Water Quality Analysis of Water Bodies of the San Bernardino National Forest, California

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Table of Contents

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I would like to thank my advisor, Dr. Jennifer Alford. Not only did she teach me valuable field and lab skills throughout the duration of the internship, she also influenced and supported my decision to continue my education beyond a bachelor's degree. Thank you for sharing your knowledge and helping to prepare me as a move forward in my studies.

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Executive Summary

Participation in water-related recreational activities (i.e. swimming, boating, fishing) are increasing greatly, however, water quality impairments in recreational waters are also increasing. While most of the degradation is attributed to anthropogenic sources, dramatic shifts in climatic conditions exacerbate the water quality impairments. This is of concern because recreational waters provide many benefits including the support of numerous anthropogenic and ecological activities. In addition, the degradation of recreational waters can result in a multitude of public and ecological health issues. Seeley Creek, Lake Gregory, and Lake Arrowhead are three popular inland recreational waters located in the San Bernardino National Forest (SBNF). Due to their proximity to the Inland Empire and several other highly populated regions (i.e. LA), the recreational waters of the SBNF are frequently populated with visitors year-round. As such, this project sought to (1) explore the extent to which human activities, climatic factors, and landscape factors impact the water resources of the SNBF, (2) identify the physicochemical water quality parameters that exceed regulatory standards for healthy water quality as outlined by various federal and state agencies.

Project Objectives

Participation in water-related recreational activities (i.e. swimming, boating, fishing) are increasing greatly with approximately 49.4 million Americans visiting recreational waters in 2018 alone (ASFS, 2019). Recreational waters are diverse, and may include both inland (i.e. rivers, lakes) and coastal waters (i.e. beaches). They provide many benefits including the support of various anthropogenic and ecological needs such as providing potable water and food resources, opportunities for recreation and exercise, and habitats for wildlife and aquatic species. Unfortunately, recreational waterways are subjected to a variety of adverse impairments. Most of the impairments are attributed to anthropogenic sources such as discharge from industrial and agricultural facilities, and waste from failing septic and sewer systems. The excessive nutrients and bacteria pollutants that are introduced into the water, because of these human sources, increase the potential for water impairments such as the formation of harmful algae blooms (HABs), which are a hazard to both human and ecological health (CAWQ 2020a-c). Dramatic shifts in climatic conditions often exacerbate such water quality impairments. For example, stormwater flows occurring during and after precipitation events traverse anthropogenic

landscapes, picking up pollutants from impervious surfaces and related infrastructure (i.e. septic and sewer systems), and deposit the pollutants into waterways. Another example is drought conditions, which reduce flows in headwater streams, and result in reductions in stream segments, lakes, and reservoir levels downstream. The lack of freshwater dilution concentrates pollutants present in the water and increases the potential of various water quality impairments such as the formation of HABs, eutrophication, or hypoxic conditions. The degradation of recreational waters can result in numerous public and ecological implications. It can cause various human illnesses, limit drinking water resources, and limit recreational opportunities. Ecologically, water quality impairments can cause aquatic species to become sick or die (CAWQ 2020a-c).

Seeley Creek, Lake Gregory, and Lake Arrowhead are three popular inland recreational waters located in the San Bernardino National Forest (SBNF). Due to their proximity to the Inland Empire and several other highly populated regions (i.e. LA), the recreational waters of the SBNF are frequently populated with visitors year-round. Seeley Creek, Lake Gregory and Lake Arrowhead are some of the primary contributors to the Mojave River Basin. Spillway water released from the dams of Lake Gregory and Lake Arrowhead become tributary streams, which eventually flow into the Mojave River Basin. Seeley Creek is a tributary stream of Silverwood Lake, a downstream lake utilized for recreation and a reservoir for the California State Water Project. Spillway water released from Silverwood Lake forms to become a headwater stream of the Mojave River Basin.

Each one of these recreational waters provide its own benefits. Visitors go to Seeley Creek to hike, exercise, play in the water, and enjoy the aesthetic qualities of the natural area. Lake Gregory also supports various recreational activities; however, its main attractions are the swimming beach, water park and boat rentals at the southwest side of the lake, and fishing that occurs at all other shorelines. Lake Arrowhead supports similar water-based recreational activities. However, unlike the other two recreational waters, Lake Arrowhead is a primary source of drinking water for the Lake Arrowhead community. All three recreational waters provide habitat for the local flora and fauna species.

Each one of these recreational waters are located within mixed landscapes, which include commercial, residential, and natural land use types. Stormwater and overland flows resulting from precipitation events traverse these landscapes, picking up contaminants, and deposit them

into the SBNF recreational waters. Once in the water, various water quality impairments can emerge, and be exacerbated by climatic conditions. For example, in recent years, HABs were identified in Lake Gregory, causing recreational managers to discontinue all water contact activities as a measure to protect public health. It has been suggested that what use to be a seasonal affair, has become a year-round occurrence due to increasing drought conditions (CAWQ 2020b).

Due to the important role the water bodies of SBNF play in providing water resources, any impairments to them may have adverse local and regional impacts to water resources, and environmental and public health. As such, in an effort to better understand water quality trends occurring at Seeley Creek, Lake Gregory, and Lake Arrowhead, this project sought to, (1) explore the extent to which human activities, climatic factors, and landscape factors impact the water resource of the SBNF, (2) identify the physicochemical water quality parameters that exceed regulatory standards for healthy water quality as outlined by various federal and state agencies. Data collected during this project may offer an opportunity to educate community members and assist resource agencies in developing sustainable water management strategies, so that the water resources of the San Bernardino National Forest can be enjoyed by generations to come.

Working on this internship project has allowed me to use the knowledge that I have acquired through my coursework at California State University San Bernardino and apply it toward real-world situations. While in the field, I was able to learn about hydrology, water quality analysis, and water quality regulations. I also learned many new field methods and laboratory skills, which I believe will be extremely beneficial in graduate school and a career. I believe that I will be able to apply the skills learned throughout this internship toward several careers, including careers with the United States Department of Agriculture (USDA) National Resource Conservation Service, or the USDA Forest Service. Water conservation is a primary goal of both the USDA National Resource Conservation Service, and the Forest Service. Because of this internship, I now understand the importance of water conservation, and I now possess skills needed to practice proper water conservation.

Project Approach

To explore the extent to which human activities, climatic factors, and landscape factors impact the water resources of the SBNF, we collected and analyzed surface water quality data from Seeley Creek, Lake Gregory, and Lake Arrowhead recreational waters. Multiple testing sites were established at each recreational water.

Three testing sites were established along Seeley Creek (labeled HR1-HR3). HR1 was located below Camp Seeley, an LA own camp, and along the trailhead of a hiking trail which follows Seeley Creek downstream. HR2 was also located near the hiking trail, but further downstream than HR1. HR3 was located the furthest downstream. While recreational activities occurred along the entire mileage of Seeley Creek, the stream segment where HR3 site was located was most frequently populated with recreationalist participating in water-related activities. There were four testing sites (labeled LG1-LG4) established at Lake Gregory. LG1 provided the closest access to the swimming beach/waterpark located on the southwestern shore of the lake. LG2 was a BMP outlet located on the southern shoreline where fishing activities occur year-round. LG3 was the BMP inlet located south of LG2. LG4 was located on the northwestern shore near the spillway dam that "creates" Houston Creek. Because Lake Arrowhead is a private Lake reserved for residents only, no testing sites were established along the actual shoreline of Lake Arrowhead. Instead, we established three testing sites, each one at one of three tributary inlet streams of Lake Arrowhead (labeled LBC, BMC, and OC creeks). LBC ran through a commercial area before entering Lake Arrowhead. BMC ran through mixed commercial and residential area, and OC ran through primarily residential area before entering Lake Arrowhead.

Testing for each site occurred bi-weekly during the dry season. However, during the wet season, testing occurred more frequently so that water quality trends occurring around precipitation events could be documented. The climatic data will be used to find correlations between climatic variations and the surface water quality data collected from each of the testing sites.

While in the field, we tested each site for several water quality metrics using Vernier LabQuest 2 instrument probes. The water quality metrics tested included dissolved oxygen (DO), pH, conductivity, ammonium (NH_4^+), nitrate (NO_3^-), and turbidity. Additional grab samples were also collected in the field at each site, but later tested in a laboratory for total coliform (TC),

and Escherichia coli (E. coli). The water quality metrics used to test the quality of the recreational waters were chosen because of the health and environmental implications they pose. For example, DO is a measure of the amount of dissolved oxygen in the water. DO levels above 4.0 mg/L are required for the survival of fish and other aquatic species. Recreational waters that become depleted of dissolved oxygen become less able to support aquatic life (USGS, 2006). Total coliform is also an important metric to measure because total coliform counts give a general indication of the sanitary condition of a water resource (NYDH, n.d.). If this metric is detected at high levels, then this can increase the likelihood of people becoming sick when in contact with the water.

While in the lab, we identified which of the above water quality metrics exceeded regulatory standards for healthy water quality. This was done by using the data collected from each testing site and comparing it to water quality objectives outlined by various federal and state agencies, including the U.S. Environmental Protection Agency (EPA), and the California State Water Resources Control Board. Such comparisons were made to determine if the sampled recreational waters of the SBNF were meeting federal and state water quality objectives for public and ecological health.

Project Outcomes

Stay at home orders following the recent coronavirus pandemic caused field testing to end earlier than anticipated. However, enough data was collected, so the team was still able to analyze some of the data remotely.

At this point, results regarding water quality metrics exceedances are only available for Lake Gregory. During the entire study period, there was only one occurrence when dissolved oxygen exceeded its regulatory standard of greater than 4mg/L. The exceedance was due to an individual sampling event in which DO was recorded below 4mg/L. Besides this one occurrence, DO at Lake Gregory was sustained at a healthy level. Numerous individual samples across Lake Gregory testing sites had ammonium and nitrate parameters exceed regulatory standards. EPA Aquatic Life Criteria recommends ammonium fall between a range of 0.02-0.4 mg/L to maintain healthy water quality. Most of the exceedances related to ammonium were because samples were recorded above this criteria range. San Bernardino Mountains Hooks Creek Objectives recommends nitrate fall between a range of 0.8-2.5 mg/L. Exceedances related to nitrate were

because samples were recorded both above and below this criteria range. Excessive nutrients (i.e. ammonium and nitrate) in the water can result in increased plant growth (eutrophication), which may lower DO concentrations and result in hypoxic conditions (USGS, 2006). All Lake Gregory testing sites had some individual samples exceed the California State Water Resource Control Board's regulatory standard for total coliform. Increased inputs of nutrients and bacteria (i.e. total coliform) can lead to increased occurrences of HABs and other water quality impairments.

Both Lake Gregory and Lake Arrowhead were in the center of commercial and residential areas, so they were easily accessible by car. In comparison, Seeley Creek was located primarily in a natural area, so it was less accessible when compared to the other two recreational waters. As a result, our team had to hike the testing gear to and from each Seeley Creek testing site. Oftentimes strong winds or fallen trees prevented the team from reaching and testing the Seeley Creek sites. For these reasons there are periods of missing data for Seeley Creek. Site 3 at Lake Gregory also has periods of missing data, because it frequently went dry in between precipitation events and during mid-summer season. Snow events during the wet season also prevented the team from reaching any of the study sites at the three recreational waters. For all these climatic reasons, there are periods of missing data for the three recreational waters. There were also occasional issues with the water quality analysis probes that caused a loss in data. Besides these drawbacks, water quality data was collected regularly at each recreational water.

Conclusion

This project focused on the collection and analysis of surface water quality data for several recreational waters of the San Bernardino National Forest. Although field testing for water quality is currently paused due to the coronavirus pandemic, there will be further analysis of the data to (1) explore the extent to which human activities, climatic factors, and landscape factors impact the water resource of the SBNF, (2) identify the water quality parameters that exceed regulatory standards for healthy water quality. Analyses on Lake Gregory data have already begun. Seeley Creek and Lake Arrowhead will be analyzed at a later time.

The project has highlighted the importance of comprehensive and site-specific water resource management plans. Such plans should include frequent monitoring of the various water quality parameters, as used in this project, and the inclusion of site specific climatic and

landscape data. Such assessments may assist resource managers in developing and implementing management plans that better protect recreational water resources from further degradation.

Further research may include the identification of water impairment sources occurring at the SBNF recreational waters. For example, much of the residential area surrounding Lake Gregory uses septic systems, which may be the cause of excessive nutrients and bacteria levels that have been recorded in the lake. However, it is difficult to identify the location of the septic system due to a lack of records. If we can figure out which homes are connected to the septic system, then we may be able determine if the local septic system is in fact contributing to excessive bacteria and nutrients in the lake.

I had a very enjoyable and rewarding experience working as a USDA intern. Growing up in the San Bernardino National Forest I feel that this project spoke to the heart of my interests- ensuring the ecological health of my community. I also found this project to be beneficial to my education because it allowed me to apply concepts learned through various courses at CSUSB and apply them toward real-world situations. Working on this project, I was also able to learn new things about hydrology, water quality analysis, and water quality regulation. I believe the skills and knowledge I acquired through this internship will be extremely beneficial in graduate school and a career. I believe that I will be able to apply the skills learned throughout this internship toward several careers, including careers with the USDA National Resource Conservation Service, or the USDA Forest Service. Water conservation is a primary goal of both the USDA National Resource Conservation Service, and the Forest Service. Because of this internship, I now understand the importance of water conservation, and I now possess skills needed to practice proper water conservation.

Appendix

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