

# Investigation of trophic changes in Lake Minnewaska, a pristine sky lake in Ulster County, New York

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## Introduction and Methods

Lake Minnewaska is a central feature of Minnewaska State Park Preserve in New Paltz, NY. In the 1990s and early 2000s, Lake Minnewaska was considered to be a relatively pristine sky lake - water clarity was very high, pH and nutrient levels were low, and the lake had a unique, beautiful turquoise color. The lake also harbored unique biota, most notably a rare moss (*Sphagnum trinitense*) growing in the deeper levels of the lake. High water clarity made Lake Minnewaska a popular recreational diving area. Results from baseline studies clearly show that Lake Minnewaska was oligotrophic. However, over the past decade, increases in pH and phytoplankton have steadily occurred, moving the lake toward mesotrophic conditions. The illegal introduction of two fish species observed in 2008 and 2012 has also had major impacts on the lake's ecosystem.

Basic water quality data have been collected from Lake Minnewaska monthly during the summer in 2000-2006, 2009, and 2011-2015. Lake Awosting, another lake within the park, has also been monitored during the summer months in 2000-2006, 2009, and 2012-2015; it has been seen as a control lake because its water chemistry has remained relatively stable over time. Data collected includes chemical, biological, and physical parameters such as water clarity (Secchi depth), phytoplankton, chlorophyll *a*, and nutrients. Nutrient samples have also been collected from near bottom waters. In response to a large phytoplankton bloom in Lake Minnewaska in 2011, monitoring frequency was increased to track trophic changes in the lake.



Lake Minnewaska



Lake Awosting

## Trophic Level Indicators

### Summary:

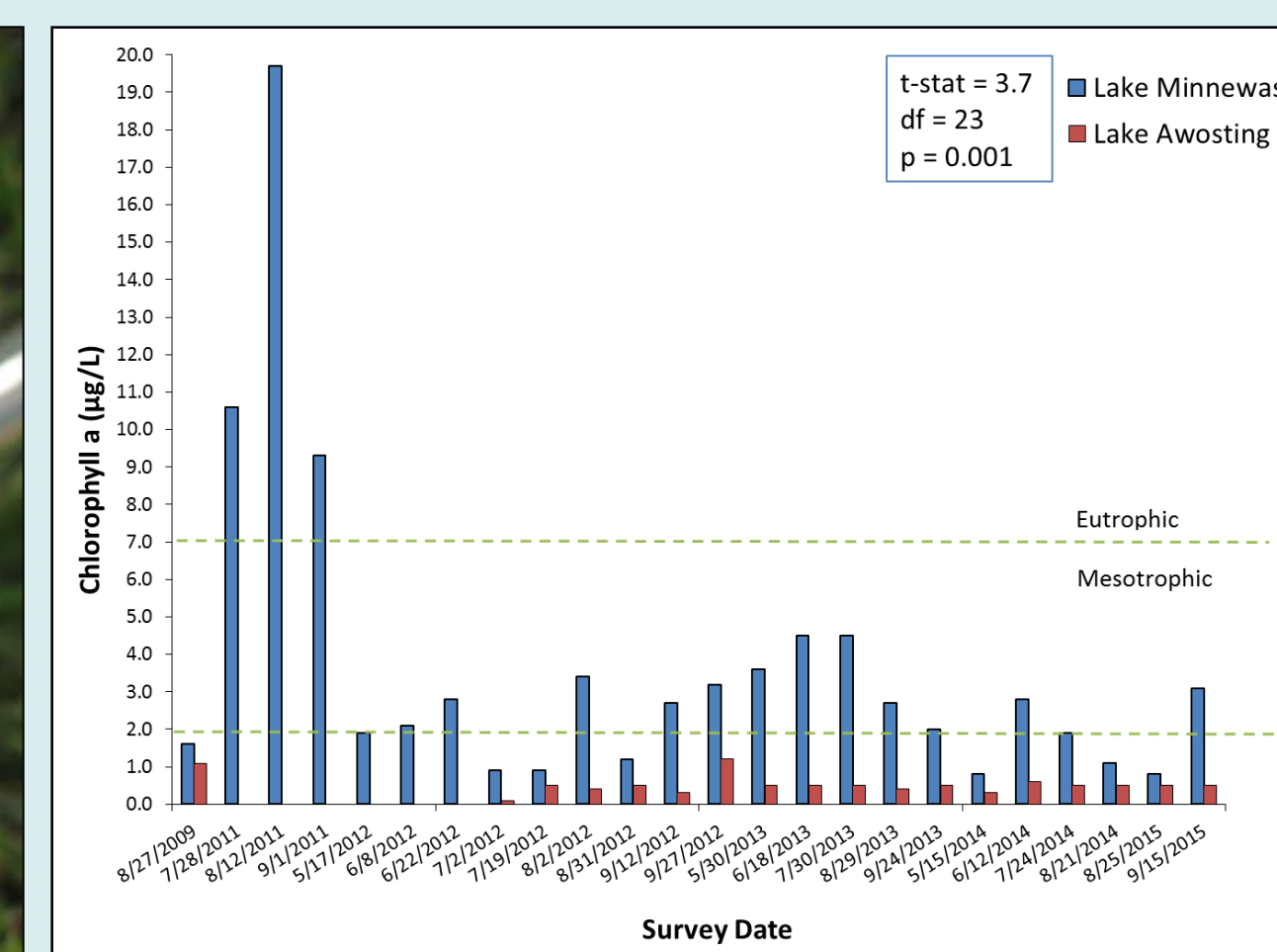
Productivity in Lake Minnewaska spiked in 2011 as evidenced by a phytoplankton bloom identified as *Spondylosium*. Productivity increased again, less dramatically, in 2013. It has since shown a trend back towards oligotrophy, despite a slight increase in chlorophyll *a* in preliminary data for 2015. Lake Awosting experienced only a minimal increase in productivity in 2013 and, for the most part, remains oligotrophic.

### Chlorophyll *a*

In 2009, samples collected from both lakes contained very low concentrations of chlorophyll *a*, indicating low productivity. In 2011, chlorophyll *a* spiked dramatically into the eutrophic range in Lake Minnewaska, with the water taking on a bright green hue (Fig. 1). Concentrations dropped in 2012 (Fig. 2) and, despite small fluctuations, have remained lower, generally in the mesotrophic range, through 2015. Chlorophyll *a* in Lake Awosting has consistently been low, not leaving the oligotrophic range.



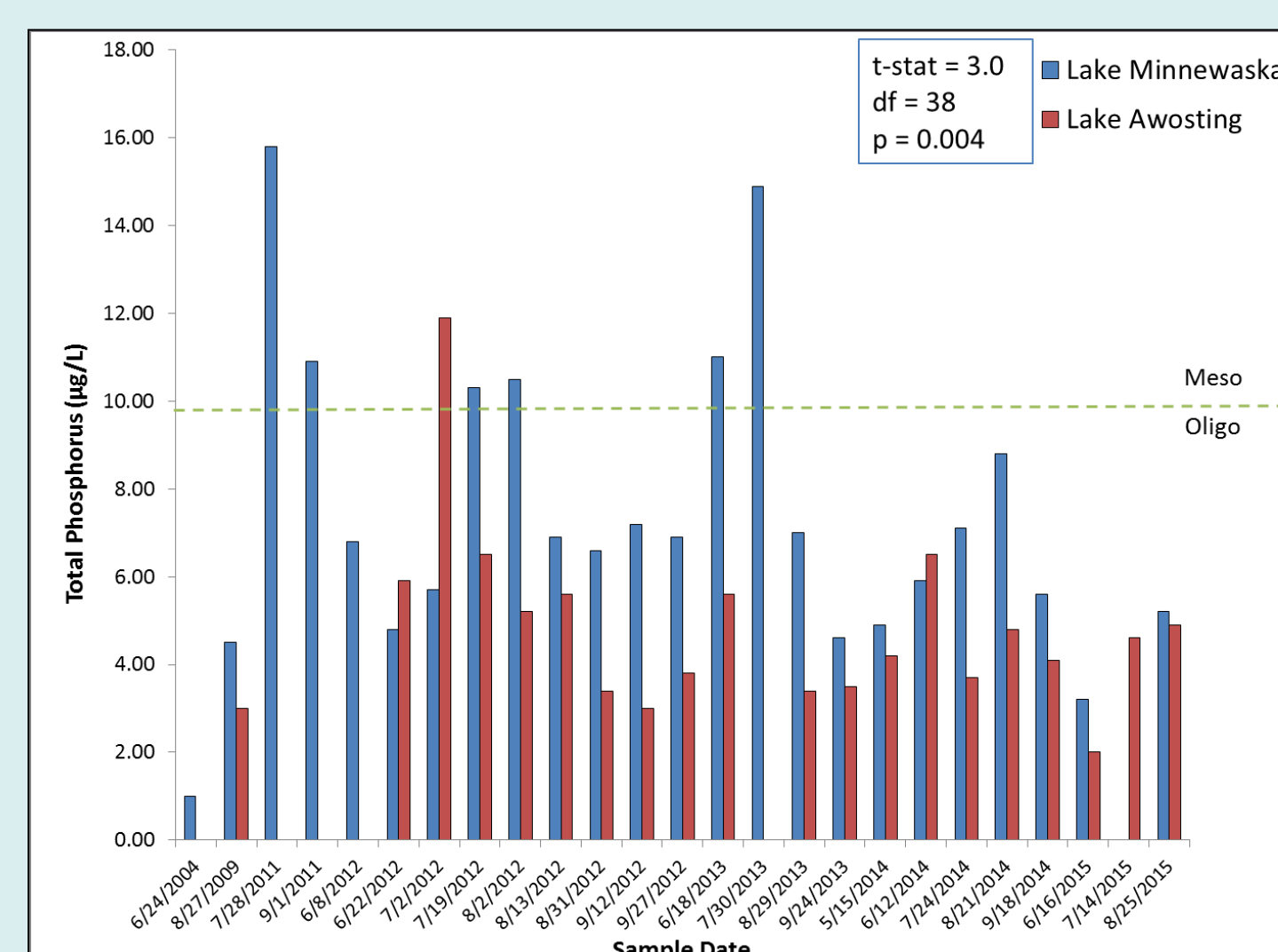
Chlorophyll *a* filter from surface water sample (August 2011).



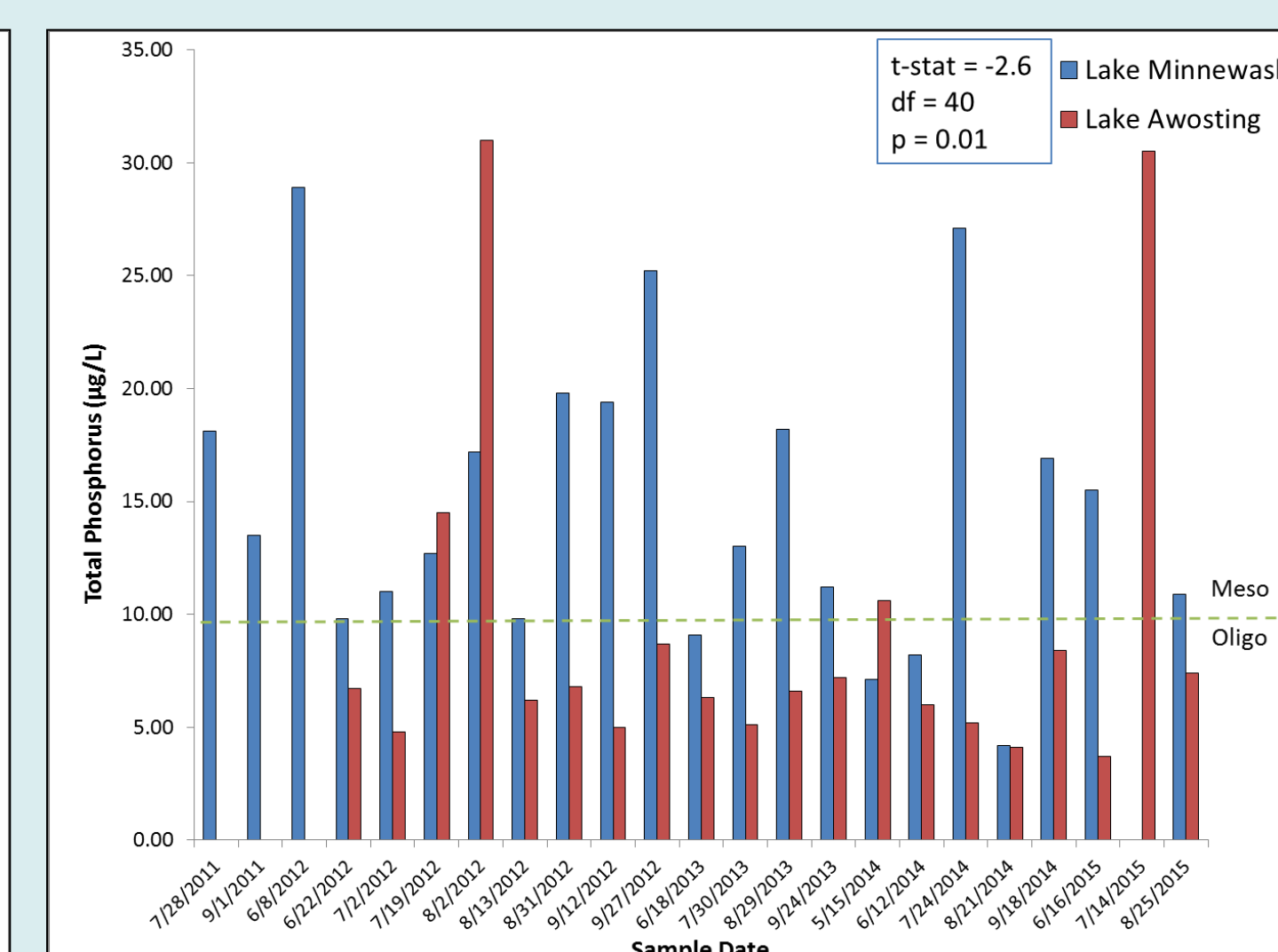
Surface water chlorophyll *a* at Lake Minnewaska, 2009-2015.

### Total Phosphorus

Surface total phosphorus samples collected from Lake Minnewaska in 2004 and 2009 were within the oligotrophic range (Fig. 3). In 2011, 2012, and 2013, total phosphorus rose into the mesotrophic range, but it dropped back into the oligotrophic range in 2014 and 2015. In comparison, surface total phosphorus readings for Lake Awosting have remained within the oligotrophic range. Samples collected from near bottom waters show higher levels of total phosphorus, likely due to migration of nutrients from bottom sediments (Fig. 4).



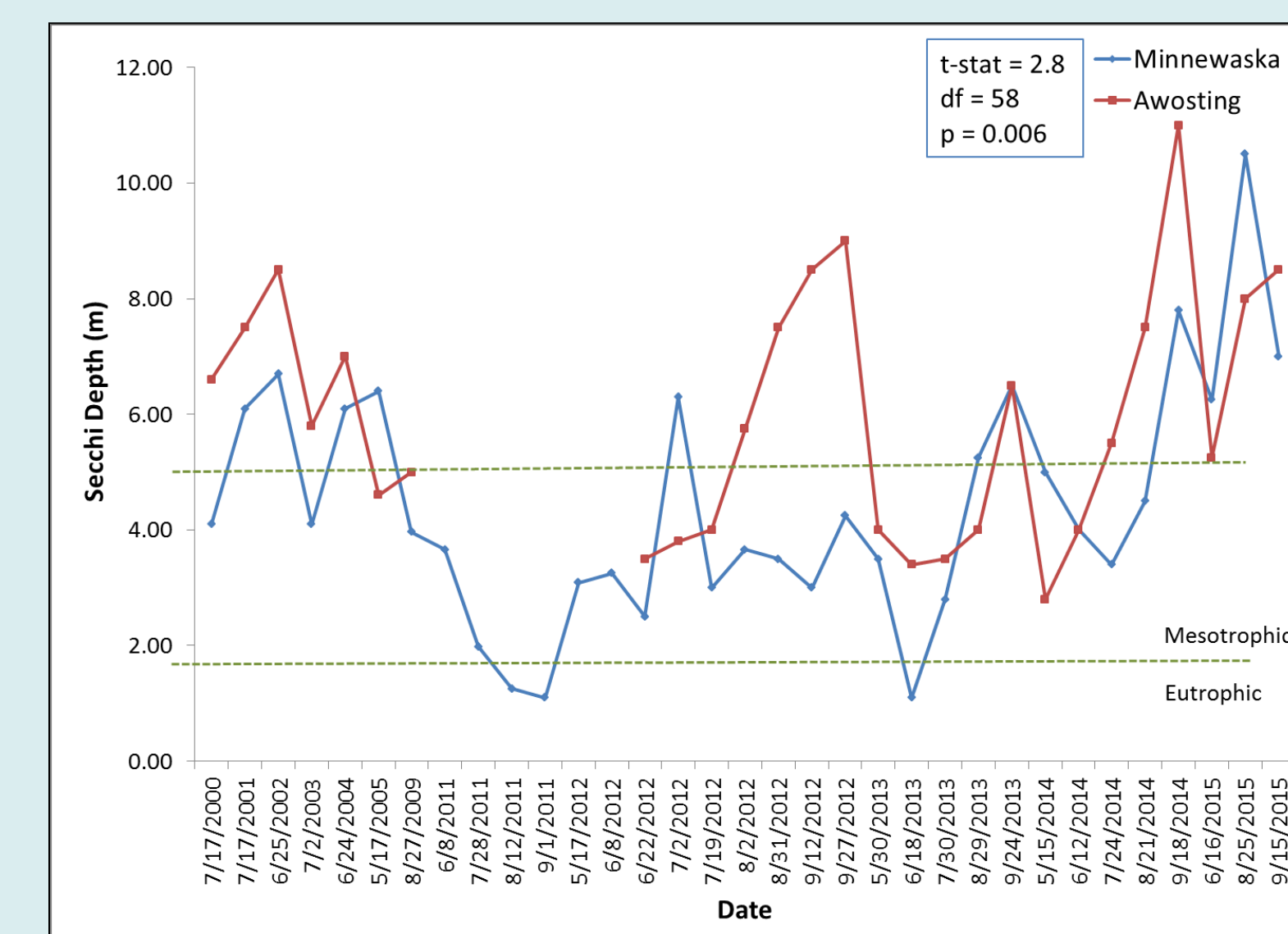
Surface water total phosphorus, 2004-2015.



Bottom water total phosphorus, 2011-2015.

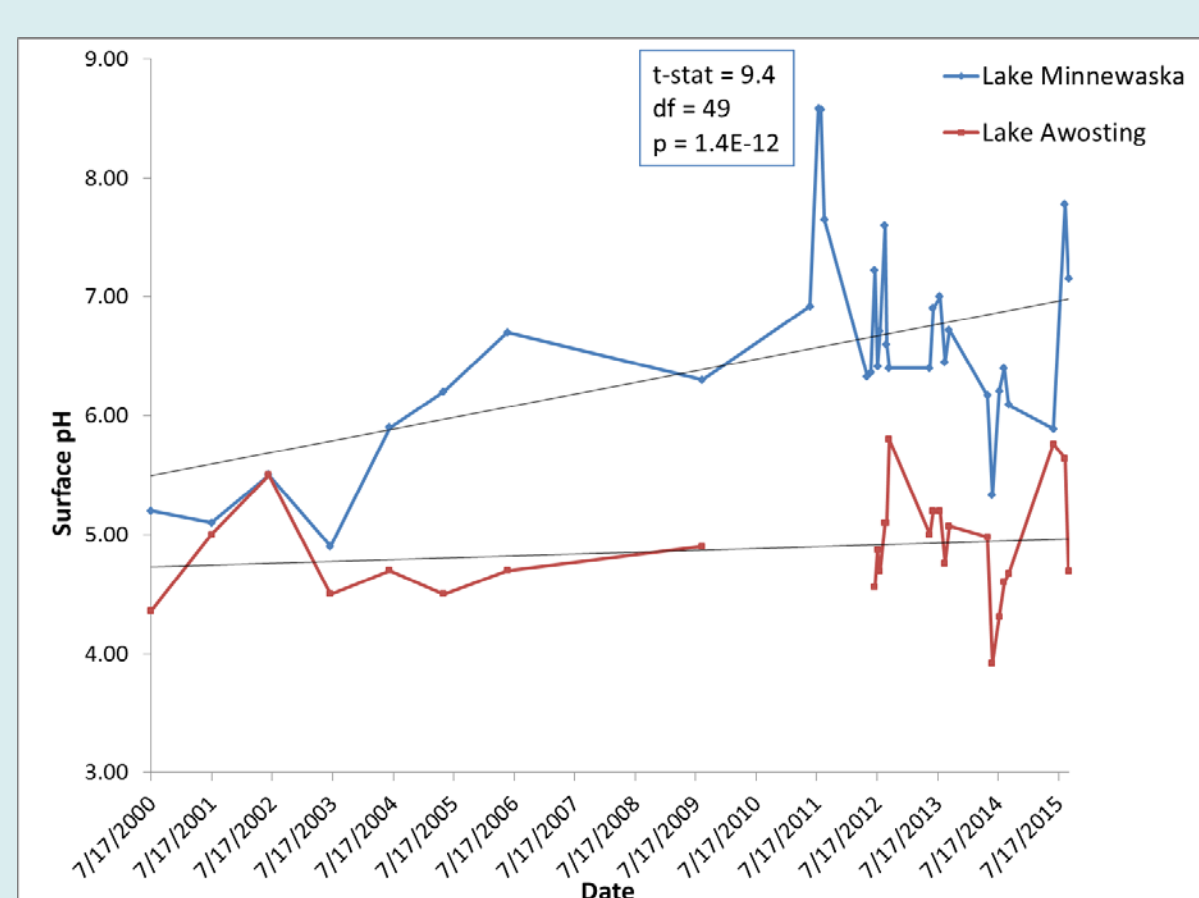
### Water Clarity

Water clarity measurements at both lakes have fluctuated over the past decade (Fig. 5). Water clarity readings at Lake Minnewaska from 2000-2009 were within either the oligotrophic range (>5 m) or at the high end of the mesotrophic range (2-5 m). In mid-summer 2011 and spring 2013, the water clarity of Lake Minnewaska declined to within the eutrophic range (<2 m), which was the lowest clarity ever observed. Readings from 2014 and 2015 indicate a rebound in clarity, however, the current water clarity is still low compared to historic data. For the most part, clarity at Lake Awosting has followed a similar pattern, but it is generally clearer than Lake Minnewaska.



Water clarity measurements (2000-2015).

## Another puzzle: pH

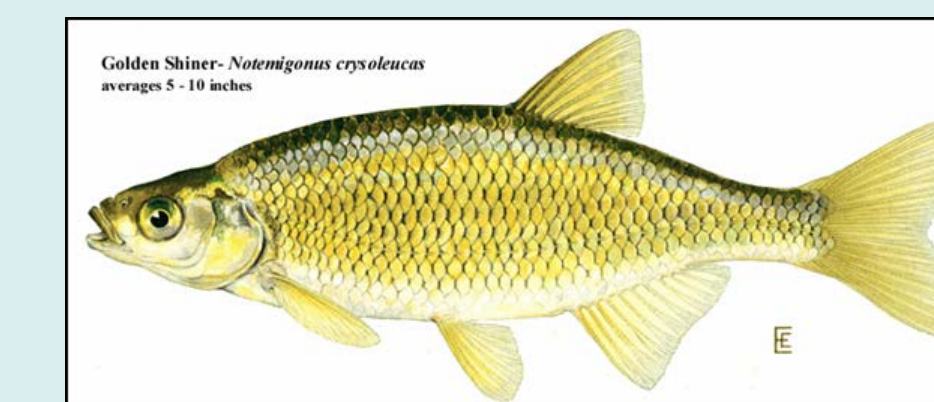


From 2000 to 2015, Lake Minnewaska's pH has been trending up to as high as 8.5, while Lake Awosting has remained relatively constant around 5.0. pH spiked at Lake Minnewaska in 2011 at the height of the algal bloom, and appeared to be decreasing until another rise in late 2015.

Factors could include: increased phytoplankton and photosynthetic activity, effects from shale bedrock, recovery from acid rain.

## Trophic Cascade

The primary factor contributing to the shift in trophic level in Lake Minnewaska was the introduction of a non-native, zooplanktivorous, bait fish species, the golden shiner (*Notemigonus crysoleucas*), which was first seen in 2008. Previously, highly acidic water prevented the survival of fish in the lake. Overall, shifts from oligotrophic-mesotrophic to eutrophic-hypertrophic conditions have been found to correlate with an increase in zooplanktivorous fish biomass (Quiros 1998). An increase in zooplankton herbivory as well as an increase in nutrients from excretion result in greater phytoplankton biomass, which leads to an overall increase in lake productivity.



In 2012, another species of fish, the primarily piscivorous largemouth bass (*Micropterus salmoides*), was first observed in Lake Minnewaska. By 2014, no golden shiners were seen in the lake, presumably all eaten by bass. Research in upcoming years will investigate impacts to the zooplankton and phytoplankton community.

Quiros, R. 1998. Fish effects on trophic relations in the pelagic zone of lakes. *Hydrobiologia* 361:101-111.

## Trophic Cascade, Part 2: Leeches

In 2014, park staff encountered large populations of tiny leeches that attached themselves to the feet of persons entering the water in the bathing beach area. The leech was determined to be a native species in the *Helobdella stagnalis/modesta* species complex. Various control methods were attempted, including bait traps and copper sulfate treatment, with no success. The shallow area of the bathing beach was closed for the entire 2014 season as a result of this "leech bloom." By the 2015 beach season the number of leeches was lower and the beach was able to be reopened following nightly use of plastic sheeting in the shallow area during the pre-season.

This leech species is not a blood-feeder. Rather, it eats small benthic worms (oligochaetes) whose species composition and abundance may respond to changes in trophic condition. Some species of zooplankton eat these oligochaetes, but with golden shiners preying on zooplankton and a shift towards meso-eutrophy, we hypothesize that the oligochaete population experienced a boom. With an abundant food source, the leech population rose as well. In 2015, the leech population may have dropped slightly, and we will continue to track it following the disappearance of golden shiners from the lake.



Feet with *Helobdella* leeches, 2014



## Site Location

Minnewaska State Park Preserve

## NYS Parks Lake Program

NYS Parks' Environmental Management Bureau - Water Quality Unit monitors Lake Minnewaska and Lake Awosting as part of a statewide lake monitoring program. The goal of the lake monitoring program is to collect water quality and aquatic plant data from State Park lakes to assist State Park staff with addressing water quality issues.

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