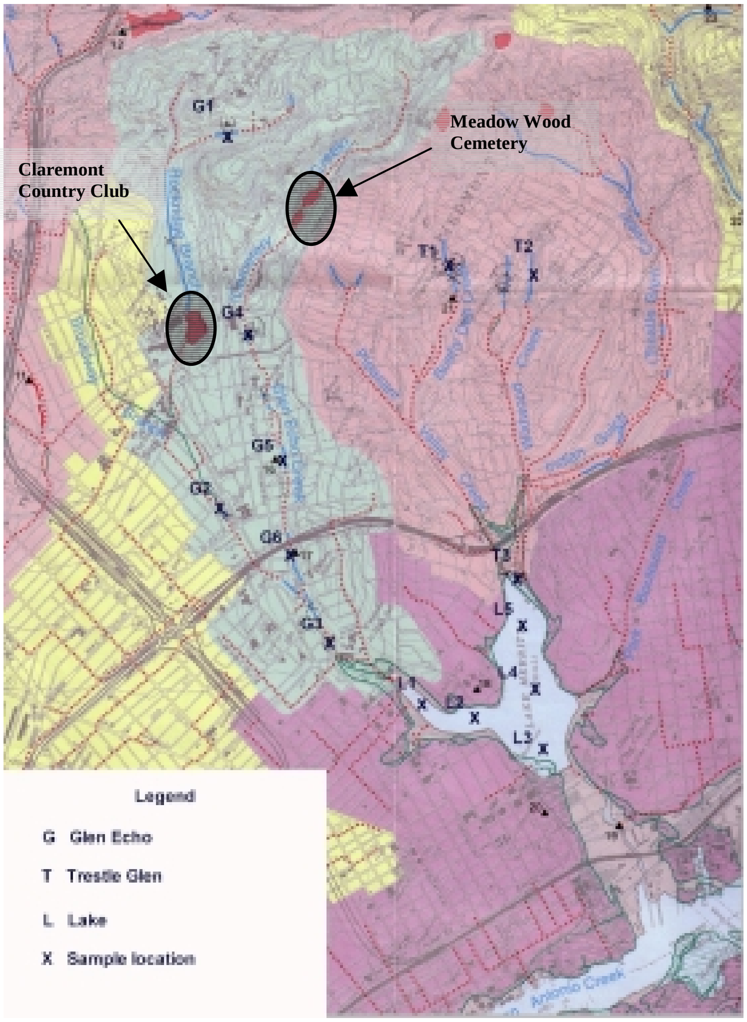

Figure 2 – Grab sample locations along drainage creeks

Similarly, along the southern fork sample a site was established below Meadow Wood Cemetery (G4). A sample site was not designated above the cemetery because of accessibility issues, but an additional sample site further downstream will provide data on the impact of the NO_3^- loading that might have come from the cemetery (G5). In addition, a sample site was selected along the southern fork after the I-580 freeway bridge provides any information regarding the possibility of sourcing NO_3^- from this location (G6).

Within the Trestle Glen Watershed, sample sites were established on the upper portions of Bushy Dell Creek (T1) and Wildwood Creek (T2), and one marking their outlet into the lake (T3). The Trestle Glen Watershed will serve as a comparison to Glen Echo Watershed. Sample locations G3 and T3 serve to compare the overall loading from Glen Echo and Trestle Glen watersheds.

Accessibility to the sample sites limited the choices to determining each sample location. The project received permission to sample behind only two residential homes sites G2 and G4. Industrial and business establishments forbade sampling behind their buildings. Other sites were geographically inaccessible for testing. Although testing behind these locations and above the cemetery would provide a clearer indication of the potential sources of NO_3^-, the other sites above and below some of these areas will provide adequate sources of information of any possible contribution that can be studied later if necessary.

Nitrate Sampling Protocol

Water quality grab samples were monitored monthly from each of the nine locations for a full seasonal year beginning in February 2004 through February 2005. Typically, one sample was taken at each site; occasionally, two tests were performed at random sites to verify consistency of the colorimeter and testing procedures. Water samples were collected at the surface of the creeks, ranging from one inch to one foot in depth, and between two and three feet from the banks. A LaMotte Nitrate-Nitrogen Test Kit model # DC1200-NA, and a LaMotte Colorimeter *Smart 2* were used to determine NO_3^- and turbidity levels from samples collected by a 500 ml glass container at each sample site. The LaMotte Nitrate-Nitrogen Test Kit utilized acid and cadmium reagents that reduce NO_3^- into NO_2^- to form a pink color which the colorimeter analyzes for NO_3^- levels. Each sample was analyzed for NO_3^- following the LaMotte Nitrate-Nitrogen manual guidelines for NO_3^- testing.

Results

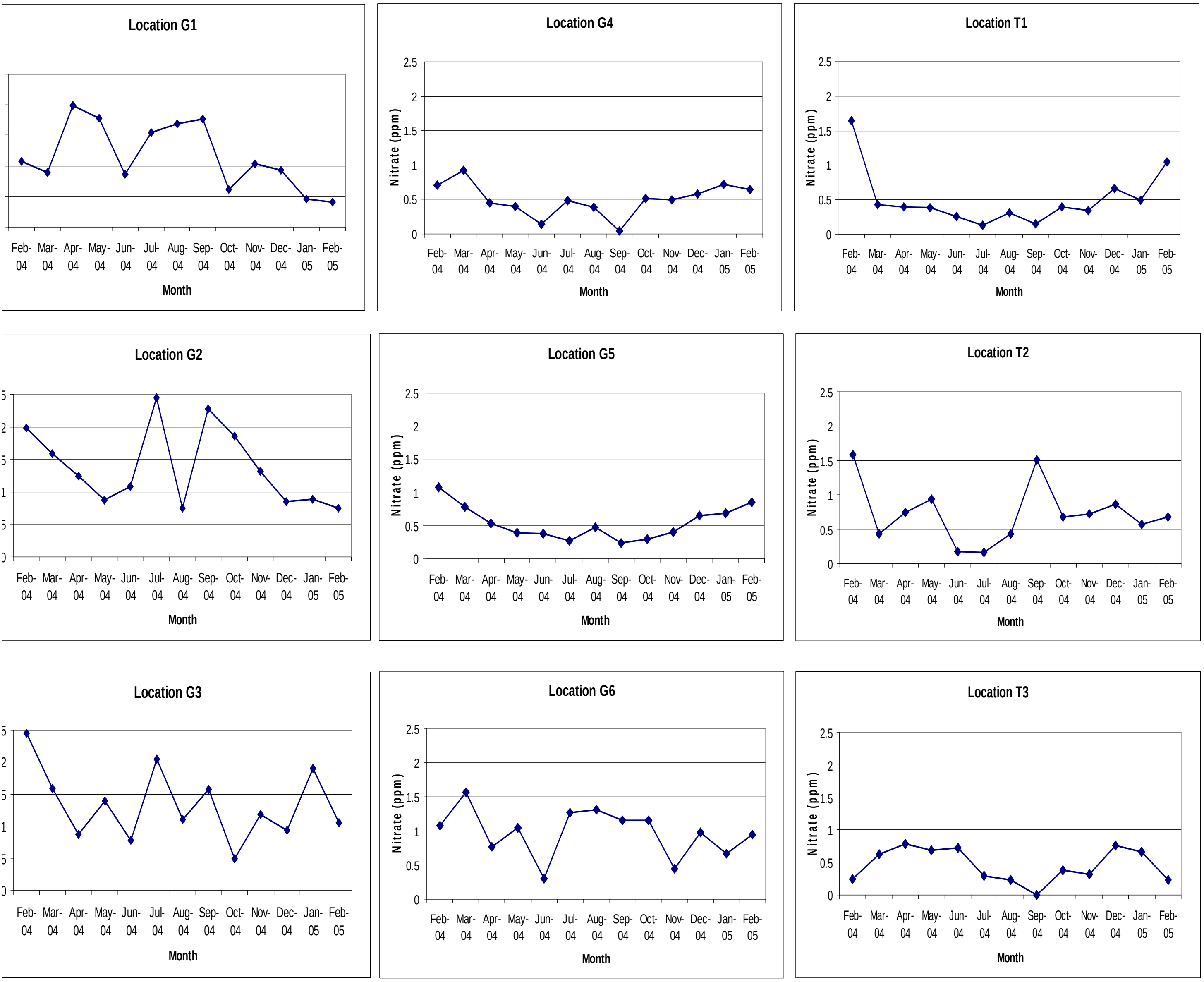

Figure 3 – Sporadic monthly nitrate data from each sample location.

NO_3^- loading in the Glen Echo watershed and the Trestle Glen Watershed exhibited random data points that could not be significantly correlated with describing the N loading trend (Fig 3). In all sampling locations, with the exceptions of G5 and T3, the NO_3^- levels are sporadic in nature, possibly due to irrigation and fertilization practices that lead to NO_3^- spikes.

In our analysis, we will use mean values of NO_3^- found at each location and the mean found for the creek overall. From the mean values we can extrapolate where the nutrient loading occurs along the pathway of the creek. We can also determine the waterway where the most nutrient seems to occur.

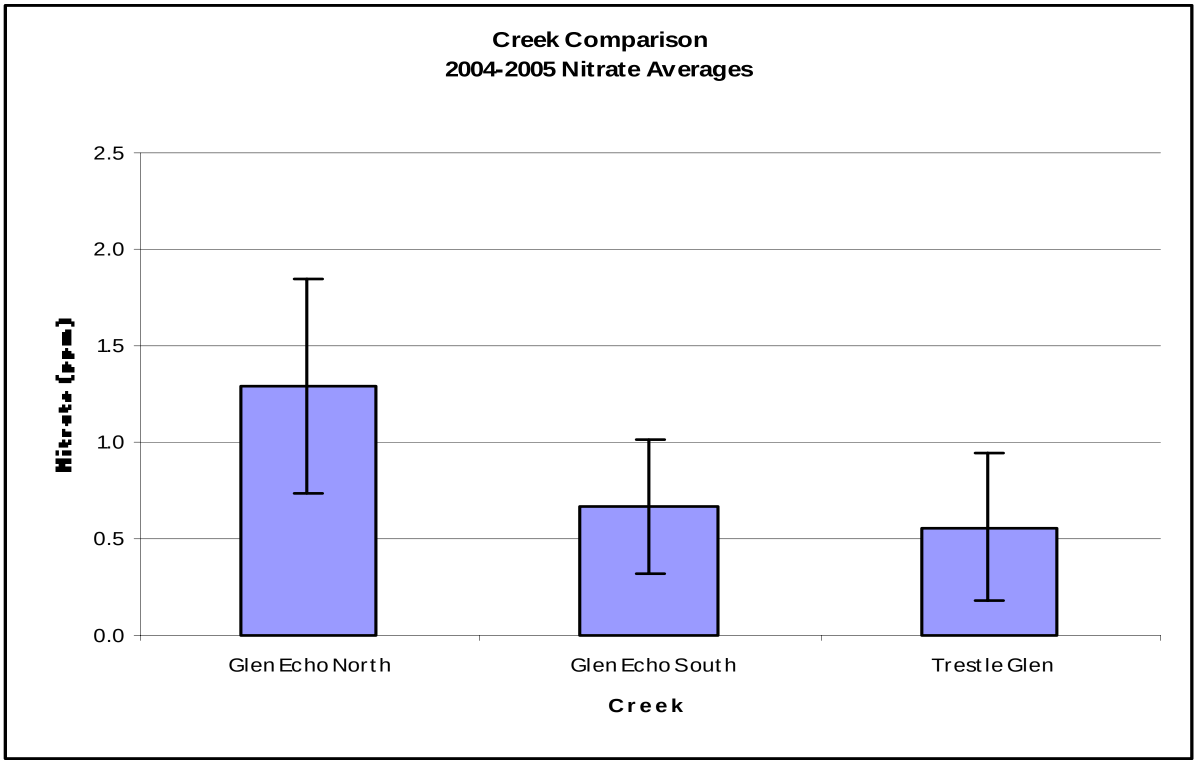

Figure 4 – Yearly Nitrate Averages for the Glen Echo Creek and Trestle Glen Creek with SD bars.

The yearly trend for the creeks shows NO_3^- loading levels in the Glen Echo Watershed to be higher in the North branch of Glen Echo Creek than the South fork and Trestle Glen Creek. The yearly average for each of the three waterways sampled depicts a substantial amount of NO_3^- contribution from the Glen Echo North Fork (Fig. 4). This does not account for the varying flow rates, and, therefore, the impact of the nutrient loading from Glen Echo North into Lake Merritt cannot be determine without further data in this respect.

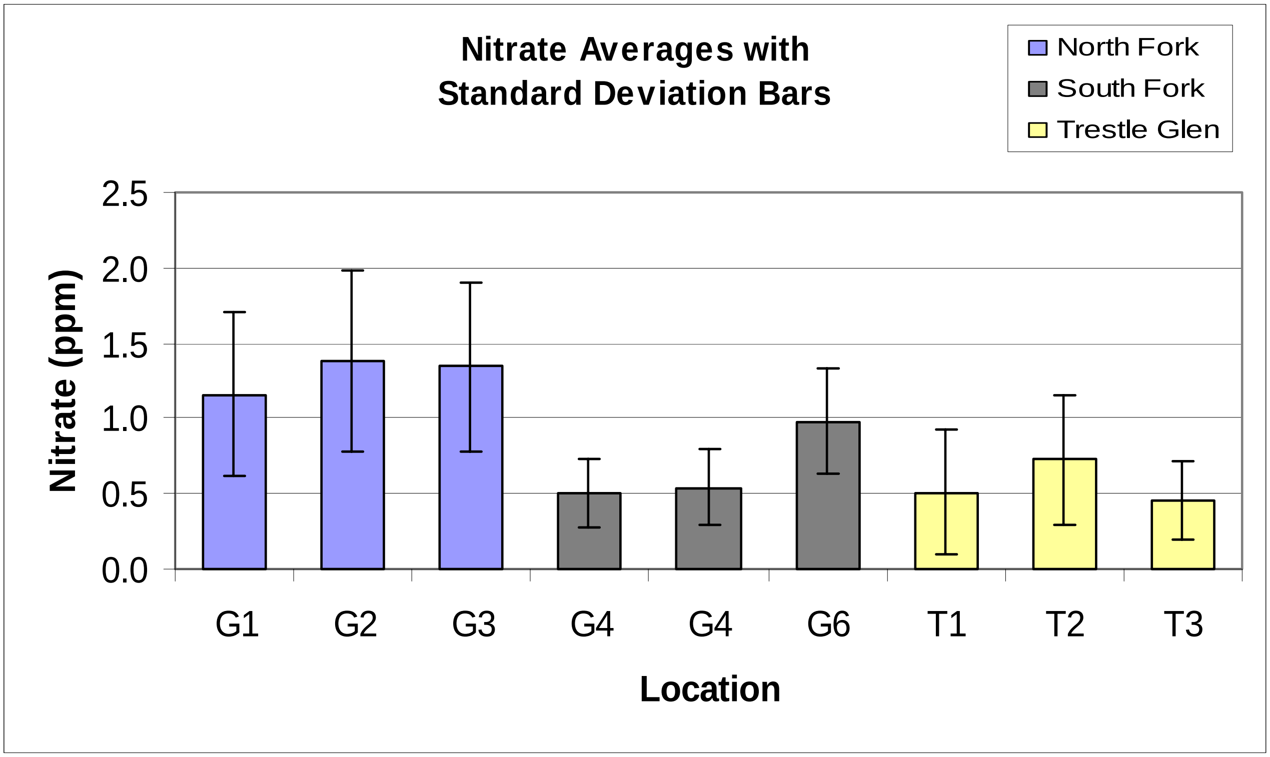

Figure 5 – Nitrate Averages for the nine sampling locations with standard deviation bars.

Further analysis along the northern fork shows a higher level of NO_3^- at location G2 than any other location (Fig 5). However, the averages of all three locations are relatively similar. Therefore it is difficult to evaluate location G2 as the primarily nitrogen contributor in the northern fork. The NO_3^- levels found at each site are not yet detrimental to Lake Merritt. NO_3^- value of 3 ppm is considered to be harmful to lake ecosystems (Carpenter 1998), but NO_3^- levels in the waterways that drain into Lake Merritt and in Lake Merritt only range from 0.5 to 2 ppm. However, continued levels such as these can amount to 3 ppm over time.

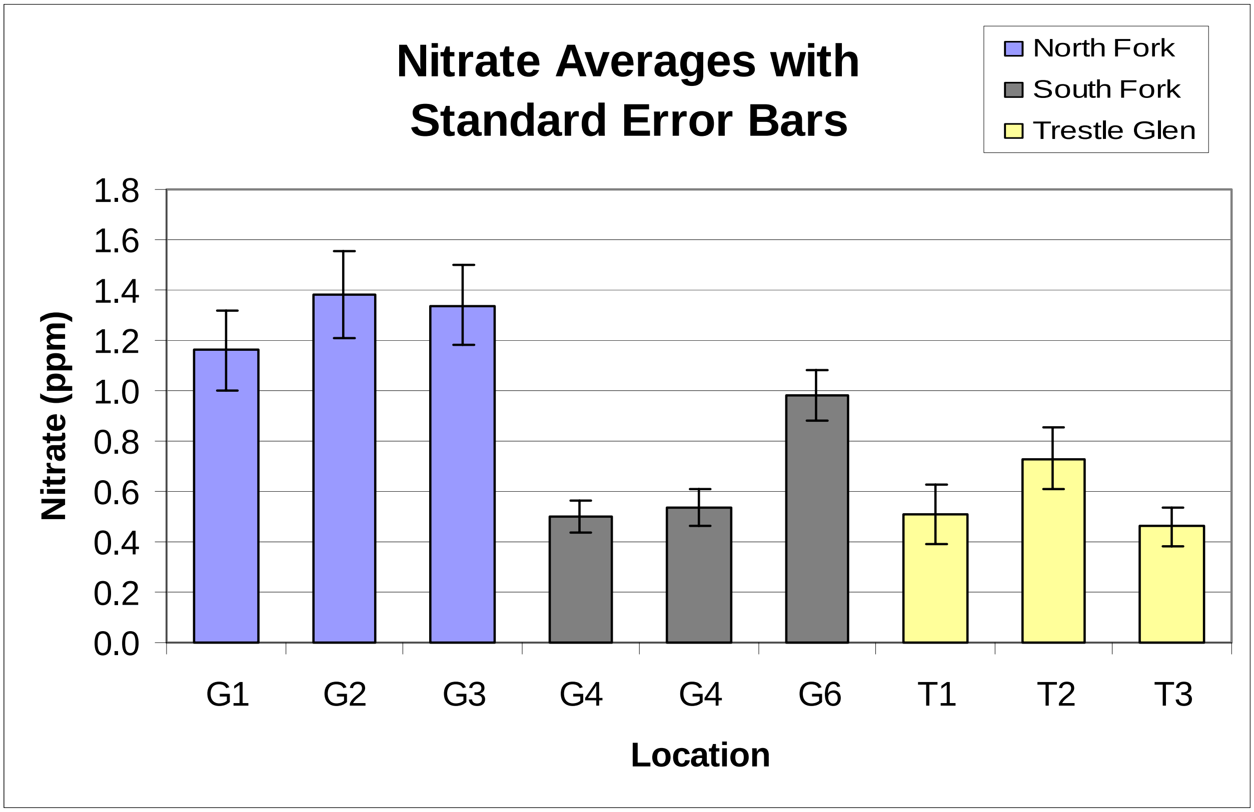

Figure 6 – Nitrate Averages for the nine sampling locations with standard error bars.

The yearly NO_3^- average in the South branch of Glen Echo Creek show location G6 (below the I-580 Highway bridge) as the primary nitrogen source in this branch. The NO_3^- average at G6 stands at about 0.5 ppm above location G4 and G5, with a standard error of 0.1 (Fig. 6).

The yearly NO_3^- levels at the Trestle Glen sites are relatively constant at each of the three sample sites. These NO_3^- levels consist of low amounts of nitrates, 0.5 ppm, and show no indication of any sudden additions of nitrates at the sample locations along this creek (Fig. 6).

Discussion

The scattered NO_3^- levels in the watersheds make it difficult to determine conclusively where the N pollution into Lake Merritt is originating from. The data spikes in the North and South forks of Glen Echo Creek indicate that there may be sporadic fertilizer application. Furthermore, we expect the NO_3^- levels to increase downstream after high levels are found upstream. Instead, we found the decrease of NO_3^- further downstream in the following months, implying that NO_3^- is being converted into nitrate, or being used by the surrounding riparian vegetation.

Although our result can not decisively determine the source of N loading as expected, the influx of NO_3^- into Lake Merritt was found to be resulting from the Glen Echo Watershed and not resulting from the Trestle Glen Watershed. The yearly nitrate levels from these two watersheds show that Glen Echo Watershed contributes more nitrates than the Trestle Glen Watershed because the Glen Echo watershed has a golf course and cemetery that seems to be adding NO_3^- through landscaping practices. The sporadic behavior found at the outlet of Glen Echo creek into Lake Merritt (G3) and the consistency found at the outlet of Trestle Glen creek into Lake Merritt (T3) shows that there is possibly an influx of additional nutrient loading in Glen Echo Creek. This analysis does not imply that it is directly resulting from a single source (the golf course, cemetery and the I-580 bridge), but it is likely that it is a combination of factors that lead to this variability.

The flow rates for the different creeks were not measured or examined in this study. Therefore, we can not explicitly state the rate and significance of N loading from the North fork verses the South fork and the Trestle Glen watershed. Further studies of flow rates, in conjunction with nutrient loading data can determine the effect of the NO_3^- input from the creeks in proportion to the flow rates and nutrient influx into Lake Merritt.

Analysis along the Glen Echo watershed show that the major contributor of N loading originates along the North fork of Glen Echo Creek. Specifically, averages for location G2 (after the golf course) seems to have more N loading than any other location in Glen Echo Creek. However, this data at G2 does not indicate a significant correlation with its NO_3^- contribution when compared to the other averages at the other two sites in the North fork.

It is possible that part of the N loading at G2 is stemming from N fallout coming upstream, above the golf course. There is no significant difference in the averages between G1 and G2 making it possible that N loading from G1 could be increasing NO_3^- levels downstream at G2. Similar findings were found by Cuppen and Gylstra, 1995: NO_3^- levels fluctuated sporadically with varying runoff, fertilizer applications, and irrigation events in specific areas. Further study in this segment of the creek must be taken in order to verify this analysis. As a result, this study can only conclude that the major contributor of NO_3^- to Lake Merritt results from some point along the northern fork of Glen Echo Creek.

The secondary source of nitrogen occurs along the southern fork. According to the comparison of the three sites within this fork, the influx NO_3^- is resulting below the I-580 bridge

(G6). This goes against the hypothesis that the cemetery would be the primary contributor along this fork. It is possible the emissions from vehicles passing over location G6 are supplying this point with higher N concentrations than the fertilizers from the cemetery. This is not uncommon, since one common pollutant from vehicle emissions is nitrogen dioxide (NO_2). NO_2 combined with particles in the air can form derivatives of N, including NO_3^- , that can runoff from roads into waterways (U.S.E.P.A. 2004).

All streams utilized in this study were urban streams, and, therefore, already impacted by runoff from developed areas (i.e. housing, shopping centers, roads, etc.) Thus, the streams contained contaminants, including pesticides and nutrients, before they entered the properties of the golf course and cemetery. It is entirely possible that as the streams flow through the golf course and cemetery, N is able to move out of the system (e.g., nutrients may be unutilized by aquatic organism and vegetation) and in the absence of additional inputs from the golf course and cemetery, the NO_3^- levels in the creek as they leave these areas are lower. Further research is necessary to establish whether or not this is accurate. If accurate, it would confirm that the runoff from the golf course and the cemetery are not the primary contributors of N loading.

Conclusion

The objective of this study was to identify the source of nitrogen contribution into Lake Merritt. It is found that the nitrogen contribution occurs along the northern fork of the Glen Echo Creek in the Glen Echo Watershed. The data in this study was not significant enough to pinpoint the exact source of the NO_3^- contribution. However, it did conclude that the primary source of nitrogen was coming from Glen Echo Creek. This will provide a valuable resource for further research of sourcing NO_3^- inputs from this waterway.

Further research might involve increased number of sampling throughout the months to gather monthly data at locations specifically around the golf course and cemetery. This data then could be compared to irrigation practices and fertilizer application data to show a correlation if any of the possible N contribution directly from these locations. Furthermore, additional testing sites along Glen Echo Creek can provide information on the cause for the decreased amount of NO_3^- further downstream.

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