Tracing Sources of Water Pollutants in Lake Tahoe

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ABSTRACT

Water quality is a serious issue that especially affects many bodies of water that are used for recreational purposes. Lake Tahoe, a large lake in northern California, is one such lake that struggles with water quality issue. This study is a synthetical analysis of Lake Tahoe water pollution sources based on seasonal trends of water clarity and its relationship with airborne pollutants. I acquired Lake Tahoe water turbidity data from the USGS datahub and multiple tools of data analysis and cleansing were applied to generate a seasonal trend, which implied melting snow and urban upland drainage are potentially critical sources of pollution. I also performed a simultaneous analysis between the seasonal trend and EPA air quality data was performed, yet the result did not show a conspicuous relationship between number of bad air quality days and water turbidity. I concluded that there are several limitations of the dataset, as well as our methods of study. I also presented a discussion on prospective policies including raising the resorts fees and occupancy taxes.

KEYWORDS

water pollution, Lake Tahoe, data analysis, policymaking, airborne pollutants

INTRODUCTION

Water pollution has become a major environmental conservation challenge in the United States (Forney et al. 2001). Typical water pollutants include organic or inorganic micropollutants such as nitrides, toxic metal, metalloids, and a large variety of synthetic organic materials from industrial plants or agricultural production (Schwarzenbach et al. 2010). Long-term water pollutions are likely to deal significant damage to the health of local ecosystems, particularly causing eutrophication by introducing excessing nutrients to waterbodies that leads to algae growth, which gives rise to significant drops in water clarity. And eutrophication can result a severe drop of water clarity.

California, particularly, is a state with critical water pollution problems that result from its high population and high levels of agricultural production and economic development (Dowd et al. 2008, Dwight et al. 2005). Water pollution in California is an economic and public health threat, as increased water turbidity could largely affect the income from tourism and spread waterborne microbial pathogens. For example, since 1968, the overall water quality of Lake Tahoe in northern California has experienced a significant decline, where excessive algae growth due to eutrophication and fine particle sediments are considered as two major factors of this issue (Domagalski et al. 2020). And as reported by USEPA, the pollution is a consequence of the development of homes, hotels, casinos, ski resorts, and urban infrastructures around Lake Tahoe area since the 1950s (EPA).

Recently, as the water quality issue has become more crucial, efforts from government agencies as well as independent organizations have been initiated to solve water quality issues in Lake Tahoe. However, while current research and policies in nearby counties of Lake Tahoe are focusing more on the removal of extant pollutants in the Lake Tahoe water body, it is also equivalently important to identify and alleviate the root causes of Lake Tahoe water pollution and establish a pertinent plan targeting crucial pollution sources (Landy 2020). Such sources may include point source pollution from urban uplands, inorganic salt drainage from roadway sanding and salting, erosion caused by steep slope development, and deposition or diffusion of airborne pollutants (Forney et al. 2001, Gertler et al. 2006). Now the pollution issue of Lake Tahoe urgently needs to be addressed, both for the restoration of local ecosystem and stimulation of economy.

My research goal is to assess major sources of pollutants that have caused a decline in Lake Tahoe water quality. To answer this question, I evaluated seasonal trends in Lake Tahoe water quality and use those trends to infer if direct urban upland drainage and melting snow are essential pollutant sources. I also determined, in terms of impact on Lake Tahoe water turbidity, if that airborne pollutant is an important source of water pollution. In addition to identifying the sources of pollutants, I discussed what kind of specific strategies (e.g., wildfire management for airborne pollutants generated by wildfire) shall be considered in mitigating Lake Tahoe water quality issue. Such strategies should be pertinent and precise targeting those pollution sources.

METHODS

Site description

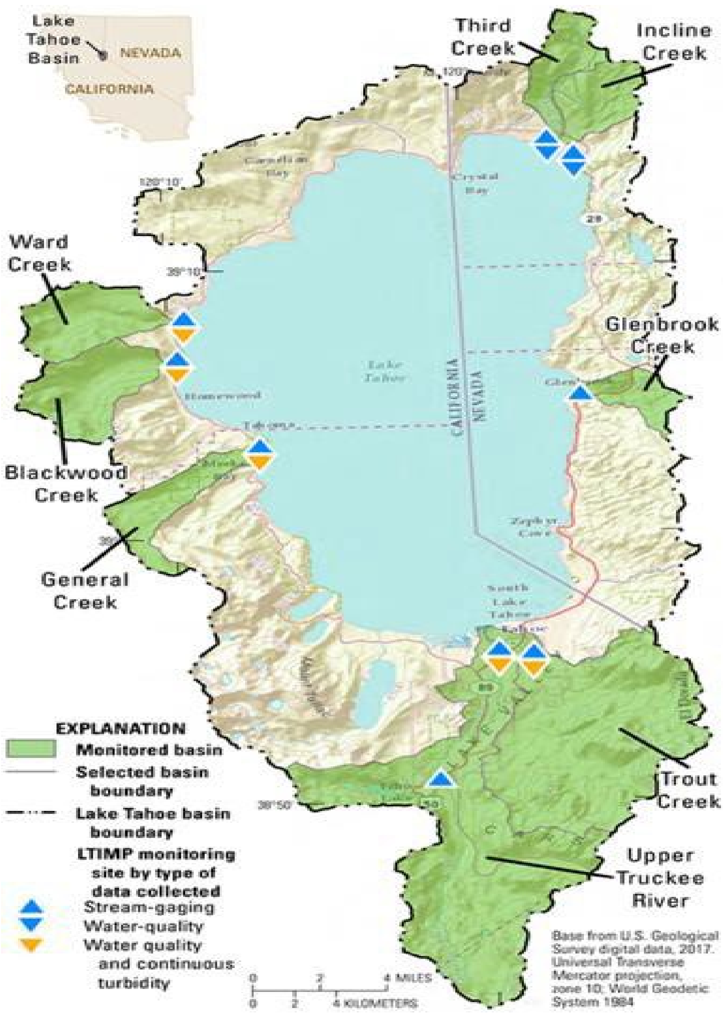
Lake Tahoe is a freshwater lake located in the Sierra Nevada Range with its basin being part of the Truckee River watershed that occupies parts of California and Nevada states (Forney et al. 2001). It has water surface area of 192 square miles and average depth of 1,000 feet, and it is the largest lake in Northern California as well as the second deepest lake in the United States (Forney et al. 2001). Since the 1950s, the development of local entertainments and infrastructures had brought a surging number of tourists to Lake Tahoe Area, which inevitably increased the amount of pollutants discharged into the lake, resulting in a diminished water clarity and cultural eutrophication which leads to algae growth (USEPA 2020). According to the data from USEPA, the average Secchi depth, which measures the water body clarity by determining the maximum visible depth of the Secchi disk, of Lake Tahoe has dropped from 100 feet to 64 feet in from 1968 to 1997, and stabilized to 67.3 feet between 2015 and 2019, which indicates the amount of suspended particles and algae have both increased.

Data Utilization

To determine the seasonal trend of Lake Tahoe water quality and figure out its relationship with airborne pollutants, I performed our analysis majorly using the Lake Tahoe water quality dataset from USGS and the historical air quality data in Sierra-Nevada region from USEPA.

The USGS water quality data monitors temperature, specific conductance, pH, dissolved oxygen, fine sediments, and concentration of nitrogen and phosphorous, in water samples at 8 sites in 7 basins of Lake Tahoe. And water turbidity and fine sediment particles are continuously monitored in 5 of those 8 sites (Figure 1, USGS 2021).

Figure 1. Sites map of USGS water quality monitoring



Water samples have been collected for lab analysis on those metrics by USGS every one to two weeks during routine visits from 1978 to present, and the data of more recent years also provides per-15-minutes measure of temperature, turbidity, nitrogen concentration, and phosphorous concentration with the built-in sensors. Individual researchers can obtain such data from the USGS webpage in both table and graph form, and within any timespan between 1973 and 2021. In this research project I utilized the data from the last 5 years (2015-2019) in the 4 sites with detailed data of water turbidity that directly reflects water quality.

The dataset from EPA records daily air quality data in major counties of the United States for O3 concentration, NOx concentration, PM10 concentration, PM 2.5 concentration, SO2 concentration, and overall air pollutants in the past 40 years (USEPA 2021). I obtained the historical air quality index and pollutant concentration in Sierra-Nevada region (El Dorado County, CA) from the USEPA, and computed the number of bad air quality days that are classified as "unhealthy" per month using the standard provided by EPA (AQI 151 or higher). Then I would compare the relationship between months with more bad air quality days and the months with higher average water turbidity that I obtained from our seasonal trend analysis.

Data Treatment and Analysis

In order to demonstrate the relationship between Lake Tahoe water quality and month of the year, I applied a linear regression test to plot graphs for each site in terms of water turbidity in each year, where I plotted a total of 25 graphs. I averaged the value of water quality metrics for each month throughout the timespan studied from 2015 to 2019.

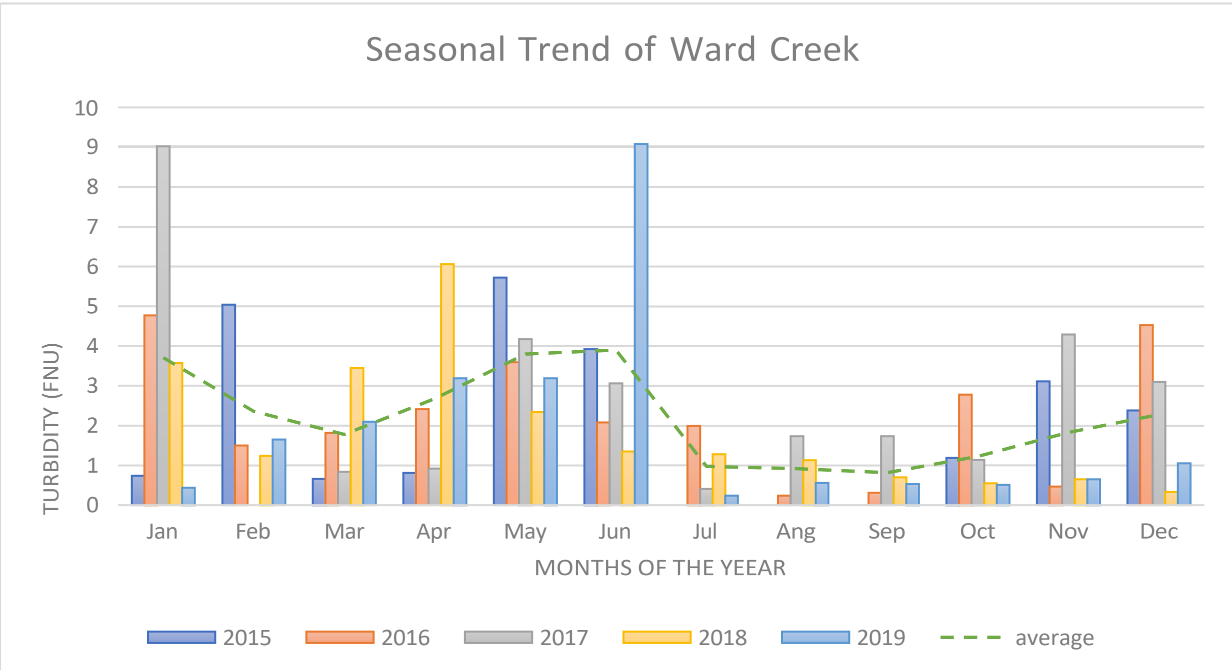
To visualize the relationship between airborne pollutants and Lake Tahoe water quality, I studied the relationship between annually bad air quality days and water quality metrics including sediment particles, turbidity, and nitrogen. I conducted statistical analyses to assess the relationship between air and water quality: First I plotted a graph comparing the number of bad air quality days (i.e., AQI 151 or higher) and monthly average water turbidity. Since the diffusion and dissolution of airborne pollutants may take time, it is more reasonable to use number of annual bad air quality days rather than real time AQI. Then I also performed a correlation analysis to determine the relationship between number of bad air quality days and water turbidity.

RESULTS

Seasonal Water Quality Trends of Lake Tahoe at Ward Creek

Based on the water quality data obtained from USGS, I plotted graphs in terms of water turbidity (FNU) and months of the year. (Figure 2). The graph demonstrates the seasonal trend of the above water quality metrics from 2015 to 2019 in at site Ward Creek North Highway 89 of Lake Tahoe watershed.

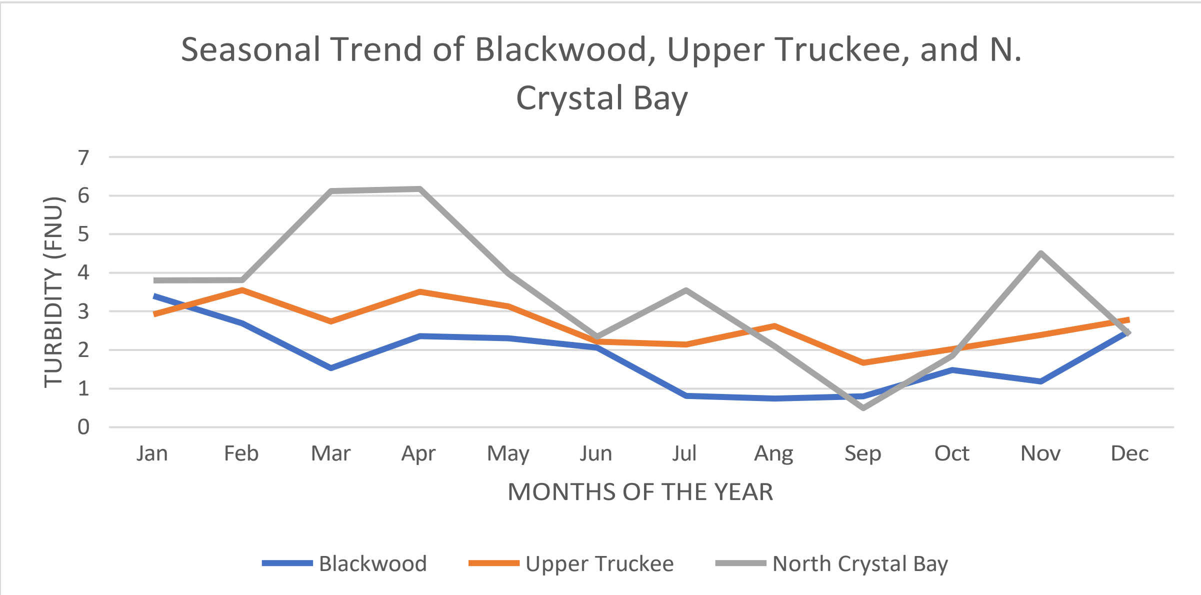
Figure 2. Seasonal trend of water turbidity at Ward Creek.



This graph reveals that in January, February, April, May, and June of the five years of observation that the average water turbidity index is particularly higher, which is 120% to 180% of the annual average of 2.19FNU. This visualization of data gives a clear seasonal trend of water pollution, which shows an overall better water quality in summer and autumn months (July to November).

Seasonal Water Quality Trends of Other Sites of Observations

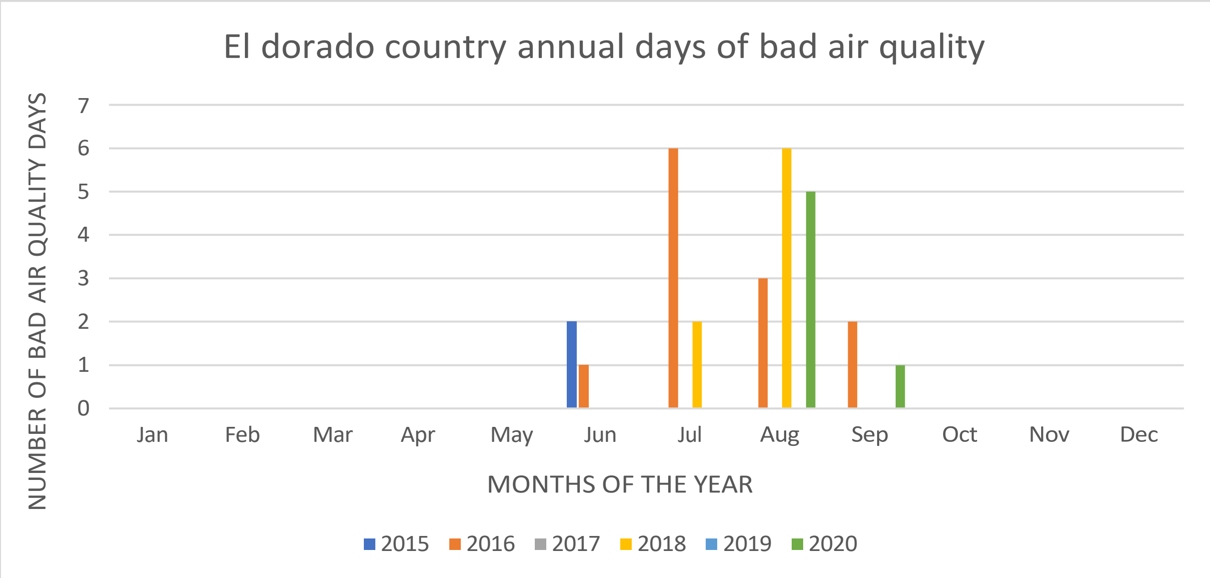
Figure 3. Seasonal trend of water turbidity at Blackwood, Upper Truckee, and North Crystal Bay.



In other sites of USGS water data observation, I did the same data analysis process, but only showing the trendlines in this section. The trendlines also demonstrate a much higher water quality among summer and autumn months. These additional sites are Blackwood, Upper Truckee, and North Crystal Bay (Figure 3)

Airborne Pollutants

Figure 4. El Dorado country annual bad air quality days from 2015 to 2020



I observed that from the AQI data over the past six years, all months with bad air quality days in El Dorado County are in between June and September. (Figure 4) This result shows there is little relevant effect of air quality index on the water turbidity, since the analysis in the previous section suggests the annual water quality is generally better during the period from June to September.

DISCUSSION

In this study, I aimed to trace major sources of pollutants in Lake Tahoe waterbody, and to achieve this goal, I demonstrated the seasonal trends of Lake Tahoe water quality in the past five years and investigated its relationship with the air quality index in El Dorado County. I expected that the seasonal trend of water turbidity would suggest an overall worse water quality in winter and snow-melt season in April to June (which can be slightly different by years), as well as a clear relationship between water turbidity and air quality indices. From the results I obtained from our study, a seasonal trend of water turbidity was conspicuously visualized by graphs and trendlines, yet the simultaneous analysis of water and air quality data did not demonstrate a clear relationship. However, I believe that a future study on the relationship between severe air pollution events such as wildfires and Lake Tahoe water turbidity could better demonstrate the effect of airborne pollutants on water quality.

Water Turbidity Seasonal Trends

From the seasonal trend I plotted in the result section, it is quite clear that for all the four sites of observation, months with higher-than-average water turbidity major fall in the range of March to July, and November to December (Figure 2, Figure 3). This seasonal trend agrees with a 2003 study that analyzed long-term water quality trends since 1967 that the Lake Tahoe waterbody was least transparent during summers, and one of the essential causes is likely to be the accumulation of mineral suspensoids deposited from land. (Jassby et al. 2003).

I can reasonably infer that, due to the high volume of tourism related to ski resorts and casinos during snow seasons, a worse water quality at spring and summer is caused by melting snow and urban sewage drainage. Specifically, besides the accumulation of mineral suspensoids in snow that then brings those suspensoids into Lake Tahoe, such upland drainage could also give rise to the growth of phytoplanktonic algae that results in a significant loss of clarity (Swift et al. 2006). And as I have shown that the water turbidity of Lake Tahoe is especially higher during winters and springs, direct drainage and melt snow are likely to be essential factors of Lake Tahoe waterbody clarity loss.

Synthesis Analysis of Air Quality and Limitations

In this study, our analysis did not demonstrate a clear relationship between the monthly number of bad air quality days and Lake Tahoe water quality. However, research conducted by UC Davis proves that airborne pollutants, especially severe air pollution events like the Angora wildfire in summer 2007, could affect Lake Tahoe water quality significantly (Oliver et al. 2012). This study found that wildfire specifically caused an increase in fine sediments and suspended particles in Lake Tahoe water. However, I did not measure those specific metrics in this study. Hence, I believe that our study did not fully capture the relationship between water quality and air quality.

Prospective Policies

From the tax report of South Lake Tahoe city, the transient occupancy tax and resort fees contribute a considerable portion of the city's gross tax income, which proves that the amount of tourists each snow season is extremely huge. At the same time, current regulations and policies are focusing on the removal of pollutants through geophysical methods in the Lake Tahoe watershed, for example, the Environmental Improvement Program (EIP), the Lake Clarity Crediting Program, and Lake Tahoe Nearshore Evaluation and Monitoring Framework, among other efforts made by regional and federal governments, as well as NGOs like Keep Tahoe Blue (EPA 2011).

However, despite the efforts made by various agencies, the restoration of Lake Tahoe water quality still has a long way to go. Since the best way to mitigate pollution is to prevent its formation, I suggest that the resort fee from ski resorts and nearby hotels can be raised to 18% or more from the current level of 10% to 12%. This additional tax could be helpful in controlling the amount of visitors during peak seasons, and the extra income could be applied to Lake Tahoe water quality programs by the local government, for example, those contributing to the reduction of mineral suspensoids and nutrients that cause eutrophication in Lake Tahoe.

Limitations

Since this study did not come up with a significant relationship between air quality and water turbidity, I hypothesis that below are some potential factors that lead to this result.

1) The air quality data provided by EPA is the average for the entire El Dorado County, where south Lake Tahoe is only a tiny part of it. In this case, the AQI of El Dorado Country may not pertinently reflect the air pollution of Lake Tahoe watershed.
2) The airborne pollutants could take longer time to diffuse into Lake Tahoe waterbody than expected, and depending on the climate and temperature, it is also hard to forecast how much time would be demanded for the airborne pollutants to affect water quality. And this fact would create a time lag between poor air quality events and poor water quality time period that is hard for me to detect in this study.
3) The delayed effect of airborne pollutants on the overall water quality may coincide with the months with higher water turbidity, which makes it hard to observe the actual effect

of air pollution on water quality.

Future Directions and Broader Implications

Considering the limitations of the study of airborne pollutants in this project, I believe that investigating the relationship between wildfires in Sierra-Nevada Region and Lake Tahoe water quality could more precisely reveal the effect of airborne pollutants, which would lead to a better prospective strategy of policymaking. According to the research led by Oliver and Reuter, the severe Angora fire in summer 2007 in the Sierra Nevada region has a complicated influence on the Lake Tahoe watershed. Specifically, this wildfire introduces pollutants, chemicals, as well as extra nutrients to Lake Tahoe waterbody. (Oliver et al. 2012) In this case, it is reasonable that I could connect the severe air pollution events and water quality at that certain time as a more feasible way to investigate the relationship between airborne pollutants and water quality.

As considerable efforts in the restoration of Lake Tahoe water quality have been made by agencies like USGS and EPA, as well as NGOs like Keep Tahoe Blue in recent decades, the decreasing average Secchi Depth has stabilized since 2012. (EPA) However, to further alleviate Lake Tahoe water pollution, it is still significant to limit the amount of pollutants from its source. Hence, along with this study, prospective works on Lake Tahoe pollution management could put more attention on the classification of pollution sources, and therefore help mitigate this issue from the aspect of policy making. Overall, there is still a very long way to go in fully solving this issue, from both the aspects of governments and NGOs.

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