City of Lakewood
Volunteer Lake Monitoring Program
2017 Season Report

Introduction

The City of Lakewood's volunteer lake monitoring program began in 2000 with the goal of collecting data to establish long-term trends in lake water quality, provide the citizens and the City with a better understanding of lake processes, and provide information on American, Gravelly, Louise, Steilacoom, Carp, and Waughop Lakes that will be helpful in making appropriate management decisions. While conditions may vary from year to year, long-term data collection is the key to tracking trends in water quality over time.

In 2017, monitoring was conducted on American, Gravelly, Louise, Steilacoom, and Waughop Lakes. Carp Lake was not monitored this year. These lakes vary in size and depth – American Lake is the largest at 1100 acres and 92 feet at maximum depth, Gravelly Lake is 160 acres and 55 feet at maximum depth, Steilacoom Lake is 320 acres and 20 feet at maximum depth, Lake Louise is 39 acres and 35 feet at maximum depth, and Waughop Lake at 33 acres and 14 feet at maximum depth. All of these lakes are located in the Chambers-Clover Watershed within the city limits of Lakewood.

Eighteen volunteers participated in the monitoring program and contributed a total of 145 hours of volunteer time.

Sampling Program

Water chemistry and physical characteristics of lakes vary both seasonally and with depth. Lake volunteers record observations and collect physical data (secchi depth, lake stage, water color, weather conditions); temperature and dissolved oxygen profile measurements; pH measurements; and water samples for chemical analysis (total phosphorus, chlorophyll *a*) once a month from early May through the end of October. An additional monitoring session is conducted on American and Gravelly Lakes once they have completed the fall turn-over, which is generally in late November or early December.

These water samples are collected from one meter (shallow sample) below the surface of the lake. Three times during the monitoring season, vertical profile samples are also collected from the lakes. The profile samples include shallow samples that are analyzed for alkalinity, nitrate nitrogen, nitrite nitrogen, and ammonia nitrogen; mid-depth samples collected for chlorophyll *a* analysis; and deep samples taken one meter above the bottom of the lake and analyzed for total phosphorus, nitrate nitrogen, nitrite nitrogen, and ammonia nitrogen. Waughop Lake is a shallow lake and although the additional shallow samples were collected, the mid-depth and deep profile samples were not collected.

All analyses for concentrations of nutrients, chlorophyll *a*, and alkalinity were performed by Water Management Labs of Tacoma, Washington. Field data collected in 2017 can be found in Table 1.

This report is organized and discussed on the basis of parameters measured and constituents analyzed in 2017, not on the basis of individual lakes. Graphs for individual lakes are included at the end of the report.

Dissolved Oxygen and Water Temperature Profiles

Dissolved oxygen and temperature are important attributes of a lake ecosystem and both are critically important to determining the types of aquatic life found in lakes. The amount of oxygen dissolved in water is affected by the water temperature – all other factors being equal, cold water holds more oxygen than warm water. The amount of dissolved oxygen present in water will determine where in the lake plants and animals can live.

With the onset of warmer weather in spring and early summer, deep lakes will begin to separate into a warmer, low-density layer at the surface, known as the epilimnion, and a cooler, high-density layer at the bottom, known as the hypolimnion. Between the epilimnion and the hypolimnion is a layer of rapidly changing temperature called the thermocline. Thus, begins the process of thermal stratification. Once this condition is fully developed in deeper lakes, usually in summer, there is no vertical mixing of the upper and lower layers because of their density differences. Shallower lakes may also separate into these layers although the layers may not remain separate throughout the entire summer. These shallower lakes will mix on windy or stormy days.

With the arrival of cooler weather in the fall, the thermal stratification begins to break down and the shallow and deep layers of water begin to mix vertically once again. This phenomenon is usually called turnover.

The 2017 temperature profiles for American, Gravelly, Louise, and Steilacoom indicate that they were beginning to stratify thermally in May. American and Gravelly Lakes remained strongly stratified until December. Louise and Steilacoom remained stratified until October as in previous years. Waughop is fairly shallow and did not show any real stratification this past year.

Like temperature profiles, dissolved oxygen levels vary with depth and over time. The upper layer of water (epilimnion) has abundant oxygen as a result of the diffusion of oxygen from the atmosphere and the presence of algae that produce oxygen as a byproduct of photosynthesis. Meanwhile, as spring and summer progresses the lower layer (hypolimnion) has reduced or no oxygen. This is the result of decomposition of organic matter that settles into that layer, no diffusion of oxygen from the atmosphere, and not enough sunlight to support oxygen-producing plant life. These low oxygen conditions will remain until the lake mixes again at the time of fall turnover. These conditions occur even though the general rule is cold water can hold more dissolved oxygen than warm water.

The 2017 dissolved oxygen profiles for American and Gravelly are similar to their temperature profiles and show that stratification was already underway in early May, and that these two lakes remained stratified until late fall. Both lakes also showed a mid-depth increase in oxygen due to the presence of algae undergoing photosynthesis at that depth. Dissolved oxygen profiles for Louise and Steilacoom are also very similar to their temperature profiles and display a smaller mid-depth increase in oxygen due to algal photosynthetic activity. While the dissolved oxygen profiles for Waughop are also similar to its temperature profiles, it does show a decrease in oxygen levels with depth. Individual lake temperature and dissolved oxygen profiles can be found at the end of the report.

Lake Stage

Lake stage, lake water surface level, varies seasonally and also year to year. While precipitation and evaporation are the main causes of fluctuating lake levels, water levels are also affected by watershed area, land uses in the watershed, vegetation types and cover, presence of wetlands, geology, surface and subterranean hydrology, and type of outflow structure (if present). The source, amount, and composition of the water flowing into a lake also impact the water quality of that lake.

Lake monitors recorded lake stage from staff gauges (calibrated in feet) located on American, Gravelly, Louise, and Waughop each sampling session. The staff gauges on American, Gravelly and Louise have been surveyed so that elevation above sea level is known. While there is a gauge on Waughop, its actual elevation with respect to sea level is unknown; therefore, the data presented for that lake reflects relative changes only. Lake stage data for American Lake was directly recorded as elevation above sea level. There is no gauge on Steilacoom.

American, Gravelly, Louise, and Waughop Lakes showed a typical lake stage fluctuation pattern of highest in spring and declining through the summer to a seasonal low in fall. Precipitation data is collected for the Lakewood area at Joint Base Lewis-McChord, and total recorded precipitation for water year (Oct-Sept)2017 was 47.78 inches. Annual precipitation since 2000 is displayed in Figure 1 for comparison. Lake stage this year fluctuated 2.0 ft. in American, 4.97 ft. in Gravelly, 2.93 ft. in Louise, and 3.19 feet in Waughop between May and October (see individual lake level graphs at the end of the report).

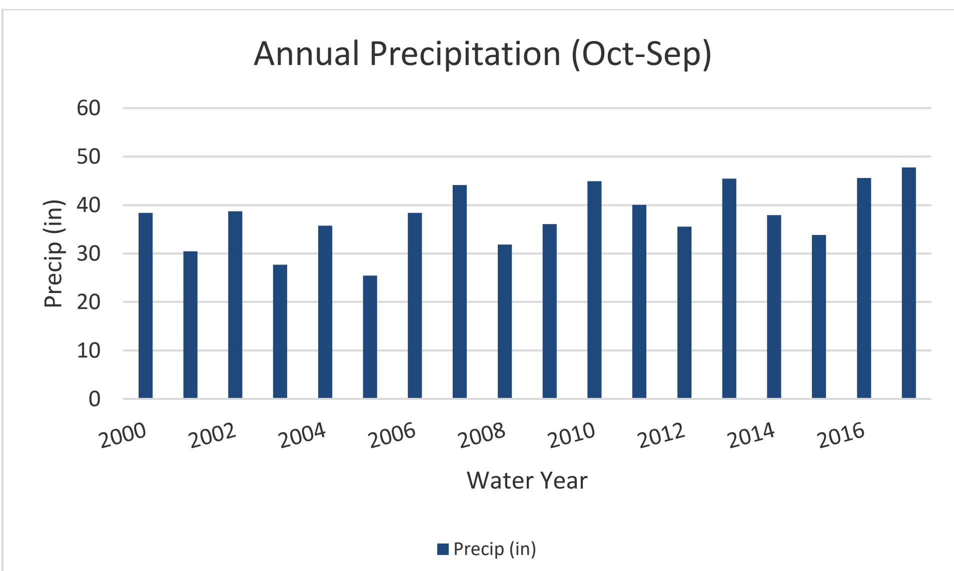


Figure 1.

Water Transparency

Water transparency is measured with an eight-inch diameter, black and white secchi disk and is traditionally reported as secchi depth, in meters (1 meter = 3.3 feet). Transparency is influenced by several factors such as dissolved substances, algae, and sediment particles. Transparency readings can also be affected by waves, wind, and glare at the water surface. Higher secchi depth readings indicate clearer water (more transparent) while lower secchi depth readings indicate more turbid water. Clear water allows more light to penetrate deeper into the lake, allowing photosynthesis in aquatic plants and algae to occur; this leads to higher levels of dissolved oxygen. A decrease in transparency is often seen with an increase in algal density, or an influx of sediment and detritus due to a major storm event in the watershed. Secchi depth is used primarily as an approximate indicator of algal abundance. Secchi depth data for the lakes in 2017 are provided in Figure 2. As shown below, Waughop had the lowest secchi depths while American had the highest secchi depth. Graphs displaying historical secchi depths for individual lakes are included at the end of the report.

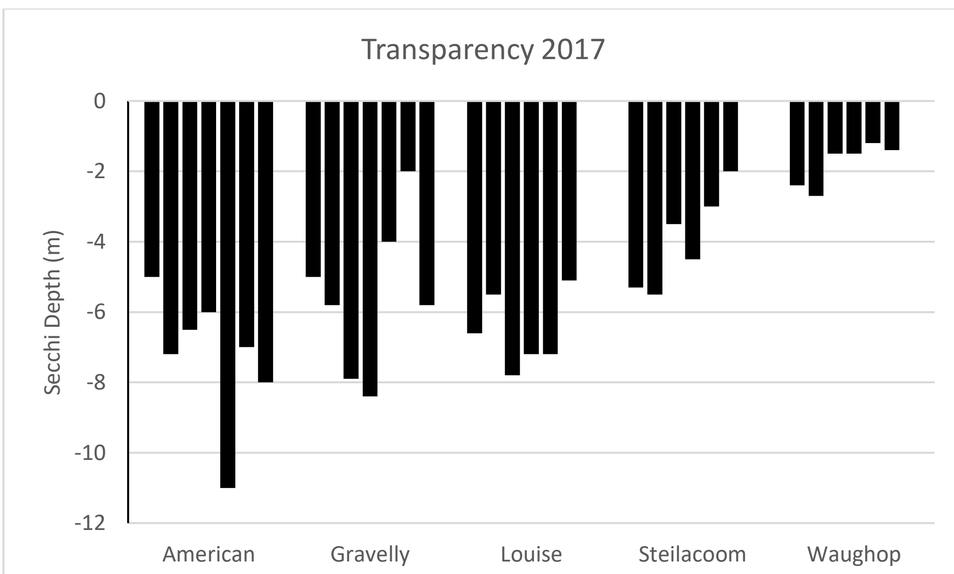


Figure 2.

pH & Alkalinity

pH is a measure of the hydrogen ion concentrations in water and indicates whether water is acidic, basic, or neutral. The pH scale goes from 0 to 14 with 7 being neutral. pH above 7 is considered basic and pH below 7 is considered neutral. The pH scale is logarithmic, meaning that a change of one whole number on the scale is a tenfold change in acidity. pH affects nearly every water function where chemistry is involved.

Beginning in 2017 volunteers measured pH levels at one-meter below the surface each month and at depth (one-meter above the bottom) in May, August, and October. Results of the shallow pH measurement were near neutral ranging to more basic (pH range = 7 to 9.1). The deeper pH results ranged from neutral to more acidic (pH range = 7 to 6.25). Photosynthesis in the upper portion of the lake tend to push the pH levels higher (more basic), and decomposition of organic material at the lake bottom tend to push the pH levels a little lower (acidic). pH results for the lakes are in Table 1.

While pH measures acidity, it does not tell us how well the lake will tolerate addition of acid or alkaline substances. Alkalinity is a measure of the acid-neutralizing or buffering capacity of water. In other words, it is the ability of water to resist changes in pH caused by the addition of acids or bases and is considered the main indicator in susceptibility to acid rain. Aquatic organisms benefit from a fairly constant pH, and to maintain a stable pH, higher alkalinity is preferable. One source of alkalinity is calcium carbonate, which is dissolved in ground and surface waters that flow through rock and soils that contain calcareous minerals. Other sources of alkalinity include certain plant activities and industrial wastewater discharges.

Most streams and ground water in western Washington, where acidic soils dominate, have relatively low alkalinity that range from about 20 to 200 mg/l $CaCO_3$. In eastern Washington, where alkaline soils dominate, the range is from about 100 to 500 mg/l $CaCO_3$.

The 2017 alkalinity concentrations for the lakes is shown below in Figure 3. These results are similar to alkalinity levels in previous years. Louise and Waughop had the lowest alkalinity concentrations while Gravelly had the highest alkalinity. Graphs showing the historical alkalinity concentrations, as well as other chemical data collected since 2000, are included for each lake at the end of the report.

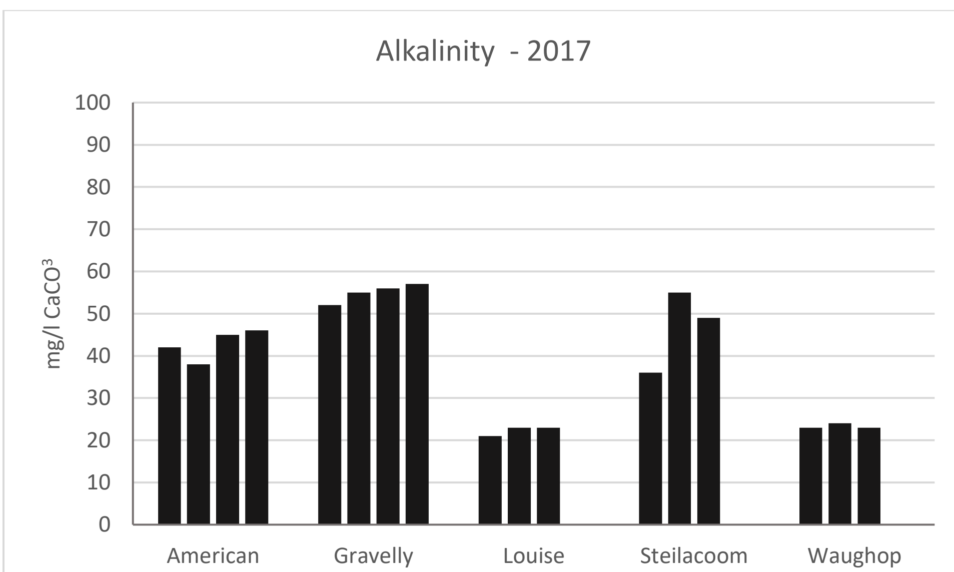


Figure 3.

Nutrients

Nutrients are necessary for the growth of algae, aquatic plants, and fish in a lake. Phosphorus and nitrogen are the main nutrients of concern in a lake system. In many lakes, phosphorus is the limiting nutrient in the system, which means it is only available to plants and algae in very limited quantities; once the limited supply of phosphorus is exhausted, the algal population will stop expanding. However, too many nutrients, especially phosphorus, can create problems leading to unpleasant algae and plant growth. Nutrients enter lakes through stormwater runoff or from streams flowing into lakes. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems, and erosion from land-clearing and construction activities.

In lakes that stratify, phosphorus concentrations in the hypolimnion increase and remain higher there than in the epilimnion until the time of turnover. This increase of phosphorus in the lake's hypolimnion is caused by the decomposition of organic matter and the release of phosphorus from bottom sediments in low-oxygen environments. When mixing eventually occurs in the lake, nutrients that have accumulated in the hypolimnion are brought to the surface and it is not unusual for algal blooms to develop in the epilimnion at this time from the sudden influx of nutrients from below.

The 2017 annual total phosphorus levels for each lake are depicted in Figure 4. The concentrations for each lake are similar to last year's results.

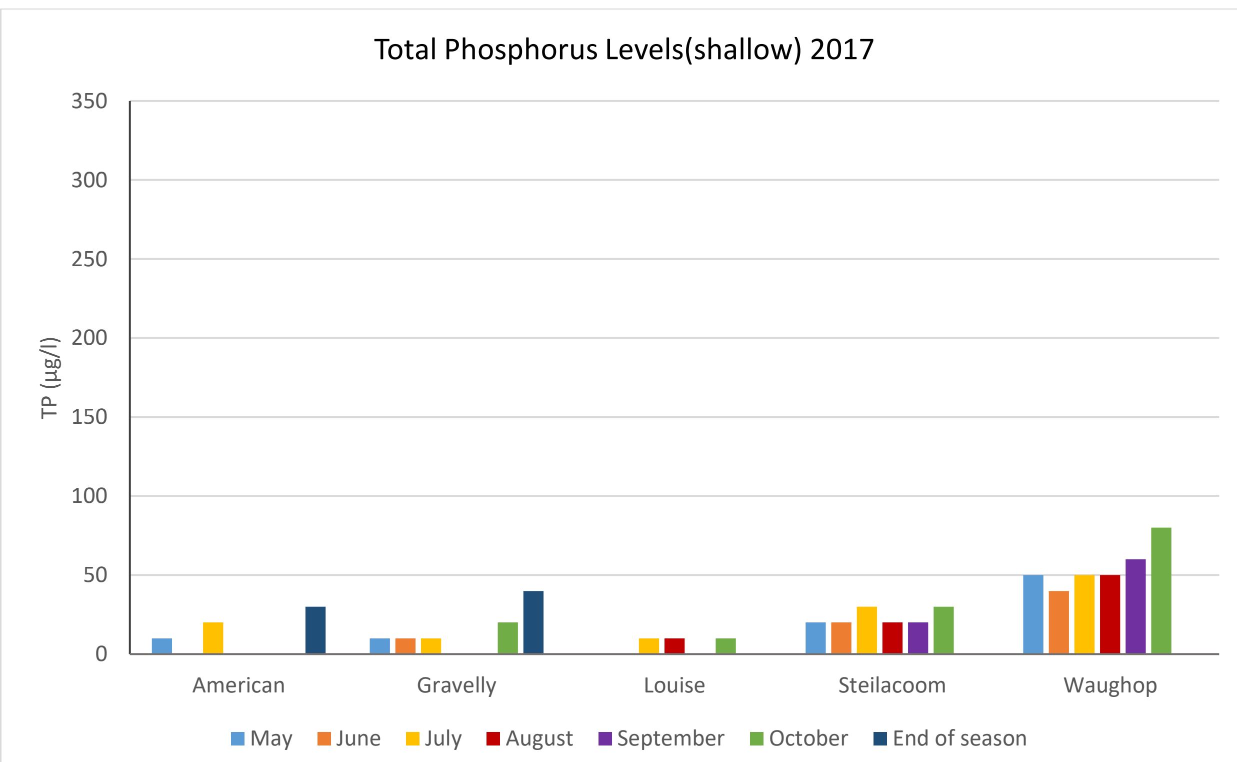


Figure 4.

Total phosphorus concentrations in deep (hypolimnion) samples are generally higher than seen in the shallow samples for the same sampling dates and tend to occur during late summer and early fall when dissolved oxygen concentrations in the hypolimnion were at their lowest. Figure 5 displays the 2017 total phosphorus concentrations for the deep samples. There are no deep samples collected for Waughop. Historical individual lake total phosphorus levels (shallow and deep) can be found at the end of the report.

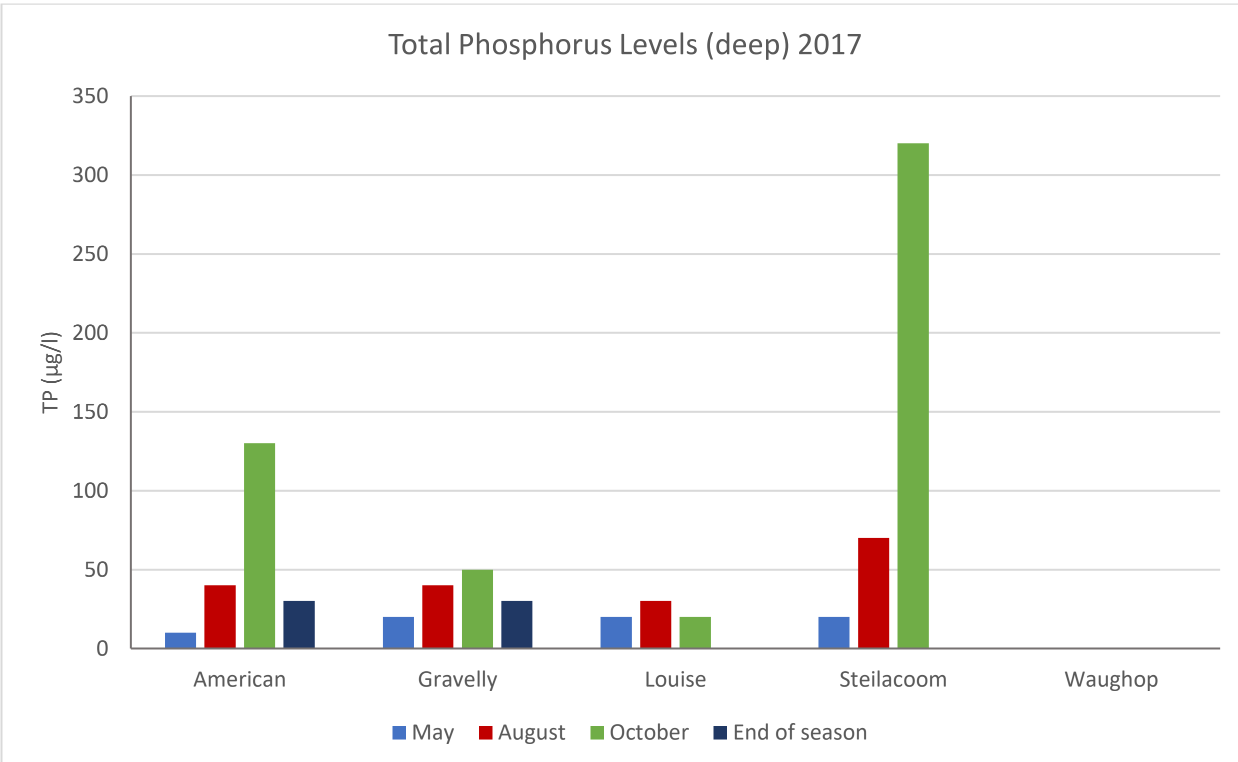
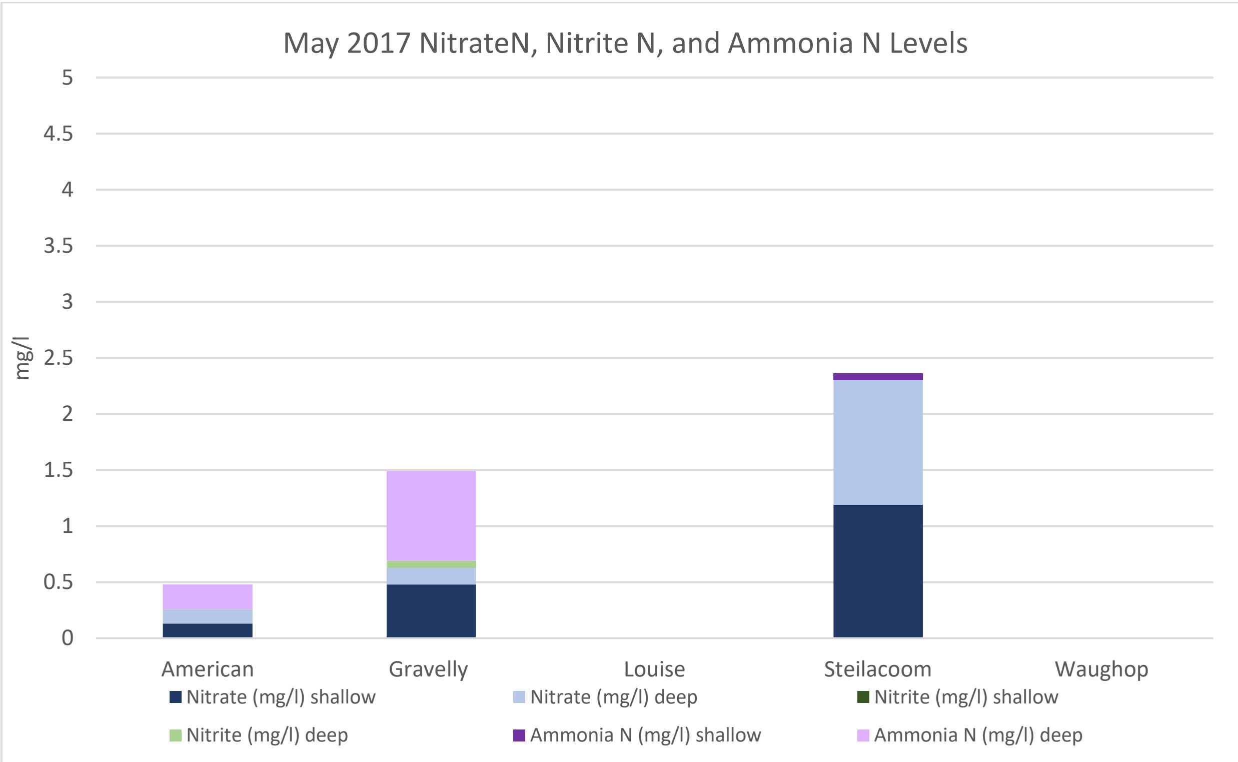
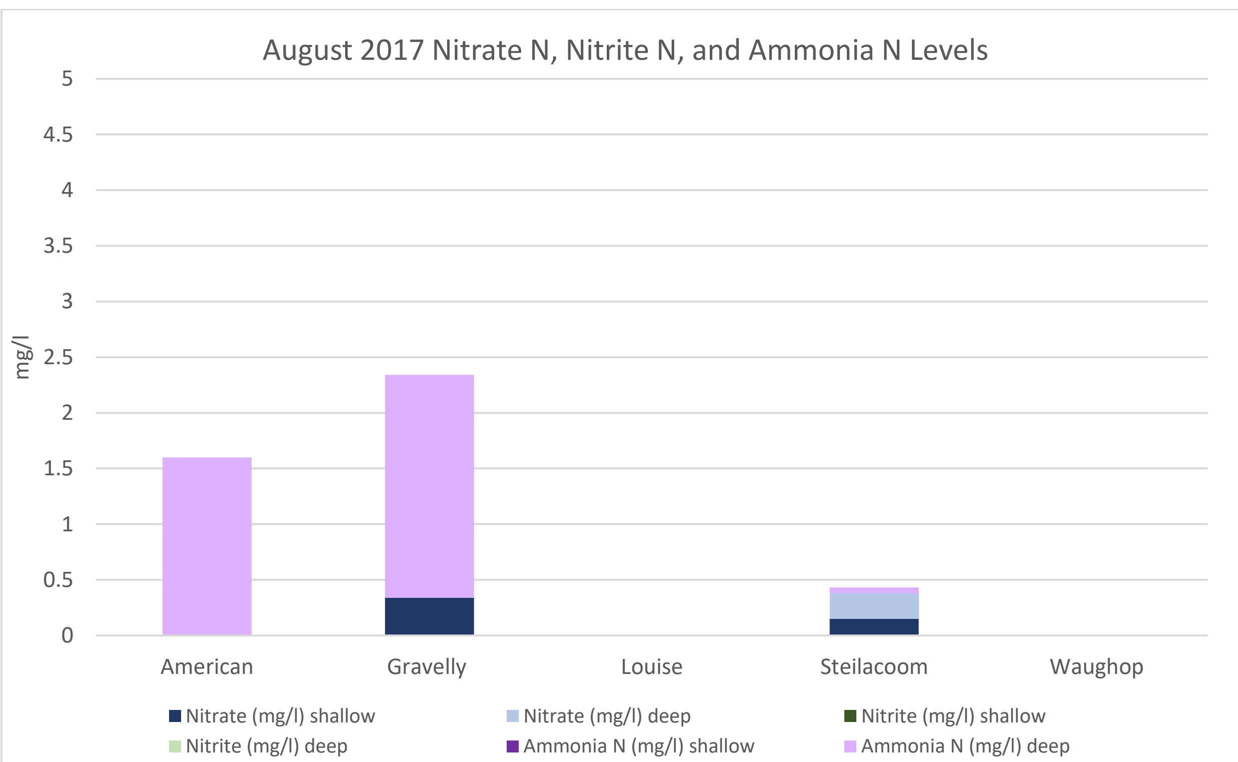


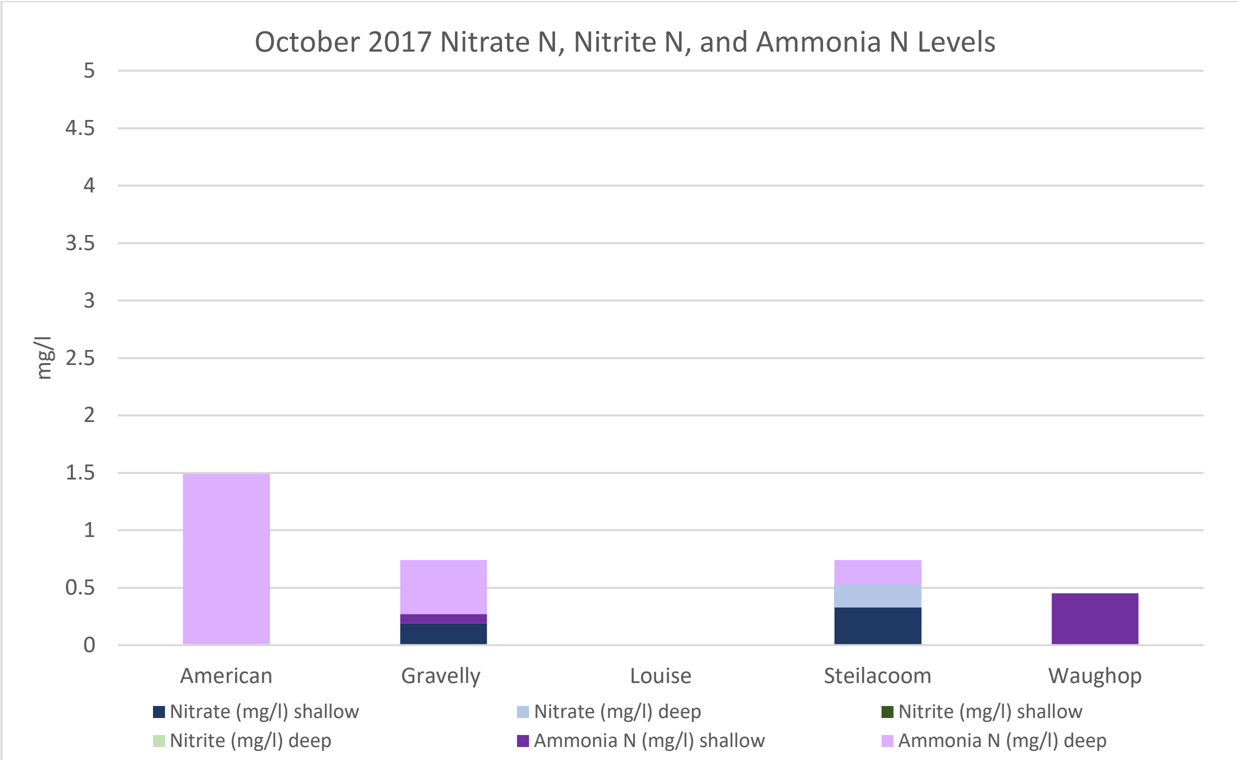
Figure 5.

Nitrogen is usually more abundant in the environment than phosphorus, but can be limiting to algal growth when phosphorus levels are high. Various forms of nitrogen can be found in water. Organic nitrogen includes proteins and amino acids from plants and animals; while inorganic forms include nitrate, nitrite, ammonia, and nitrogen gas (atmosphere) and come from sources other than plants and animals. Generally, algae and plants are able to directly use inorganic forms of nitrogen. Like phosphorus, nitrogen may enter the lake by way of precipitation, stormwater runoff, and ground-water inflow. Sources of nitrogen related to land use practices include fertilizers (from lawns and agricultural uses), animal/pet wastes, and inefficient septic systems. Atmospheric nitrogen can also be used as a nutrient source by some types of cyanobacteria.

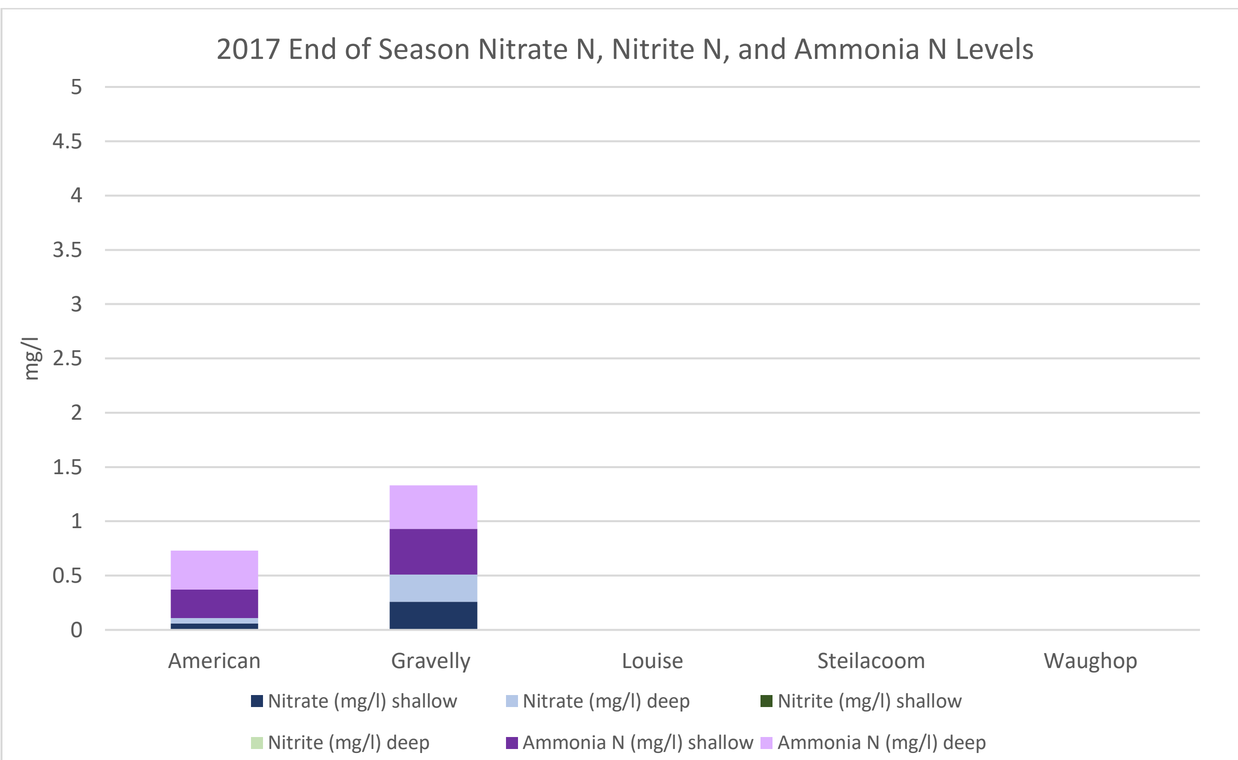
Results for samples collected from the lakes in May, August, October, and December 2017 are found in the Figure 6, below, and for all years of data collection at the end of the report.


May 2017 NitrateN, Nitrite N, and Ammonia N Levels
mg/l
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
American
Gravelly
Louise
Steilacoom
Waughop
Nitrate (mg/l) shallow
Nitrate (mg/l) deep
Nitrite (mg/l) shallow
Nitrite (mg/l) deep
Ammonia N (mg/l) shallow
Ammonia N (mg/l) deep


August 2017 Nitrate N, Nitrite N, and Ammonia N Levels
mg/l
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
American
Gravelly
Louise
Steilacoom
Waughop
Nitrate (mg/l) shallow
Nitrate (mg/l) deep
Nitrite (mg/l) shallow
Nitrite (mg/l) deep
Ammonia N (mg/l) shallow
Ammonia N (mg/l) deep



October 2017 Nitrate N, Nitrite N, and Ammonia N Levels
mg/l
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
American
Gravelly
Louise
Steilacoom
Waughop
Nitrate (mg/l) shallow
Nitrate (mg/l) deep
Nitrite (mg/l) shallow
Nitrite (mg/l) deep
Ammonia N (mg/l) shallow
Ammonia N (mg/l) deep



2017 End of Season Nitrate N, Nitrite N, and Ammonia N Levels
mg/l
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
American
Gravelly
Louise
Steilacoom
Waughop
Nitrate (mg/l) shallow
Nitrate (mg/l) deep
Nitrite (mg/l) shallow
Nitrite (mg/l) deep
Ammonia N (mg/l) shallow
Ammonia N (mg/l) deep

Figure 6.

Chlorophyll *a*

Chlorophyll *a* is one of the green pigments found in nearly all algae. The amount of chlorophyll *a* present is commonly used to estimate the amount of algae in a lake, and to assess the biological productivity (trophic state) of the lake. Test results must be interpreted carefully, however, because algal populations, and therefore chlorophyll *a* levels, typically vary both spatially and temporally, as they are dependent on changing conditions of light, temperature, and nutrient concentrations. For these reasons, it is not at all uncommon for the densest algal concentrations to occur at locations or depths other than pre-determined sampling points. In addition, various species of algae contain differing amounts of chlorophyll per cell; the densest algal populations, therefore, do not always lead to the highest chlorophyll concentrations.

Chlorophyll *a* concentrations for the lakes in 2017 are shown in Figure 7. Levels of chlorophyll *a* are similar to 2016 levels.

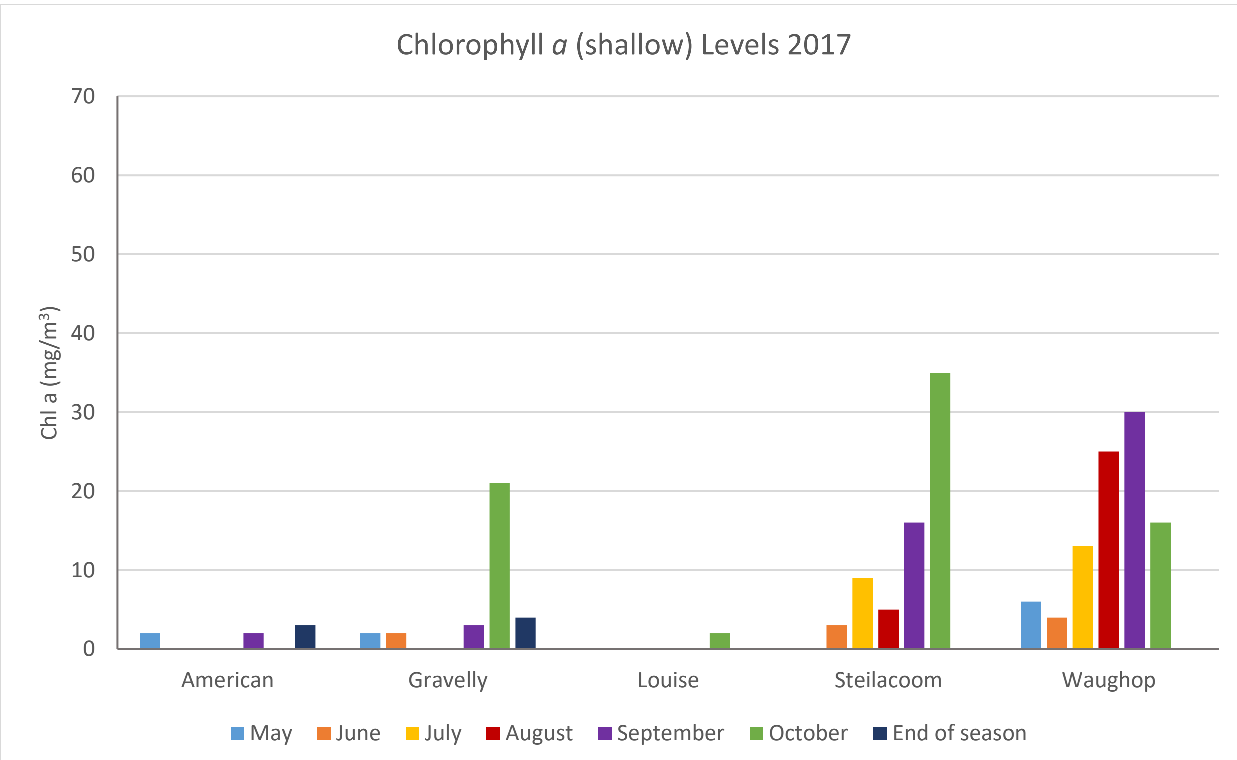


Figure 7.

Chlorophyll *a* concentrations collected at mid-depth in American, Louise, and Steilacoom (the deeper lakes) are shown in Figure 8. Mid-depth samples were not collected in Waughop. Chlorophyll *a* levels are higher for Steilacoom and lower for American and Gravelly in 2017 when compared to 2016 results.

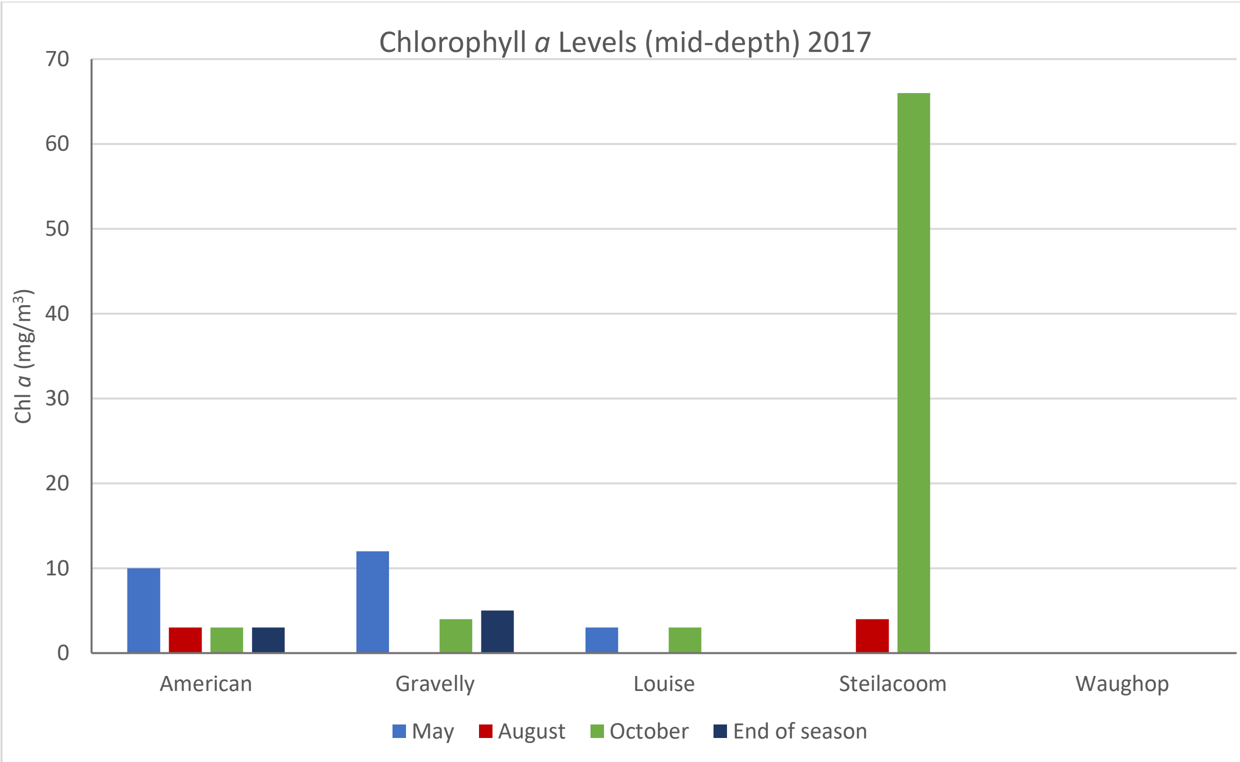


Figure 8.

Trophic State Index

All lakes go through a natural process of aging as a result of enrichment by nutrients and sediment. This process is called eutrophication and as more nutrients and sediment flow into lakes there is increased growth of aquatic plants and algae. Lakes will gradually fill up with organic material over thousands of years.

Lakes can be classified by their degree of eutrophication, also referred to as the trophic state. Lakes are usually classified as being in one of three possible trophic states - oligotrophic, mesotrophic, or eutrophic. Oligotrophic lakes have very clear water, low levels of nutrients, and few aquatic plants and animals. Mesotrophic lakes have more nutrients and tend to support more aquatic plants, and algae, and have lower water clarity. Eutrophic lakes are quite biologically productive and support an abundance of aquatic plants and animals, tend to have frequent algae blooms, lower water clarity, and lower dissolved oxygen in bottom waters.

Cultural eutrophication occurs when the natural aging process is accelerated by human activities in the lake watershed. Stormwater runoff from agricultural areas, fertilized lawns, failing septic systems, logging, urban development, and construction areas all contribute to accelerated enrichment (aging) of our lakes.

The Trophic State Index (TSI), a rating system, is used to determine the trophic state of a lake. The index ranges from 1 to 100 (see Table 2) with low TSI values indicating low biological productivity (oligotrophic) and high TSI (eutrophic) values indicating high biological productivity. TSI values are calculated each year for the lakes based on averaged summer values for secchi depth, total phosphorus, and chlorophyll *a.*

The TSI calculations for the monitored lakes are based on summer (mid-June through mid- September) values of chlorophyll *a*, total phosphorus, and secchi depth. Since 2005, TSI calculations have been determined from the averages of only three sampling results (July, August, and September). Therefore, one dramatically different result can significantly impact the TSI value.

Table 2: Comparison of Trophic State Index to Water Quality Parameters and Lake Productivity

Trophic State	TSI	Secchi Disk (m)	Total Phosphorus (µg/l)	Chlorophyll *a* (µg/l)
Oligotrophic	0	64	0.75	0.04
	10	32	1.5	0.12
	20	16	3	0.34
	30	8	6	0.94
Mesotrophic	40	4	12	2.60
	50	2	24	6.40
Eutrophic	60	1	48	20
	70	0.5	96	56
	80	0.25	192	154
	90	0.12	38	427
	100	0.062	768	1,183

(NOTE: The original source of this table and the equations is Carlson, R.E., 1977. A Trophic State Index for Lakes. Limnology and Oceanography, 22:361-369.)

The 2017 TSI values are displayed below in Figure 9.

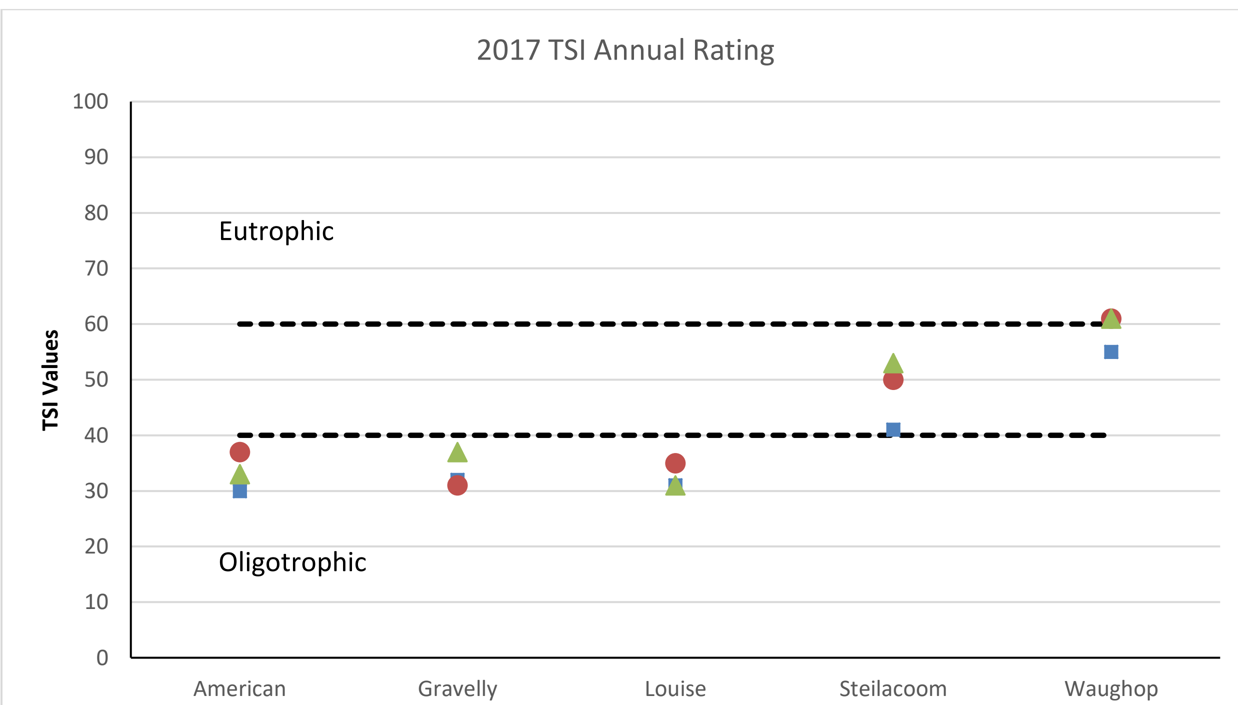


Figure 9.

This year's TSI calculations indicate that American, Gravelly, and Louise are oligotrophic lakes while Steilacoom and Waughop are mesotrophic lakes. Graphs of the TSI values for all years are at the end of the report.

Algae and Invasive Aquatic Plants

The Tacoma Pierce County Health Department has an ongoing program for detecting occurrences of toxic algae and it continues to collect and analyze samples from lakes that show signs of toxic algal blooms. In 2017 a "Caution" advisory was posted on Steilacoom (8/29-11/17) and Waughop (7/3). A sewage spill advisory was also posted on Waughop in early 2017.

Eurasian watermilfoil, an invasive aquatic weed, was detected in American Lake in 2016. The City has received grant funding to develop an aquatic vegetation management plan for the lake.

Considerations

Many lakes suffer from too much phosphorus, which comes from homes in the watershed that drain into the lake. When it rains the phosphorus and bacteria wash into ditches and down storm drains eventually ending up in the lake. This can lead to problems such as excessive algae and plants, lower water clarity, stressed fish and wildlife, and lower property values.

Phosphorus comes from many common household sources like fertilizers, pet and animal wastes, septic systems, and dirt from driveways, roofs, and erosion. Soils in our area are naturally rich in phosphorus.

Lake management is a complicated job and takes the combined efforts of local government, community groups, individuals, and landowners. To be effective lake management is a long-term commitment and investment. Here are some voluntary actions lake watershed residents can take to protect the health of the lake:

- Avoid fertilizer. If you do fertilize choose phosphorus-free products.
- Scoop pet waste, bag it and toss it in the trash.
- Divert runoff from roofs and driveways into stable vegetated areas.
- If you have a septic system, schedule routine inspections.
- Cover bare soil area with mulch or plants.
- Fix eroding areas in the yard, driveway, and parking areas.
- Maintain existing natural shorelines – these areas provide additional wildlife benefits for birds, turtles, frogs and other aquatic life.
- If you are a boater or angler prevent the spread of aquatic invasive species in your lake using the Clean/Drain/Dry method recommended by Washington State Department of Fish & Wildlife. Check here for more information: https://wdfw.wa.gov/ais/youcanhelp.html.