LAKE ROESIGER

REPORT DESCRIPTION

This report is an update on the health of Lake Roesiger based on water quality data collected from 1991 through 2016 by local volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Lake Roesiger, please visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Lake Roesiger is located north of Monroe about seven miles east of Lake Stevens. Several small streams feed the lake. The outlet, Roesiger Creek, flows into Woods Creek and eventually to the Skykomish River. The lake is divided into three basins and has a total surface area of 348 acres. The north basin of the lake covers about 200 acres and has a maximum depth of 33 meters (108 feet). The south basin of the lake covers 104 acres and has a maximum depth of 21 meters (69 feet). The middle basin is about 44 acres in size with a maximum depth of only 3.7 meters (12 feet).

The shoreline of Lake Roesiger is densely developed with permanent homes and seasonal cabins. The watershed, which is the land area that drains to the lake, is relatively small (only 6.3 times the size of the lake) and is comprised mostly of commercial forest lands. Therefore, the lake primarily receives pollution from shoreline development and from commercial logging activities.

LAKE CONDITIONS

Water quality monitoring is conducted in both the north and south basins of the lake. The following graphs illustrate the summer averages and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for each of the basins. Phosphorus data from 1992 through 2000 were collected in a different manner than more recent data, so the two data sets are analyzed separately. Please refer to the tables at the end of the report for long-term averages and for averages and ranges for individual years for each lake basin.

Water Clarity

The water clarity of a lake, measured with a Secchi disk, is a reading of how far one can see into the water. Water clarity is affected by the amount of algae and sediment in the lake, as well as by water color. Lakes with high water clarity usually have low amounts of algae, while lakes with poor water clarity often have excessive amounts of algae.

Water clarity in the north basin of Lake Roesiger is high. The 1991 – 2016 long-term summer average is 5.6 meters (18.4 feet). There has been very little variation from year to year in water clarity and no statistically significant trend up or down between 1991 and 2016. However, the summer averages from 2011 through 2013 were the lowest on record. This could be related to the high levels of algae as indicated by high chlorophyll *a* (algae) summer averages in those years. The water clarity was slightly better from 2014 to 2016.

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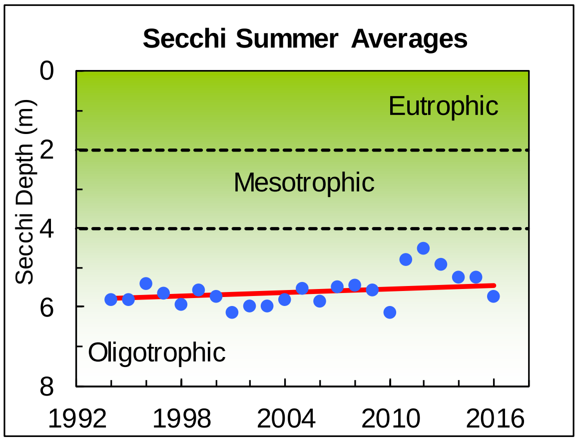
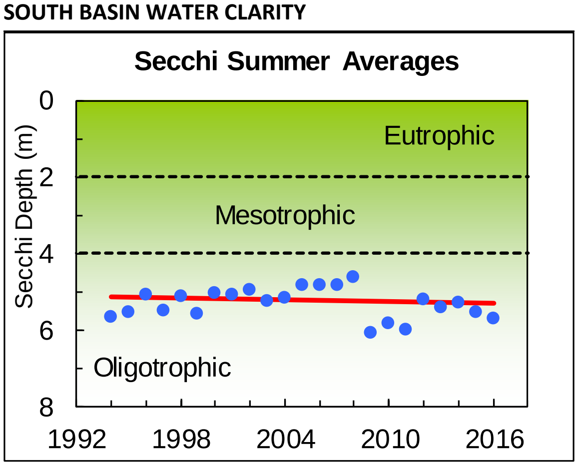
NORTH BASIN WATER CLARITY



Water clarity in the south basin of Lake Roesiger is also high, with a 1992 – 2016 long-term summer average of 5.3 meters (17.4 feet). From 2000 through 2008, there appeared to be a gradual reduction in water clarity. Then, the measurements showed substantially better water clarity in 2009 through 2011. The water clarity summer averages for 2012 to 2016 were closer to the long-term average. Different individuals conducting the monitoring (SWM staff and volunteers) might have affected some of the water clarity measurements.

SOUTH BASIN WATER CLARITY



Water Color

The color of lake water affects water clarity and the depths at which algae and plants can grow. In many lakes, the water is naturally brown, orange, or yellow. This darker color comes from dissolved humic compounds from surrounding wetlands and does not harm water quality. Measurements of true water color provide clues to changes in water clarity. True water color is only the color from dissolved materials and not of the color of algae or sediment suspended in the water.

The water color of Lake Roesiger in 2010 – 2011 averaged 8 pcu (platinum-cobalt color units) in the north basin and 9 pcu in the south basin. Both of these averages indicate a slight amount of color in the lake water, which is not significant enough to affect water clarity or algae growth. However, there was a slight increase in color from a 1972 reading that measured 5 pcu in both the north and south basins.

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Temperature

The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake, and these layers do not mix easily. This process is called stratification and occurs during the warm months. The warm, upper water layer is called the epilimnion. The colder, darker bottom zone is called the hypolimnion. These layers will stay separated until the fall when the upper waters cool, the temperature differences decrease, and the entire lake mixes, or turns over.

From May through October 2016, temperature data were collected at each meter throughout the water column in the south basin of Lake Roesiger. Temperature profiles for 2016 (see graph) show that throughout the sampling season the lake was strongly thermally stratified. This means that there was a large temperature difference between the warm upper waters and the cool bottom waters, and mixing did not occur between these layers. In May, the upper waters measured about 64° F (18°C) in temperature. Temperatures warmed through the summer, and by July had reached a peak of 73° F (23°C). At the same time, bottom water temperatures changed only a little and remained between 42 - 43°F (5-6°C). In September, the upper waters began to cool, and continued to cool off in October. Eventually, the temperatures will be almost equal from top to bottom. As stratification weakens, the lake water will turn over (or mix). The lake will stay mixed during the winter until springtime, when the upper waters begin to warm again.

Dissolved Oxygen

Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished with oxygen because of the separation between water layers. Meanwhile, bacteria in the lake bottom are consuming oxygen as they decompose organic matter. Eventually oxygen is depleted in the bottom waters. Low dissolved oxygen in the bottom waters can lead to a release of nutrients from the lake sediments.

The depth profiles of dissolved oxygen in the south basin measured in 2016 generally correspond with the temperature profiles seen during that time period (see graph). Oxygen levels were relatively high in the upper waters beginning in May. As the water temperatures increased, dissolved oxygen levels near the surface declined slightly because warmer water cannot hold as much oxygen as colder water. From May through August, dissolved oxygen levels increased sharply between 15 and 20 feet deep. This is likely due to vigorous algae growth at the interface between the upper and lower waters. Algae often thrive in this zone because there is available light in the upper waters and higher nutrients available in the lower waters.

During the stratified summer period, oxygen in the lower waters (below about 25 feet) is consumed by the decomposition of organic material within the lake. When the lake is stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or the atmosphere. As the summer progresses, the amount of dissolved oxygen in the bottom waters slowly decreases and the zone of low oxygen expands. The bottom of the lake will remain devoid of oxygen until the lake mixes (typically in late October/early November). The lake then remains mixed through the winter until springtime when the upper waters begin to warm and dissolved oxygen begins to decline again in the bottom.

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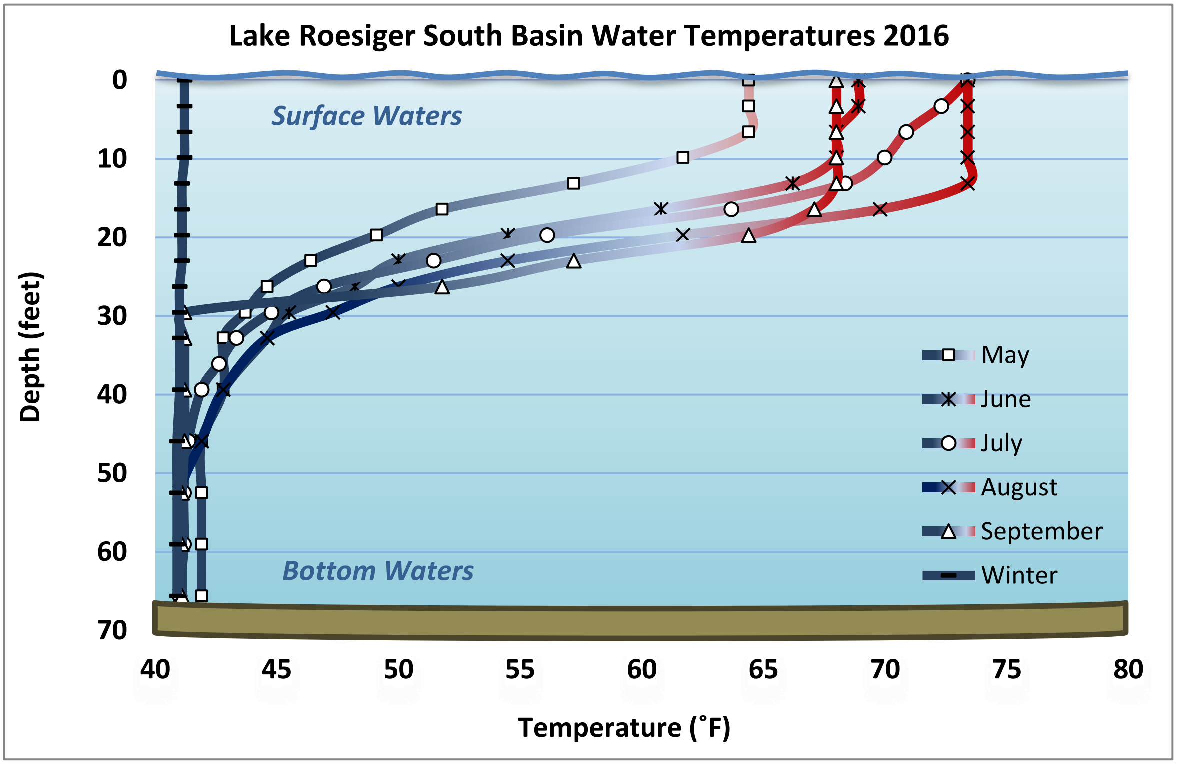

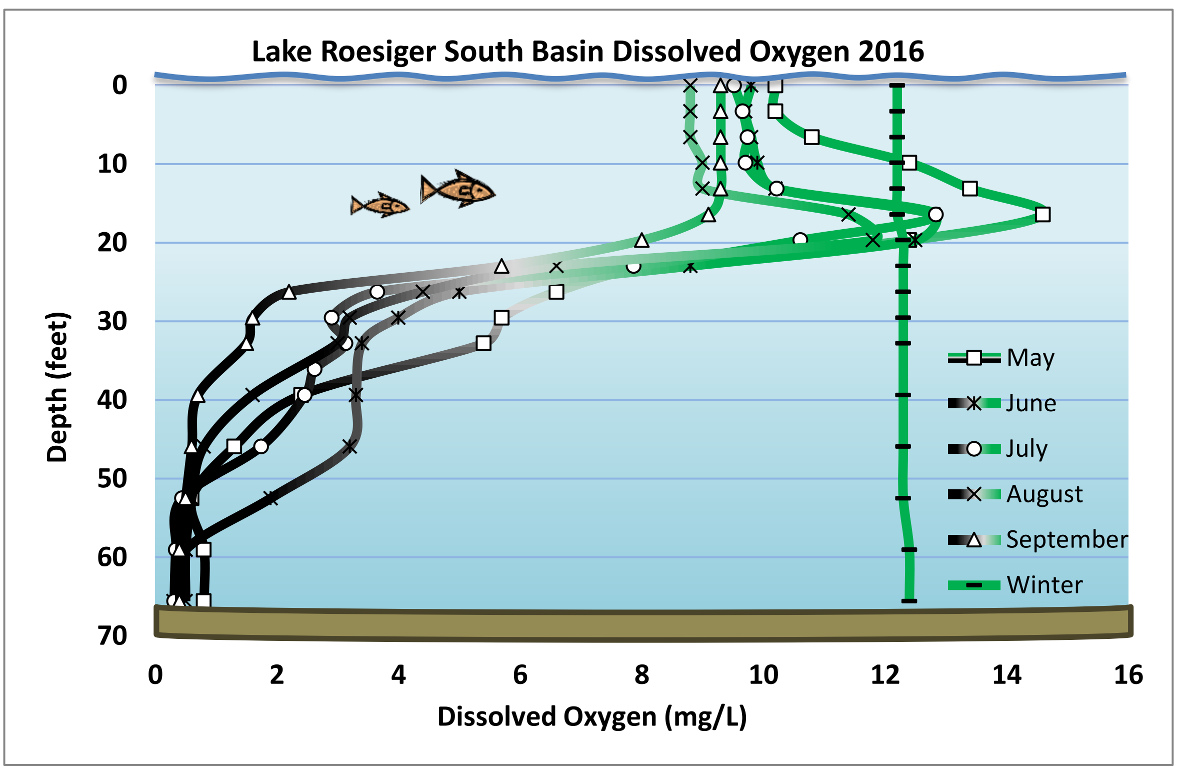

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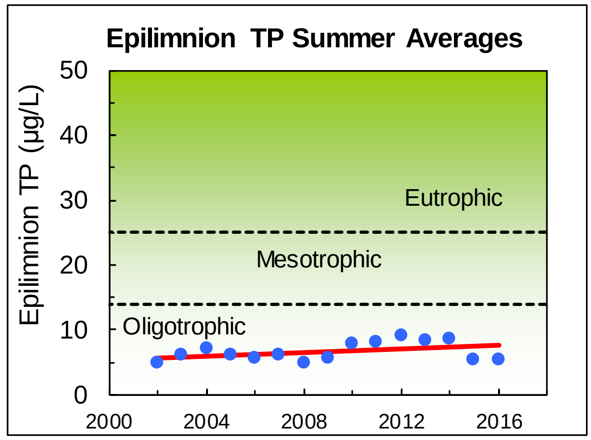
Phosphorus (key nutrient for algae)

Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems and erosion from land clearing and construction. Monitoring of phosphorus levels over time helps to identify changes in nutrient pollution.

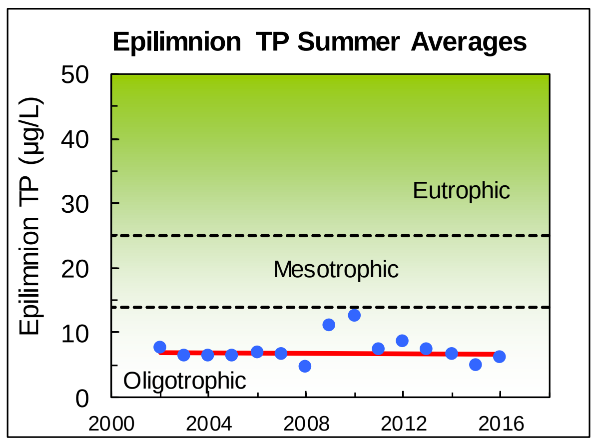
Total phosphorus (TP) concentrations in the epilimnion (upper waters) are low in Lake Roesiger, with little year-to-year variation in either the north or south basins. The phosphorus levels in the epilimnion are actually some of the lowest of all the monitored lakes in Snohomish County.

Between 1992 and 2000, the long-term summer average was 6 µg/L (micrograms per liter, which is equivalent to parts per billion) for the upper waters in both basins. From 2002 through 2016, the overall average has been 7 µg/L in both basins. Between 2002 and 2016, there was a small, but statistically significant, increase in phosphorus in the upper waters of the north basin ($p=0.03$). This trend disappeared in 2016, and corresponded with an apparent increase in algae levels in the north basin, as described below. There has been no statistically significant trend in phosphorus levels in the epilimnion of the south basin, although phosphorus concentrations there were higher in 2009 and 2010 and algae levels are increasing over time.

NORTH BASIN TOTAL PHOSPHORUS – EPILIMNION

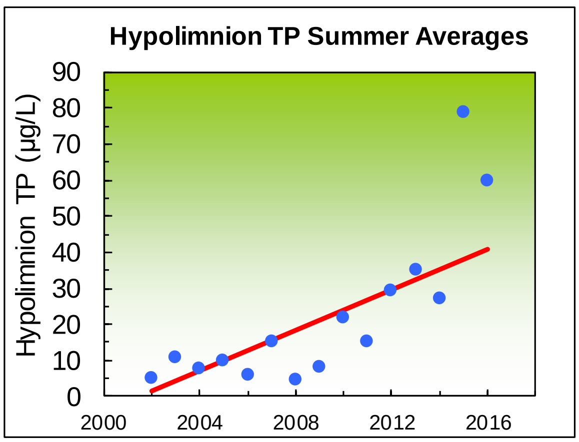


SOUTH BASIN TOTAL PHOSPHORUS – EPILIMNION



Summertime phosphorus averages in the hypolimnion (bottom waters) are also low. In the north basin, the 1992 - 2000 long-term summer average was 13 µg/L, while the 2002 - 2016 long-term average is 22 µg/L. The two time periods are considered separately because samples from the earlier period were taken in a different manner and in some years were taken at deeper depths. Between 2002 and 2016, there has been a statistically significant increasing trend in phosphorus concentrations in the bottom waters in the north basin (p=0.00). The summertime total phosphorus average in the bottom waters during 2015 was 79 µg/L, the highest average on record.

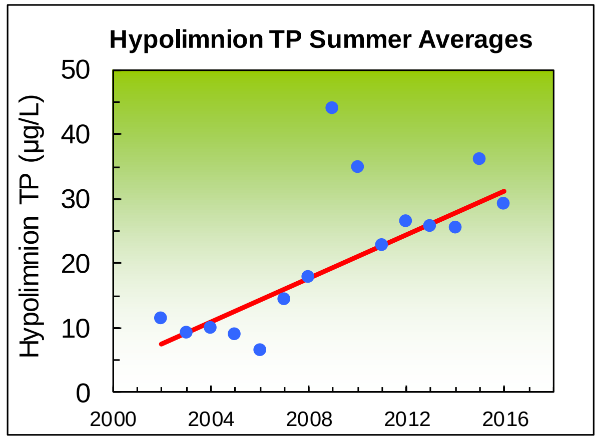
NORTH BASIN TOTAL PHOSPHORUS – HYPOLIMNION



The 1992-2000 summertime phosphorus average in the hypolimnion of the south basin was 22 µg/L. The 2002 - 2016 long-term average is also 22 µg/L. Between 2002 and 2016, there has been a statistically significant trend toward higher phosphorus levels in the bottom waters of the south basin (p=0.01). The summer averages have been especially high in certain years (but the 2009 average was based on a single September sample and the samples have been taken from a slightly deeper sampling depth since 2008). Because of the changes in data collection methods, this trend should be viewed cautiously.

If phosphorus levels continue to increase in the bottom waters of both basins, then it may be a sign that phosphorus is being released from the lake sediments during periods of low dissolved oxygen. Any increases in phosphorus can ultimately lead to more nutrients being available to promote algae growth within the lake.

SOUTH BASIN TOTAL PHOSPHORUS - HYPOLIMNION



Chlorophyll a (Algae)

Algae are tiny plant-like organisms that are essential for a healthy lake. Fish and other lake life depend on algae as the basis for their food supply. However, excessive growths of algae, called algae blooms, can cloud the water, form unsightly scums, and sometimes release toxins. Excess nutrients, such as phosphorus and nitrogen, are the main cause of nuisance algae growth in a lake. Chlorophyll *a* measurements are one method for tracking the amount of algae in a lake.

Chlorophyll *a* values show low to moderate levels of algae in both basins of the lake. From 2002 through 2016, the long-term summer average was 2.7 µg/L in the north and 2.8 µg/L in the south basin. Data from 1992 through 2000 collected by the Washington Department of Ecology showed similar algae levels.

Between 2002 and 2016 there has been a statistically significant increasing trend in

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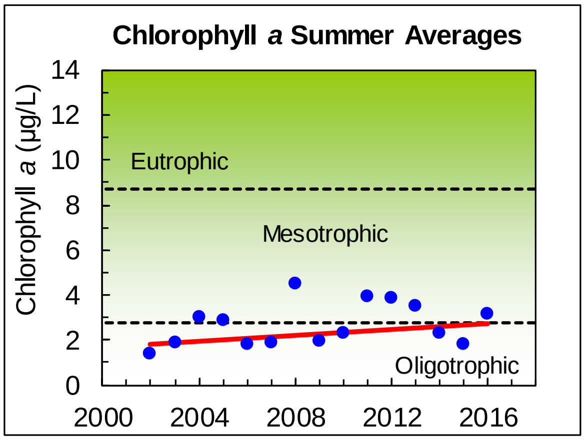
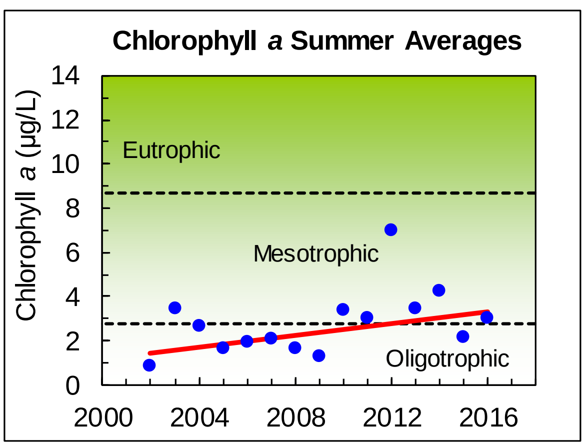
Chlorophyll *a* concentrations in the north basin (p=0.10). Although there has been no statistically significant increasing trend in the south basin, it appears there have been higher chlorophyll *a* averages in some recent years. This corresponds with increases in phosphorus levels in both basins.

NORTH BASIN CHLOROPHYLL *A*



SOUTH BASIN CHLOROPHYLL *A*



Lake Roesiger does have a history of occasional nuisance algae blooms. During the late spring of 2003, the lake experienced a severe algae bloom. The lake turned brown and smelled like dead fish. The bloom lasted for several weeks and was caused by a type of golden-brown algae, *Uroglenopsis.* This species is most prevalent in the spring and is less likely to cause problems during the summer months. Several other lakes in the region experienced similar blooms during the same time period. There was a similar, but much less dense, bloom of golden-brown algae in the spring of 2004. Again, in the spring of 2011, there was a dense bloom of golden-brown algae. These blooms were likely the result of unique weather patterns that favored this particular type of algae rather than evidence of excess nutrients in the lake.

There was also a blue-green algae bloom in the early summer of 2014. Blue-green algae, also called cyanobacteria, are a group of algae capable of producing toxins during periods of high growth. The toxins can cause serious illness in people and pets that come into contact with affected water. Blooms often look like blue or green paint floating on the surface. Lake users should avoid contact with the water and keep pets away from the lake when it is experiencing a blue-green algal bloom. The 2014 algae bloom had very low levels of the liver toxin, microcystin.

Nitrogen (another essential nutrient for algae)

Nitrogen is another important nutrient for plant and algae growth. Similar to phosphorus, lakes with high levels of nitrogen typically have more aquatic plants and algae. From 2014 to 2016, both basins of Lake Roesiger had low levels of total nitrogen (summer averages of 259 µg/L in the north basin and 253 µg/L in the south basin). This is consistent with the low to moderate chlorophyll *a* concentrations measured in the lake basins in 2016.

The relative abundance of nitrogen and phosphorus can also be a useful indicator of lake conditions. This is referred to as the nitrogen to phosphorus ratio or N:P ratio. When lakes have low N:P ratios (typically less than 20), algae growth is often high and harmful blue-green algae blooms may be a problem. Low N:P ratios may also indicate that fertilizers, septic systems, polluted runoff from developed areas, and release of phosphorus from the lake bottom sediments are contributing most of the nutrients to the lake.

In contrast, when lakes have higher N:P ratios (greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. The north basin of Lake Roesiger had a moderate average N:P ratio of 37, and the south basin had an average N:P ratio of 42 in 2016. No nuisance algae blooms were reported in either basin in 2016.

Aquatic Plants

Aquatic plants are also important in a lake ecosystem. Plants provide food and shelter for fish and other aquatic animals, stabilize the shoreline and bottom sediments, and in some cases increase water clarity by out-competing algae for nutrients. Some plants grow entirely submersed under the water (like elodea), some have leaves that float on the surface (like lilies), and others have roots under the water with most of the plant standing above the water (like cattails).

Although aquatic plants are essential for lake health, excess growth of aquatic plants can interfere with swimming, boating, fishing, and wildlife habitat. In addition, invasion by non-native plant species can seriously damage a lake ecosystem. Non-native aquatic plants choke out native plants and form dense stands that are a nuisance to humans and wildlife.

An invasion of Eurasian watermilfoil was discovered in Lake Roesiger in 1998. Milfoil is a non-native invasive aquatic plant that threatens the use and enjoyment of the lake. SWM worked with local residents to secure a grant from the Washington State Department of Ecology to provide initial response to the milfoil infestation.

The milfoil is concentrated in several spots in the south basin and in the middle of the middle basin. There are also scattered plants around the shoreline of the south basin, and to a lesser extent, around the north basin. Each year from 1998 through 2010, SWM conducted diving surveys and performed hand removal of the milfoil. This effort has been able to keep the milfoil in check, but not eliminate it. In 2009, a large new patch was discovered in the south basin. Many of these plants were removed in 2010. Very limited control work occurred in 2011 through 2015. SWM staff and divers returned to the middle and north basins in 2016. A large patch was found and pulled in the middle basin. The western shoreline of the north basin was surveyed and no plants were found. Unfortunately, there is no longer adequate funding to survey the lake and remove milfoil plants each year. Without more funding, it may not be possible to prevent milfoil from spreading around the lake.

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SHORELINE CONDITION

The condition of the lake shoreline is important to understanding overall lake health. As development on a lake increases, lake shorelines typically are modified either through removal of natural vegetation, the installation of bulkheads or other hardening structures, and/or removal of partially submerged logs and branches. These types of alterations can be harmful to the lake ecosystem because natural shorelines protect the lake from harmful pollution, prevent bank erosion, and provide important habitat for fish and wildlife.

Most of the Lake Roesiger shoreline supports dense residential development. In the mid-90s there were 386 homes bordering the lake. There are also 453 docks present on the lake indicating that development likely increased in the past decade. Over half of the lake shoreline (56%) has been armored or modified. Most of the armoring is bulkheads or rock and log revetments. Shoreline vegetation has also been greatly altered—only 20% is still classified as intact native vegetation. The remaining 80% has been altered and, in many cases, replaced by grass lawns down to the shore. Lawns can be a source of nutrients and do not protect the lake as well as a buffer of native vegetation. There is also only a low amount of large wood still remaining in Lake Roesiger (about 98 pieces). These old logs and branches are valuable for fish and wildlife habitat. The high level of shoreline modification leaves the lake susceptible to pollution from the watershed, eliminates the buffer of native vegetation that can filter out pollution, and limits the amount of habitat available for fish and wildlife. The loss of native vegetation along the shoreline can also lead to shoreline erosion.

SUMMARY

Trophic State

All lakes go through a process of enrichment by nutrients and sediment. In this process, known as eutrophication, nutrients and sediment contribute to the ever-increasing growth of algae and aquatic plants. Over thousands of years, lakes will gradually fill up with organic matter and sediments.

Lakes can be classified by their degree of eutrophication, also known as their trophic state. There are three primary trophic states for lakes—oligotrophic, mesotrophic, and eutrophic—as well as intermediate states. Oligotrophic lakes are usually deep, with clear water, low nutrient concentrations, and few aquatic plants and algae. Mesotrophic lakes are richer in nutrients and produce more algae and aquatic plants. Eutrophic lakes are often shallow and characterized by abundant algae and plants, high nutrient concentrations, limited water clarity, and low dissolved oxygen in the bottom waters.

The trophic state classification of a lake does not necessarily indicate good or bad water quality because eutrophication is a natural process. However, human activities that contribute sediment and excess nutrients to a lake can dramatically accelerate the eutrophication process and result in declining water quality.

Based on the long-term monitoring data, both the north and south basins of Lake Roesiger may be classified as oligo-mesotrophic, with high water clarity, low phosphorus, low to moderate algae and low to moderate productivity of plants and algae. The shallow middle basin is more eutrophic and supports dense growths of aquatic plants.

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Condition and Trends

Lake Roesiger is meeting most of its water quality targets of maintaining stable water clarity and low phosphorus levels. Water clarity in both the north basin and south basin has remained stable since the early 1990s.

Overall, the lake also appears to be maintaining low total phosphorus levels. Phosphorus levels in the epilimnion (upper waters) in both basins have remained relatively consistent, but the north basin has shown a statistically significant increasing trend in the recent past. Phosphorus concentrations in the hypolimnion (bottom waters) are more variable, but there are statistically significant trends toward increasing phosphorus in both basins. However, these apparent trends may be influenced by changes in sampling methods and depths. Additional years of consistent data collection will help to determine if the trends are valid. Chlorophyll *a* averages also appear to be increasing, and show a statistically significant trend towards increasing Chlorophyll *a* values in the north basin.

Overall, Lake Roesiger is in excellent condition. The increasing phosphorus levels in the upper and bottom waters are a concern and may be an early warning of accelerating eutrophication that may lead to unwelcome algae growth in the future. The primary threat to lake water quality is any increase of nutrients entering the lake, particularly through new development and from other human activities in the watershed. Measures to control nutrients in the watershed should be taken now to prevent any future negative impacts to the lake. To find out more about ways to protect lake water quality and information on the causes and problems of elevated lake nutrient levels, please visit www.lakes.surfacewater.info

DATA SUMMARY FOR LAKE ROESIGER - NORTH						
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
Bortleson, et al, 1976	**7/25/72**	3.0	29	33	-	-
Sumioka and Dion, 1985	**7/6/81**	5.2	10	10	-	2.3
KCM, 1989	**1988**	4.0 - 7.0 (5.7) *n = 10*	3 - 8 (5) *n = 10*	7 - 97 (22) *n = 10*	-	3.6 - 15 (6.7) *n = 10*
DOE	**1991**	3.4 - 7.0 (5.0) *n = 8*	-	-	-	-
LR Volunteer or DOE	**1992**	4.9 - 6.2 (5.4) *n = 15*	5 - 9 (7) *n = 12*	15 - 32 (21) *n = 10*	-	0.5 - 3.7 (2.2) *n = 12*
LR Volunteer or DOE	**1993**	4.0 - 8.2 (5.8) *n = 12*	2 - 16 (6) *n = 10*	3 - 36 (15) *n = 11*	-	0.7 - 5.9 (2.3) *n = 10*
LR Volunteer or DOE	**1994**	5.2 - 6.6 (5.8) *n = 20*	1 - 27 (5) *n = 12*	3 - 29 (14) *n = 12*	-	1.3 - 5.7 (2.4) *n = 11*
LR Volunteer or DOE	**1995**	4.6 - 7.6 (5.8) *n = 16*	2 - 9 (5) *n = 9*	2 - 22 (11) *n = 11*	-	1.2 - 4.2 (2.4) *n = 9*
LR Volunteer or DOE	**1996**	3.4 - 6.6 (5.4) *n = 16*	1 - 8 (4) *n = 9*	7 - 32 (14) *n = 12*	-	0.5 - 16 (4.3) *n = 9*
LR Volunteer or DOE	**1997**	4.9 - 6.1 (5.7) *n = 7*	3 - 9 (5) *n = 5*	5 - 30 (15) *n = 4*	-	1.5 - 3.6 (2.8) *n = 3*
LR Volunteer	**1998**	5.5 - 6.4 (5.9) *n = 2*	5 - 6 (6) *n = 2*	6	-	1.2 - 2.4 (1.8) *n = 2*
LR Volunteer or DOE	**1999**	4.4 - 6.1 (5.6) *n = 11*	4 - 8 (6) *n = 7*	5 - 16 (8) *n = 8*	-	1.1 - 7.1 (2.8) *n = 6*
LR Volunteer or DOE	**2000**	4.6 - 6.7 (5.7) *n = 5*	4 - 15 (10) *n = 2*	7 - 13 (10) *n = 2*	-	2.7 - 4.8 (3.6) *n = 3*
LR Volunteer or DOE	**2001**	6.1 - 6.2 (6.1) *n = 3*	-	-	-	-
Volunteer	**2002**	4.7 - 7.0 (6.0) *n = 8*	4 - 7 (5) *n = 4*	4 - 6 (5) *n = 4*	-	0.3 - 2.0 (1.4) *n = 4*
Volunteer	**2003**	4.0 - 7.6 (6.0) *n = 6*	5 - 7 (6.0) *n = 3*	8 - 15 (11) *n = 3*	-	1.1 - 2.4 (1.9) *n = 3*
Volunteer	**2004**	4.0 - 7.2 (5.8) *n = 7*	7 (7) *n = 4*	7 - 9 (8) *n = 4*	-	0.7 - 9.1 (3.0) *n = 5*

DATA SUMMARY FOR LAKE ROESIGER - NORTH

Source	Date	Water Clarity (Secchi depth in meters)	Total Phosphorus (µg/L) Surface	Total Phosphorus (µg/L) Bottom	Total Nitrogen (µg/L) Surface	Chlorophyll *a* (µg/L) Surface
Volunteer	**2005**	4.3 - 6.7 (5.6) *n = 7*	4 - 9 (6) *n = 4*	3 - 26 (10) *n = 4*	-	1.1 - 7.2 (2.9) *n = 4*
Volunteer	**2006**	4.9 - 6.5 (5.9) *n = 6*	3 - 8 (6) *n = 4*	3 - 8 (6) *n = 4*	-	1.3 - 2.7 (1.8) *n = 4*
Volunteer	**2007**	4.6 - 6.8 (5.5) *n = 8*	6 (6) *n = 3*	7 - 33 (16) *n = 3*	-	1.6 - 2.1 (1.9) *n = 3*
Volunteer	**2008**	3.6 - 6.8 (5.5) *n = 9*	4 - 6 (5) *n = 4*	4 - 5 (5) *n = 4*	-	1.9 - 12 (4.5) *n = 4*
Volunteer	**2009**	4.9 - 6.7 (5.6) *n = 10*	4 - 7 (6) *n = 4*	5 - 16 (8) *n = 4*	-	1.6 - 2.1 (1.9) *n = 4*
Volunteer	**2010**	5.4 - 8.0 (6.2) *n = 10*	6 - 9 (8) *n = 4*	15 - 27 (22) *n = 4*	-	1.6 - 2.7 (2.3) *n = 4*
Volunteer	**2011**	2.4 - 6.4 (4.8) *n = 9*	6 - 11 (8) *n = 4*	12 - 21 (15) *n = 4*	-	1.3 - 8.5 (3.9) *n = 4*
Volunteer	**2012**	3.2 - 6.3 (4.5) *n = 9*	5 - 14 (9) *n = 4*	14 - 58 (30) *n = 4*	-	1.8 - 8.0 (3.9) *n = 4*
Volunteer	**2013**	4.2 - 6.1 (5.0) *n = 11*	5 - 14 (8) *n = 4*	19 - 81 (35) *n = 4*	-	2.1 - 4.8 (3.5) *n = 4*
Volunteer	**2014**	*3.7 - 6.8* *(5.3)* *n = 11*	*4 - 12* *(9)* *n = 4*	*19 - 39* *(27)* *n = 4*	230 - 277 (255) *n = 4*	*1.3 - 4.4* *(2.3)* *n = 4*
Volunteer	**2015**	3.2 - 6.8 (5.2) *n = 12*	4 - 8 (6) *n = 4*	41 - 127 (79) *n = 4*	159 - 261 (222) *n = 4*	1.3 - 2.3 (1.8) *n = 4*
Volunteer	**2016**	4.3 - 7.2 (5.8) *n = 8*	5 - 7 (6) *n = 4*	31 - 99 (60) *n = 4*	206 - 427 (299) *n = 4*	2.1 - 4.6 (3.1) *n = 4*
Long Term Avg		**5.6** **(1991-2016)**	**6** **(1992-2000)** **7** **(2002-2016)**	**13** **(1992-2000)** **22** **(2002-2016)**	**259** **(2002-2016)**	**2.7** **(2002-2016)**
TRENDS		**None**	**None**	**Increasing**	**NA**	**Increasing**

NOTES

- Table includes summer (May-Oct) data only.
- Each box shows the range on top, followed by summer average in ( ) and number of samples (*n*).
- Total phosphorus data from 1992 - 2000 are from **composite samples** taken at varied depths.
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- DOE = Washington Department of Ecology
- LR Volunteer = Lake Roesiger Resident Monitors citizen volunteer monitoring program

LAKE ROESIGER

DATA SUMMARY FOR LAKE ROESIGER - SOUTH						
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
Bortleson, et al, 1976	**7/25/72**	3.0	5	18	-	-
KCM, 1989	**1988**	4.2 - 6.5 (4.9) *n = 10*	3 - 8 (6) *n = 10*	13 - 56 (35) *n = 10*	-	1.6 - 9.5 (5.3) *n = 10*
DOE	**1990**	-	7 - 13 (10) *n = 2*	-	-	-
LR Volunteer or DOE	**1992**	3.7 - 5.8 (4.6) *n = 11*	4 - 34 (12) *n = 9*	17 - 35 (22) *n = 10*	-	1.1 - 4.1 (2.5) *n = 11*
LR Volunteer	**1993**	4.9 - 7.0 (5.6) *n = 10*	2 - 20 (9) *n = 8*	2 - 27 (15) *n = 8*	-	1.7 - 5.7 (2.9) *n = 8*
LR Volunteer	**1994**	4.6 - 6.6 (5.7) *n = 18*	1 - 8 (4) *n = 10*	6 - 41 (24) *n = 10*	-	1.6 - 4.0 (2.9) *n = 7*
LR Volunteer or DOE	**1995**	4.7 - 6.6 (5.5) *n = 14*	2 - 8 (4) *n = 8*	5 - 42 (16) *n = 13*	-	1.1 - 5.2 (2.8) *n = 8*
LR Volunteer or DOE	**1996**	3.4 - 6.1 (5.1) *n = 14*	1 - 7 (4) *n = 8*	5 - 97 (42) *n = 9*	-	0.6 - 8.8 (3.0) *n = 9*
LR Volunteer or DOE	**1997**	5.0 - 6.2 (5.5) *n = 7*	3 - 5 (4) *n = 2*	5 - 55 (21) *n = 6*	-	2.8 - 5.6 (4.1) *n = 3*
LR Volunteer or DOE	**1998**	4.6 - 5.8 (5.1) *n = 8*	-	-	-	-
LR Volunteer or DOE	**1999**	4.6 - 6.4 (5.6) *n = 9*	4 - 15 (7) *n = 6*	9 - 26 (16) *n = 4*	-	0.7 - 2.7 (1.4) *n = 4*
LR Volunteer or DOE	**2000**	4.6 - 5.3 (5.1) *n = 3*	5 - 12 (7) *n = 3*	16	-	1.9 - 6.9 (4.4) *n = 2*
LR Volunteer or DOE	**2001**	4.6 - 6.1 (5.1) *n = 4*	-	-	-	-
Volunteer	**2002**	4.0 - 5.8 (5.0) *n = 9*	5 - 13 (8) *n = 4*	6 - 26 (12) *n = 4*	-	0.3 - 1.6 (0.9) *n = 4*
Volunteer or SWM Staff	**2003**	2.1 - 6.7 (5.3) *n = 7*	5 - 7 (6) *n = 3*	9 - 10 (9) *n = 3*	-	0.8 - 7.7 (3.5) *n = 3*
SWM Staff or Volunteer	**2004**	4.3 - 6.4 (5.2) *n = 8*	5 - 8 (6) *n = 4*	7 - 12 (10) *n = 4*	-	0.8 - 8.3 (2.7) *n = 5*
SWM Staff or Volunteer	**2005**	3.4 - 6.4 (4.8) *n = 6*	5 - 9 (6) *n = 4*	8 - 12 (9) *n = 4*	-	1.1 - 2.4 (1.6) *n = 4*

LAKE ROESIGER

DATA SUMMARY FOR LAKE ROESIGER - SOUTH						
		Water Clarity (Secchi depth in meters)	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**		**Surface**	**Bottom**	**Surface**	**Surface**
Volunteer	**2006**	4.0 - 6.1 (4.8) *n = 7*	6 - 8 (7) *n = 4*	6 - 8 (7) *n = 4*	-	1.3 - 3.2 (1.9) *n = 4*
Volunteer	**2007**	4.0 - 6.1 (4.8) *n = 7*	5 - 8 (7) *n = 3*	7 - 23 (14) *n = 3*	-	1.6 - 2.7 (2.1) *n = 3*
Volunteer	**2008**	3.7 - 5.5 (4.6) *n = 9*	3 - 6 (5) *n = 3*	3 - 46 (18) *n = 3*	-	1.3 - 2.1 (1.7) *n = 3*
SWM Staff	**2009**	6.1 - 6.1 (6.1) *n = 1*	11 - 11 (11) *n = 1*	44 - 44 (44) *n = 1*	-	1.3 - 1.3 (1.3) *n = 1*
SWM Staff	**2010**	5.3 - 7.0 (5.8) *n = 4*	8 - 22 (13) *n = 4*	28 - 44 (35) *n = 4*	-	2.1 - 4.3 (3.4) *n = 4*
Volunteer	**2011**	5.1 - 7.5 (6.0) *n = 11*	6 - 8 (7) *n = 4*	14 - 35 (23) *n = 4*	-	0.7 - 5.9 (3.0) *n = 4*
Volunteer	**2012**	4.1 - 6.1 (5.2) *n = 12*	6 - 10 (9) *n = 4*	13 - 38 (27) *n = 4*	-	4.1 - 8.6 (7.0) *n = 4*
Volunteer	**2013**	4.7 - 6.2 (5.4) *n = 12*	5 - 10 (7) *n = 4*	16 - 32 (26) *n = 4*	-	1.8 - 5.6 (3.4) *n = 4*
Volunteer	**2014**	4.2 - 6.7 (5.3) *n = 13*	4 - 9 (7) *n = 4*	18 - 32 (26) *n = 4*	238 - 281 (253) *n = 4*	0.50 - 11 (4.3) *n = 4*
Volunteer	**2015**	*4.2 - 6.9* *(5.5)* *n = 11*	*3 - 7* *(5)* *n = 4*	*26 - 43* *(36)* *n = 4*	*167 - 267* *(207)* *n = 3*	*1.1 - 3.2* *(2.2)* *n = 4*
Volunteer	**2016**	3.1 - 7.8 (5.7) *n = 12*	3 - 12 (6) *n = 4*	25 - 36 (29) *n = 4*	160 - 404 (287) *n = 4*	1.5 - 4.3 (3.0) *n = 4*
Long Term Avg		**5.3** **(1992-2016)**	**6** **(1992-2000)** **7** **(2002-2016)**	**22** **(1992-2000)** **22** **(2002-2016)**	**253** **(2014-2016)**	**2.8** **(2002-2016)**
TRENDS		**None**	**None**	**Increasing**	**NA**	**None**

NOTES

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