

Claire
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Student Corner

Early evidence of shoreline bog collapse in a eutrophying New Jersey lake

It's a beautiful summer day and we are out kayaking on Budd Lake for a community kayaking event coordinated by Raritan Headwaters Association, a local nonprofit dedicated to watershed health within the Upper Raritan Basin. Raritan Headwaters has been tasked to conduct a year-long baseline study of the lake by Mt. Olive Township. Part of our effort is to include community engagement with the study, so we are on one of the handful of free events we've offered over the summer. We are exploring the shoreline of the lake and have just passed by Lover's Cove, a local landmark, when someone notices what appears to be section of the bog separating from the shoreline and sinking into the lake.

As a graduate student in Western Colorado University's Master's in Environmental Management Program, I've been trained to look at ecosystems through a systems approach. I'm intrigued by our in-person observations and start to wonder whether this is a singular event or part of a *greater* trend, and what implications it might have for a eutrophying lake.

History of Budd Lake/Hattacawann:

Budd Lake is a 374-acre shallow (maximum depth 10') glacial lake located in Mount Olive Township, New Jersey. It is the largest naturally formed lake in the state. Budd Lake was formed at the terminal moraine of the late Wisconsin glaciation, approximately 21,000 years ago (Witte 1998).

Budd Lake has historically been known as Hattacawanna Lake (Dixler 2001). Hattacawanna lies within the Lenape of the Delaware Lenape Peoples (Native Land Digital n.d.). The lake is also ancestral homeland to the Mohican Peoples (Native Land Digital n.d.). The Stockbridge-Munsee

Community, who call Hattacawanna home, are known as the "People of the waters that are never still" (Stockbridge-Munsee Community 2026). Archeological remains indicate that the southwestern corner of Hattacawanna was an important meeting place for nomadic Peoples (NPS 2026).

In the 19th and early 20th Century, Hattacawanna Lake was a well-known summer destination for urban dwellers from Newark, New York City, and Philadelphia (Hilbert 2001). Many recreators came to swim or boat in the lake, relax at the hotels or tent camps, and experience the natural springs known for their healing and commercial drinking water supply (Hilbert 2001). Following the replacement of dirt tracks with the paved US-46 in the mid 20th century, as well as the establishment of water infrastructure in the area, people began living in Budd Lake year-round (Dixler 2001). Contemporarily, Budd Lake is predominantly residential, with a mix of urban, forested, and some agricultural land uses (DEP 2024).

The lake is still known for recreation; however, summer use is threatened by persistent cyanobacterial harmful algae blooms (cyanoHABs). For over 50 years, efforts have been made to address the lake's eutrophication, including small installations of floating wetlands, algaecide treatments, and nutrient binding agents. An analysis of historic (1973) phytoplankton community assemblage as compared to contemporary (2020s) data shows a shift from seasonally successive communities to a system dominated by *Microcystis aeruginosa* and *Dolichospermum flos-aquae*, lacking any apparent succession (EPA, 1973; Harris et al., 2025). Further studies in 2024 found consistently elevated levels of microcystin – at times exceeding state regulatory levels – thus severely impairing recreation and

community use of the lake (Harris et al. 2026).

The approximately 3,200-acre headwaters watershed is bounded by the Allamuchy Mountains to the northwest and Turkey Brook Park to the southeast. There are a number of small, mostly unnamed, stormwater- and spring-fed tributaries leading from the surrounding ridges into Budd Lake. Hattacawanna is the headwaters source of the South Branch Raritan River, which feeds the Spruce Run and Round Valley Reservoirs, contributing drinking water supply for approximately 2 million people (WSA 2017).

Bog study

One of the unique characteristics of Budd Lake is the Sphagnum dominant peat bog along its northern shore (Figure 1). The lake is one of two natural waterbodies found at the terminal moraine of the late Wisconsin glacier and the only waterbody in the glaciated portion of New Jersey to contain pure Sphagnum peat (Waksman 1943). The wetland covers 7,595 feet or about 45 percent of Hattacawanna's shoreline. A mix of interesting species live in the bog, including one of the southernmost locations for a forest of Black Spruce (*Picea mariana*) and Tamarack (*Larix laricina*), and rare, geographically isolated species like carnivorous pitcher plants (Waksman 1943).

Sphagnum wetlands play an outsized role in regulating water, storing carbon, and supporting biodiversity. They perform key hydrological regulation, due to their quick absorbance and slow release of water (Rocheft 2000). Sphagnum-based wetlands have been shown to increase water quality through their absorbent nature of nutrients (Tsujino et al. 2010). Wetlands perform significant global atmospheric regulation by deposition of carbon into peat



Figure 1. The bog at Budd Lake.

mass accumulation (Rocheft 2000). These ecosystems are important seed bank sources, particularly when there is significant disruption (Rocheft 2000). Due to the long term accumulating process of peat creation, the systems provide factual archives for historical environmental conditions (Rocheft 2000). Wetlands are known as nature's nursery, providing cover for many young species and contributing to their value towards biodiversity hotspots (Rocheft 2000). Excessive nutrient supply from runoff and atmospheric deposition have been called major threats to wetland ecosystems (Berger et al. 2017).

Humans have significant relationships with peat wetlands. Historical records indicate that the Stockbridge-Munsee Community may have been drawn to the area for the spring-fed water, hunting opportunities and *Sphagnum* moss

(Rocheft 2000). Indigenous practice included using *Sphagnum* as absorbent padding material for infants (Rocheft 2000). Analogous with their historical environmental information, bogs may contain anthropogenic archeological information as well (Rocheft 2000).

Methods

To assess whether the bog collapse observed may be part of a significant ecosystem change, I sought to assess whether the visually observed bog collapse may be part of a broader ecosystem change in Budd Lake. I used map layers from the New Jersey Department of Environmental Protection depicting aerial imagery of the lake dating back to 1930 and as contemporary as 2020. I used the oldest possible map to compare long-term differences in the bog. Using ArcGIS Pro (v

3.6.1), I analyzed the maps in two ways: first, I compared the maps for the bog's shoreline changes, and second, I calculated the area of the bog in each map.

For the bog shoreline changes, I compared 9 points against a far (southern) shore reference point. Site selection included 5 targeted sites – 4 tributary stream outputs (BTO) plus 1 local landmark known as Lover's Cove (LC) – and 4 nontargeted sites (A-D) – selected halfway between the targeted sites (Figure 2). I identified each site with coordinates to ensure comparability between maps. I assessed changes in the bog's shoreline by measuring the distance between the nine points to the reference point on each map, using reference markers such as road crossings to align positioning of the maps (Table 1). To measure the area of the bog, I layered the 2020 (Figure 2) aerial map on top of the 1930 map and used polygons to calculate the changes in the area (Figure 3). I used a base R function (v 4.4.2) to analyze these data with a paired t test.

Results and discussion

With the exception of Lover's Cove, all sites showed recession between 1930 and 2020 (Table 1). The greatest sections of bog shoreline loss were found at the outlets of Budd Lake tributary 5 and the combined outlet of tributaries 2 and 3 (Figure 1). The area outlined marking changes in the bog over time showed a reduction of 200,726.5 ft².

Results show significant differences between the shoreline distances from 1930 and 2020 ($p = 0.0345$, $t = -2.5439$). Results also show small but insignificant difference between tributary sites and non-tributary sites ($p = 0.1201$, $t = -2.061$). However, two tributary output sites showed far greater decline (138.3, 188.0 ft) than all other points (all others < 48 ft) These results support the anecdotal observations that the bog habitat is receding. Not only is the overall habitat in decline, but it is in decline at various rates; outputs of tributary 5 and combined output of tributaries 2 and 3 have eroded more (Table 1). Analyses with higher spatiotemporal resolution that incorporate historic weather patterns will be important to improve our understanding of this initial finding.

Erosive forces, such as waves, have a negative impact on *Sphagnum* growth due to the disturbance of substrate stability (Rocheft 2000). Sections of the bog that receive both wave action from the lake and

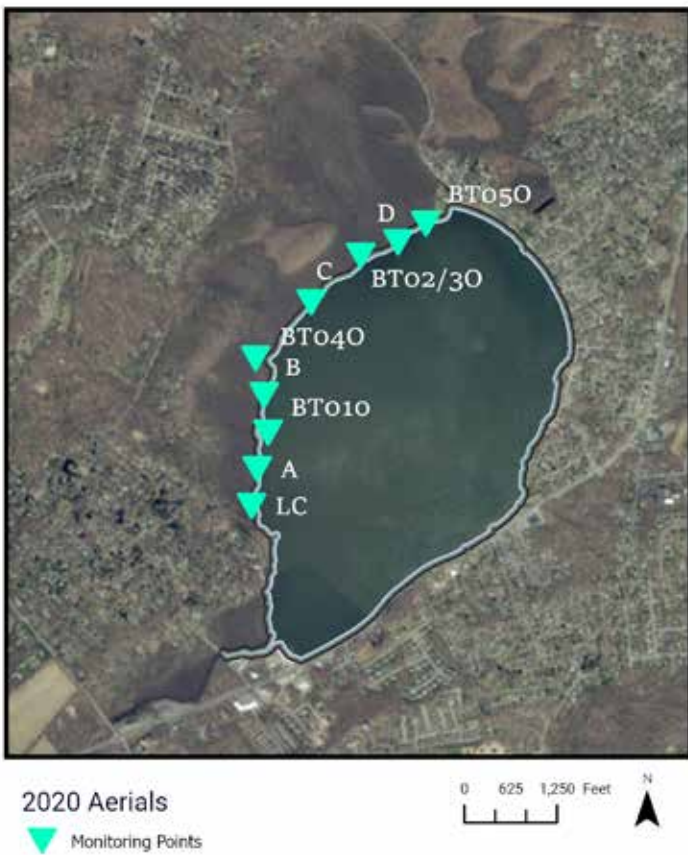


Figure 2. 2020 map of Budd Lake with Site IDs used to measure shoreline distances.

streamflow from tributary output understandably undergo more intensive erosive force. Furthermore, the lake’s polymictic regime may contribute to increased physical action along the shoreline. This relates to the findings of some shoreline loss across all study sites, with the greatest loss at tributary outputs.

Downstream of residential development and bordered by a eutrophying lake, the Budd Lake Bog is ideally located to receive excess nutrients. This long-term exposure to high nutrient levels may be contributing to the bog’s decline, as exposure over a period of years has been shown to have a detrimental effect on Sphagnum growth (Gunnarsson et al. 2000). Though known as nutrient and carbon sinks, wetlands can also become significant sources when they break down (Berger et al. 2017). Li et al. recommended regular Sphagnum harvesting in the early winter to prevent nutrient release from floating wetlands into the waterbody (Li et al. 2010). Given the bog’s age and ready access to nutrients from the lake and tributaries, it is possible the bog’s compounding upward growth and thus water table disconnect may drive this instability.

Restoration

Sphagnum has been shown to be a keystone species in wetland habitat restoration (Rocheft, 2000). Rocheft (2000) identifies three steps to restoration of Sphagnum habitat: (1) active reintroduction of moss diaspores, (2) presence of protective mulch cover, and (3) rewetting of the site. As a Sphagnum-dominant wetland ecosystem, utilizing these steps is key to an informed restoration of the Hattacawanna Bog. To address hydrology connectivity, interesting work has been performed by Bill Zydek and Van Clothier (2014) on process-based restoration efforts aimed to increase stream meandering and reconnecting floodplain. Use of stabilizing structures such as log jams could provide supportive natural structures to address shoreline stability.

Floating wetlands have been shown as effective tools to address excess nutrients in water (Li et al. 2017, Tsujino et al. 2010). Since eutrophic lake water could be damaging the growth of the Hattacawanna bog, an interception of the nutrients through a protective buffer of floating wetlands between the edge of the bog and the greater lake body could be an appropriate application of the technique. This restoration would support historic conditions: floating Sphagnum-based peat is noted in a 1943 assessment of the lake (Waksman 1943).

The Hattacawanna bog study is part of a larger characterization effort to understand the current state of Budd Lake to inform restoration and management efforts. The identification of the Bog experiencing significant shoreline loss demonstrates that a possible restoration aim could be active stabilization of the shore. An important finding here is the significant spatial differences of bog collapse. This finding can inform targeted restoration needs to protect the bog shoreline, prevent potential further eutrophication, and maintain critical habitat and biodiversity of this region.

Acknowledgement

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Figure 3. 1930 map of Budd Lake depicting changes in area of the bog.

Table 1. Measurements of shoreline distances.

Site Type	SiteID	1930 Distance (ft)	2025 Distance (ft)	Change in Shoreline (ft)
Tributary	BT050	3916.5	4054.8	-138.3
Shoreline	D	3931.7	3965.8	-34.1
Tributary	BT03/20	3849.2	4037.2	-188
Shoreline	C	3836.6	3884	-47.4
Tributary	BT040	3587.5	3633.1	-45.6
Shoreline	B	3489.9	3503.4	-13.5
Tributary	BT010	3829.1	3867.7	-38.6
Shoreline	A	3668	3672.9	-4.9

RHA. This analysis was developed using New Jersey Department of Environmental Protection Geographic Information System digital data, but this secondary product has not been verified by NJDEP and is not state-authorized. Any findings or recommendations discussed here are those of the author and do not necessarily reflect the views of the NJDEP, the Township of Mount Olive, the New Jersey Highlands Water Protection and Planning Council, or the State of New Jersey.

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