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

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Introduction
Lake Minnewaska is a central feature of Minnewaska State Park Preserve in New Paltz, NY. In the 1990s and at the turn of this century, Lake Minnewaska was considered a “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 possessed unique biota, most notably a moss (Sphagnum trinitense) growing at the deepest levels of the lake. Two rare salmonid populations were also found at the lake and exhibited unusual breeding behaviors, due to a lack of predators. High water clarity made Lake Minnewaska a popular recreational diving area. Results from baseline studies clearly show that Lake Minnewaska was oligotrophic at the turn of the century. However, over the past decades, increases in pH and phytoplankton have steadily occurred, moving the lake toward mesotrophic conditions. The illegal introduction of two fish species in the past five years has had major impacts to the lake’s ecosystem. In response to these changes, State Parks staff increased monitoring in 2011 and 2012 to assess the changes in trophic level.

Estimating Trophic Level
One of the important steps in assessing the water quality of lakes is to describe its trophic level. The trophic level of a lake is a reflection of its algal productivity. There are three general levels, oligotrophic (low productivity), mesotrophic (moderate productivity), and eutrophic (high productivity). Overall, lake productivity can affect the types and numbers of fish and aquatic vegetation found within a water body. Trophic level is assessed by comparing lake sampling results to NYDEC’s Citizens Statewide Lake Assessment Program (CSLAP) criteria for phosphorus, chlorophyll a (an indicator of algal growth), and water clarity.

Chlorophyll a
In 2009, samples collected from both lakes contained very low concentrations of chlorophyll a, indicating low productivity. Samples collected from Lake Minnewaska in 2011 indicated a higher concentration of chlorophyll a. The higher concentration of chlorophyll a was also visually observed, with the water taking on a bright green color (Fig. 1, 2). Samples were collected bi-weekly from both lakes throughout the summer of 2012, and indicated much lower concentrations of chlorophyll a at Lake Minnewaska (average 1.97 µg/L). The decline in chlorophyll a present in the lake was also observed visually, as the water lost its bright green color.

Total Phosphorus
Surface total phosphorus levels in Lake Minnewaska and Lake Awosting have fluctuated over time (Fig. 3). Samples collected from Lake Minnewaska in 2004 and 2009 were within the oligotrophic range. In 2011, results from total phosphorus samples were within the mesotrophic range. In comparison, surface total phosphorus readings for Lake Awosting have remained within the oligotrophic range. Samples collected from near bottom waters in Lake Minnewaska had higher levels of total phosphorus, most likely due to migration of nutrients from the bottom sediment (Fig. 4).

Water Clarity
Water clarity measurements from Lake Minnewaska have fluctuated over the past decade (Fig. 5). Water clarity readings at Lake Minnewaska from 2000-2009 were within the oligotrophic range (3-5 m) or at the high end of the mesotrophic range (5-8 m). During the same time period, Lake Awosting had even greater clarity. In midsummer 2011, the water clarity of Lake Minnewaska declined to within the eutrophic range (>2 m), which was the lowest clarity ever observed. Readings in 2012 indicate a rebound in clarity. However, the current water clarity is still much lower compared to historic data. Readings in 2012 indicate that Lake Awosting has retained the same level of clarity, with an average of 6.41 meters.

Methods
Data relating to basic water quality has been collected from Lake Minnewaska yearly from 2000-2006, 2009, and 2011-2012. Lake Awosting has been monitored yearly since 2000. 2006, 2009, and 2012 and is used as a control lake for comparison. Data collected includes sampling of the lake’s surface for chemical, biological, and physical parameters such as water clarity (Secchi depth), phytoplankton, chlorophyll a, and nutrients. Nutrient samples were also collected from near bottom waters.

Trophic Level Changes
Based on all available data, it is clear that the current trophic level of Lake Minnewaska reflects an increase in productivity in recent years. Lake Awosting has not experienced an increase in productivity and remains oligotrophic.

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<tbody>
<tr>
<td>Total Phosphorus (µg/L)</td>
<td>2.75</td>
<td>1.20</td>
<td>0.76</td>
<td>0.3</td>
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<tr>
<td>Chlorophyll a (µg/L)</td>
<td>1.60</td>
<td>1.10</td>
<td>1.97</td>
<td>1.1</td>
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<tr>
<td>Water Clarity (m)</td>
<td>3.00</td>
<td>2.30</td>
<td>3.60</td>
<td>2.62</td>
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Trophic Cascade
The primary factor contributing to the shift in trophic level was the introduction of a non-native fish species, the Golden Shiner (Notemigonus crysoleucus). The first observations of the golden shiner occurred in 2008. Previously, highly acidic water prevented the survival of fish in Lake Minnewaska. Overall, shifts from oligotrophic-mesotrophic to eutrophic-oligotrophic conditions were found to be greater with an increase in zooplanktonic fish biomass (Quinlan 1998). A decrease in zooplankton herbivory and increased in nutrients from excretion result in greater phytoplankton biomass, which leads to an overall increase in lake productivity.

Next Steps
Lake trophic level can change based on fluctuations of individual parameters. Continued monitoring is key to assessing the overall health of a lake ecosystem. NYS Parks will continue to collaborate with partners, including universities and non-profit organizations. NYS Parks will also develop educational signage and programming to inform our partners regarding the introduction of non-native aquatic species, as well as providing information regarding the lake ecosystem.

Acknowledgements
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