Insect Herbivore Monitoring in Chautauqua Lake 2023

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Cover

The cover photo is of the adult weevil, *Euhrychiopsis lecontei*. This herbivore is showing extensive scaring by consuming the stem of *Myriophyllum spicatum* (Eurasian watermilfoil).

This report summarizes a cooperative project conducted for the Chautauqua Lake Association, Inc. by Racine-Johnson Aquatic Ecologists from 2002 – 2022, continued by Rooney's Aquatic Biologists in 2023. The project focuses on the densities of insect herbivores, control of Eurasian watermilfoil, and the restoration of native submersed aquatic plant communities in Chautauqua Lake.

We wish to thank Robert Johnson and Paul Stage for lending us all of the equipment to collect Eurasian watermilfoil on Chautauqua Lake.

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Introduction

This report summarizes the findings of our Summer 2023 survey of invertebrate herbivores feeding on *Myriophyllum spicatum* (Eurasian watermilfoil) in Chautauqua Lake, conducted on June 21, July 19, and 20, 2023. We depict this information in tables and figures to provide current information on the herbivore populations as part of the 2002 – 2023 long-term dataset documenting those populations and subsequent plant damage. The report will include a discussion of the results of the 22-year study emphasizing essential findings from the long-term 22-year research (Johnson *et al*. 2023 – 2002).

The original study design setup in 2002 and 2003 assessed whether the invertebrate herbivores *Euhrychiopsis lecontei* (an aquatic weevil) and *Acentria ephemerella* (a pyralid moth) could limit the growth of Eurasian watermilfoil in the lake. To accomplish this, 10 locations (A, B, C, D, E, F, G, H, I, and J) within the lake's littoral zone were identified, and the resident herbivores were sampled in 2002 (Johnson and VanDusen 2003). In 2003, four additional locations (K, L, M, and BT) were added to the survey. In 2017, one last location at Bemus Bay (BB) was added to the 14 historical lake locations to assess any effect on invertebrates that herbicide applications targeting macrophytes in the lake might have. Years of research had been conducted on insects' biological control of Eurasian watermilfoil before beginning data collection at Chautauqua Lake in 2002 (Johnson and Blossey 2002). This research at Chautauqua Lake would add to our knowledge of Eurasian watermilfoil management influenced by insect herbivores.

Over the years, researchers have found that Eurasian watermilfoil provides the habitat for a suite of invertebrate herbivores attacking the plant at various times of the year, significantly limiting the growth of this non-native. These biological control agents include the weevil, *Euhrychiopsis lecontei*; the moth, *Acentria ephemerella*; the midge *Cricotopus myriophylli*; the caddis, *Nectopsyche albida* (Walker) and the caddis species, *Setodes grandis* (small caddis) also known as *Leptocerus americanus* or *Setodes americana* (Banks 1899, Johnson *et al*. 2019B, Johnson *et al*. 2012, Johnson *et al*. 2008).

The first three insects, the weevil, the moth, and the midge, consume the growing apical stem of Eurasian watermilfoil, stopping elongation to Chautauqua Lake's surface by early June. The weevil densities (number per Eurasian watermilfoil apical stem) are at their highest throughout late June through early August in the New York State lakes we have monitored (Figure 1). Eurasian watermilfoil growth begins early in the spring. Adult weevils move from shore to the water in late April or early May to lay eggs on the Eurasian watermilfoil apical tips (Figure 2). The eggs hatch as larvae and then burrow into the stem. Generally, these larvae are mining and hollowing out the plant stems by early June, resulting in the stems' collapse by late June to mid-July (Figure 2). The larvae pupate and prepare a pupation chamber further down the stem of the watermilfoil (Figure 2). An adult eventually emerges from the chamber to lay more eggs or swim to shore to overwinter if it is late summer.

The moth displays a similar life cycle pattern to the weevil (Figure 3). The annual populations of the moth show mostly two, but sometimes three, peaks in density. Generally, the overwintering generation of larvae matures through the spring, and the adults emerge from their host plant to lay clutches of 100 to 300 eggs in late June (Figure 4). These eggs hatch, and the resulting larvae grow throughout the summer until forming a cocoon on the host plant. The second-generation adult emerges from this cocoon to lay eggs in late summer (Figure 4). Once these eggs hatch, the larvae overwinter on plant stems as various larvae instars or stages (Johnson and Blossey 2002).

The Walker caddis was recorded in Chautauqua Lake as early as 1937, and resides as a specimen in the Illinois Museum of Natural History (Glover and Floyd 2004). Adult caddisflies tend to lay eggs in late spring and require flowering Eurasian watermilfoil or *Potamogeton crispus* (curly-leaf pondweed) to appear at the lake's surface to provide a suitable habitat to stick their eggs on for a successful hatch. These plant species help the caddis reproduce successfully and persist as a biological control agent of aquatic plants in Chautauqua Lake (Johnson *et al*. 2012, Johnson *et al*. 2008). The caddis larvae bite off and strip the leaflets of Eurasian watermilfoil, leaving the stem bare without whorls of leaves. Both caddis start consuming from the bottom of the

plant, working their way up the stem, eventually defoliating it. Larvae appear to require a full year for development, suggesting that they need aquatic plants to overwinter, and that the first plant species reaching the surface in the spring may be critically important for maintaining high numbers of this species (Tozer et al. 1981). The healthy plant growth of Eurasian watermilfoil decreases rapidly when there is a minimum of four caddisflies on the stem (Johnson *et al*. 2012).

The non-native Eurasian watermilfoil and curly-leaf pondweed are long-term inhabitants of Chautauqua Lake. They live in this healthy lake ecosystem as part of a very diverse macrophyte community that fosters healthy macrophyte species competition, limiting the dominance of any one species (Radomski *et al*. 2019). The current focus on removing Eurasian watermilfoil by herbicides at the expense of critical native plant growth is counterproductive due to the lack of a measurable increase in Eurasian watermilfoil mass in the last 22 years. The 2000 Lake report further declared that since 1993, in Chautauqua Lake, Eurasian watermilfoil had decreased with a corresponding increase in native macrophyte growth while suggesting herbivory by the aquatic moth and aquatic weevil as a cause of decline (Chautauqua County Planning Department 2000). That report from 2000, with the observation of a decrease in Eurasian watermilfoil, is reinforced with our measures reported here 22 years later (Johnson *et al*. 2023, 2021A, 2020A, 2019C, 2019A, 2017A, 2016, 2013, 2012, 2009 and 2008).

The vast populations of insect herbivores in Chautauqua Lake, documented yearly since 2002 by Cornell University and Racine-Johnson Aquatic Ecologists, provide the lowest cost, most effective long-term, and sustainable control possible of excessive growth of Eurasian watermilfoil (Johnson and Blossey 2002, Johnson *et al*. 2012, Johnson *et al*. 2008). Therefore, conserving these essential biological control agents is paramount in maintaining a healthy Chautauqua Lake. Protection from the wholesale elimination of macrophyte species from the littoral areas must be the top consideration in the long-term management of the lake. With the loss of macrophytes from large sections of the south basin, those areas will likely experience a decline of macroinvertebrates, the fishery, water clarity, an increase in cyanobacteria blooms (HABs), and corresponding low oxygen levels in the lake water. The management decision to prohibit herbicide use north of Long Point in 2019 was astute, and must be reinforced. Prohibiting herbicide usage in crucial fish habitats that are for spawning and nursery is paramount in areas like Tom's Point, Whitney Bay, and Irwins Bay (Luensman *et al*. 1990).

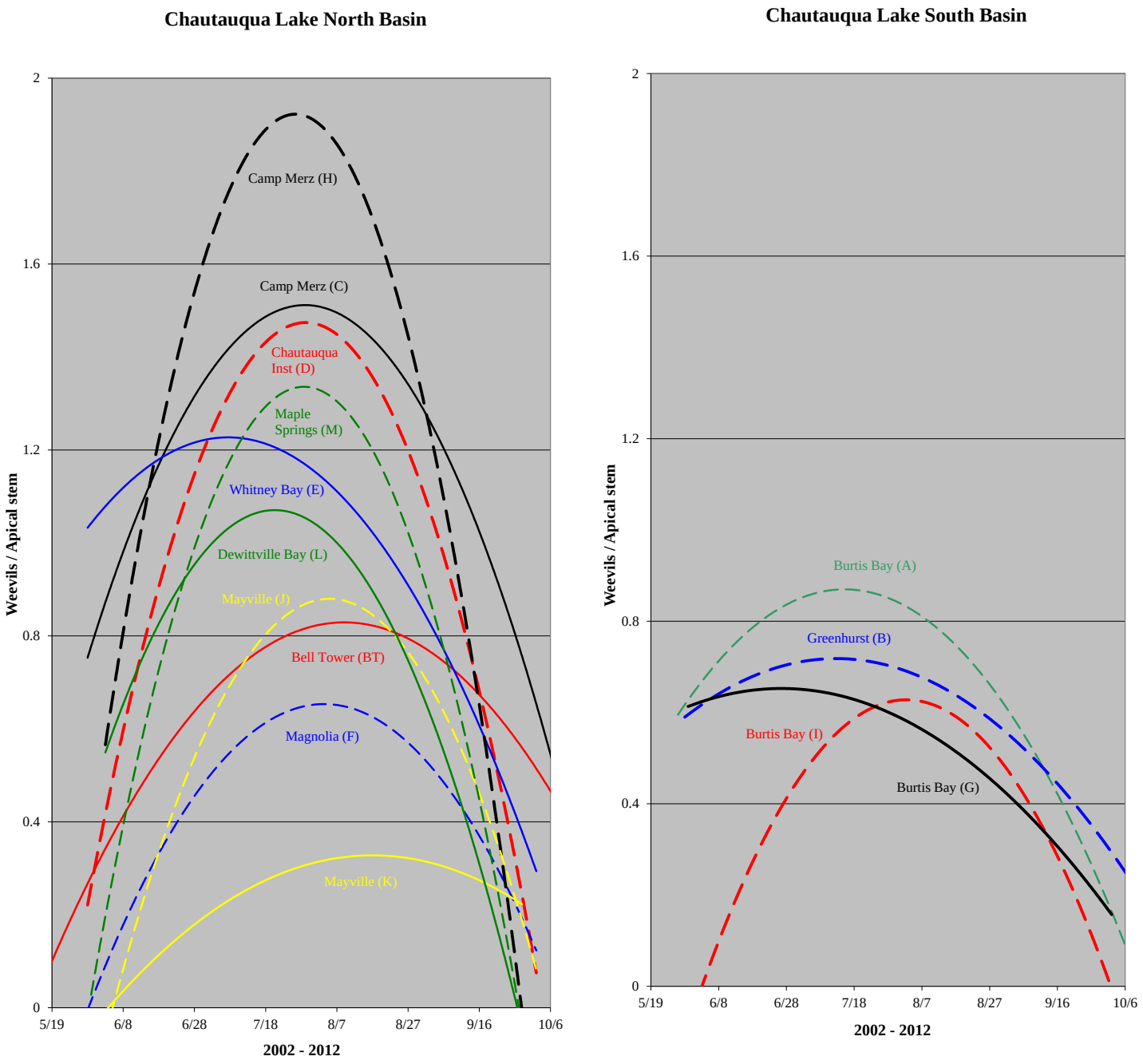


Figure 1. Densities of the weevil, *Euhrychiopsis lecontei*, from Eurasian watermilfoil apical stem surveys for the north basin (left) and the south basin (right) of Chautauqua Lake from 2002 to 2012.

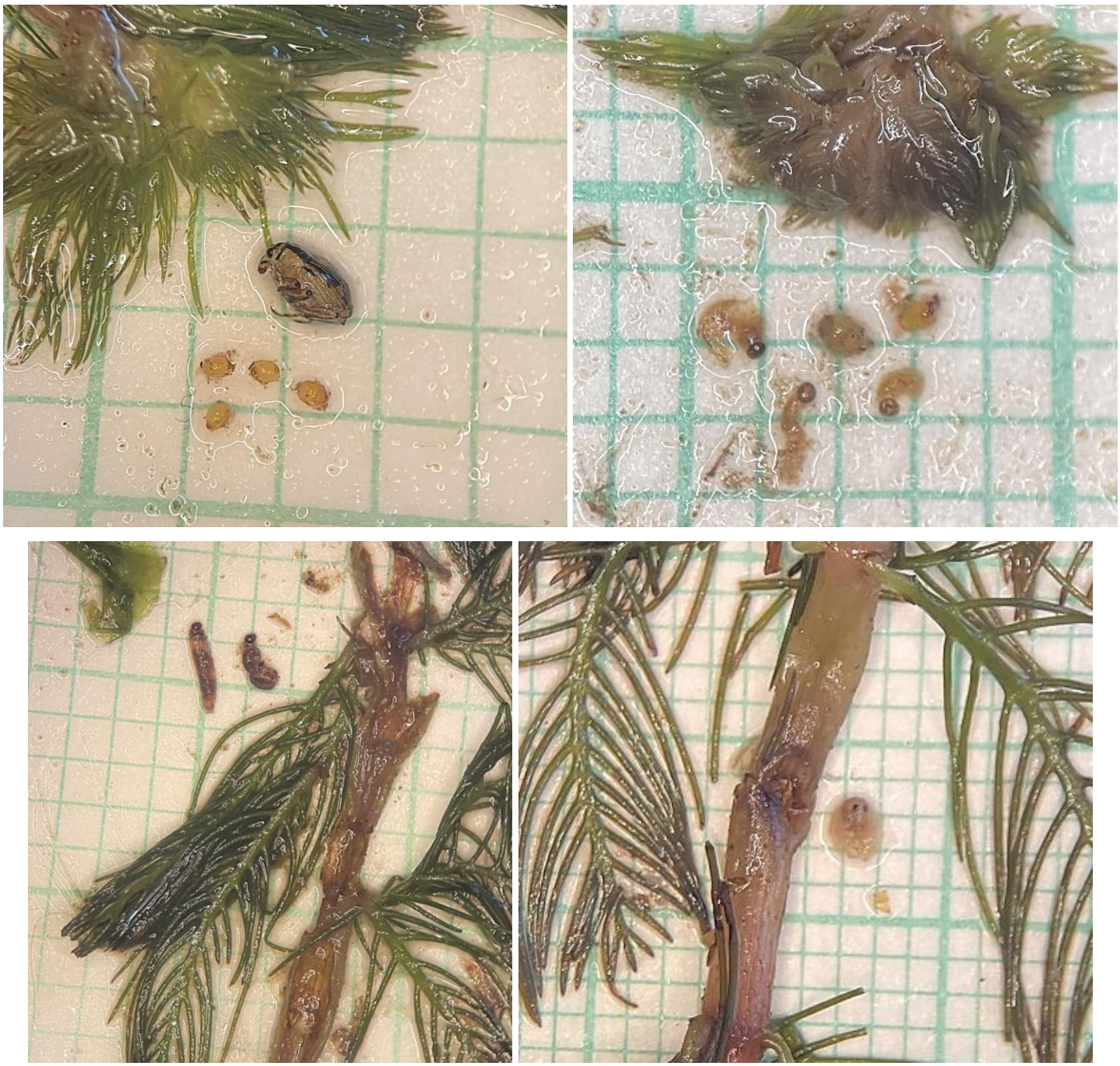
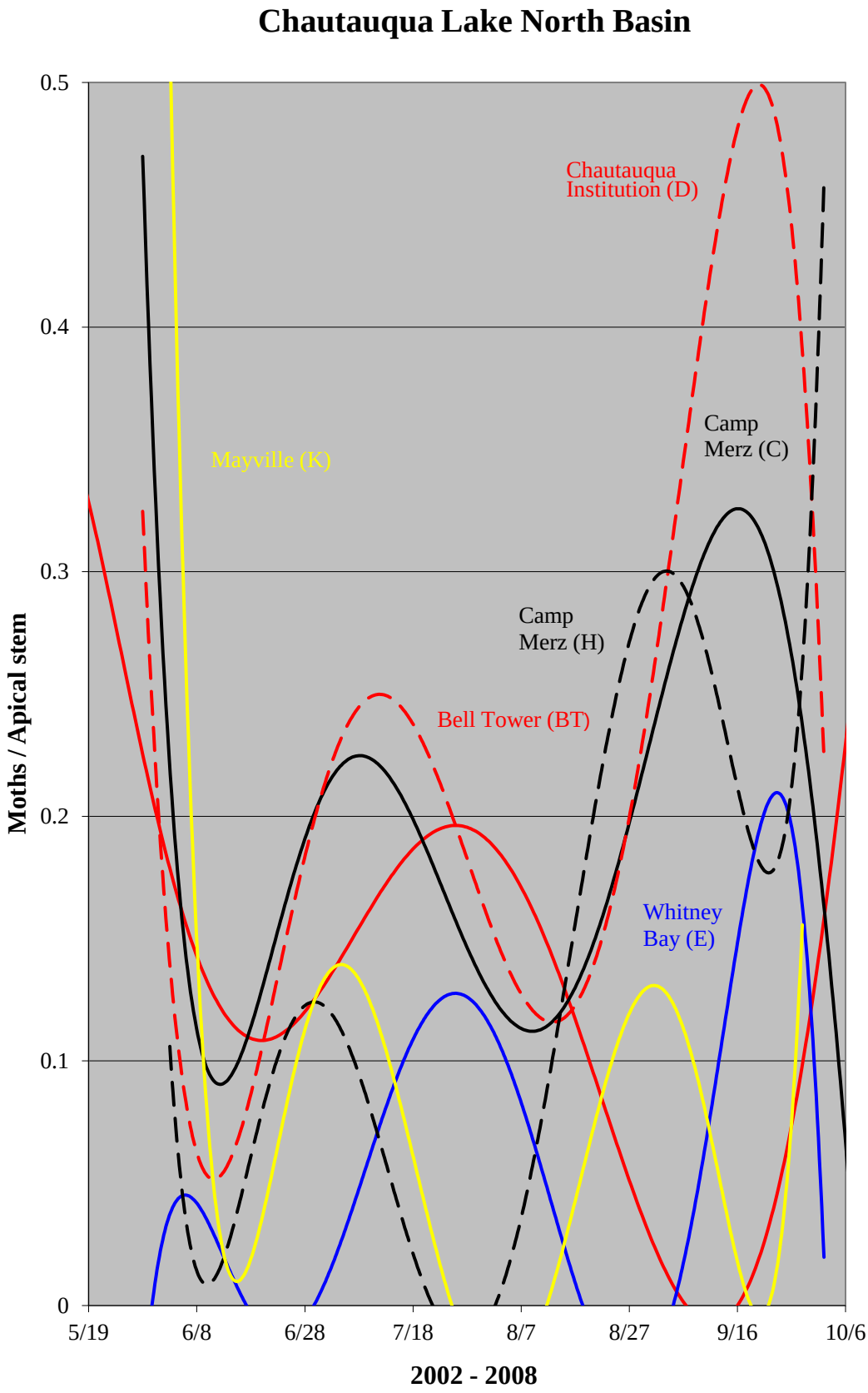


Figure 2. These photos show the life cycle stages of the weevil, *Euhrychiopsis lecontei*. The top left photo shows an adult weevil that laid four eggs on an apical stem of Eurasian watermilfoil. The top right photo shows three weevil larvae that have just hatched with two weevil eggs that have not yet developed on an apical stem of Eurasian watermilfoil. The bottom left photo shows two weevil larvae that have caused extensive damage by mining the stem of Eurasian watermilfoil. The bottom right photo shows a developing pupa removed from a pupal chamber. This is the final stage of development until the weevil becomes an adult.



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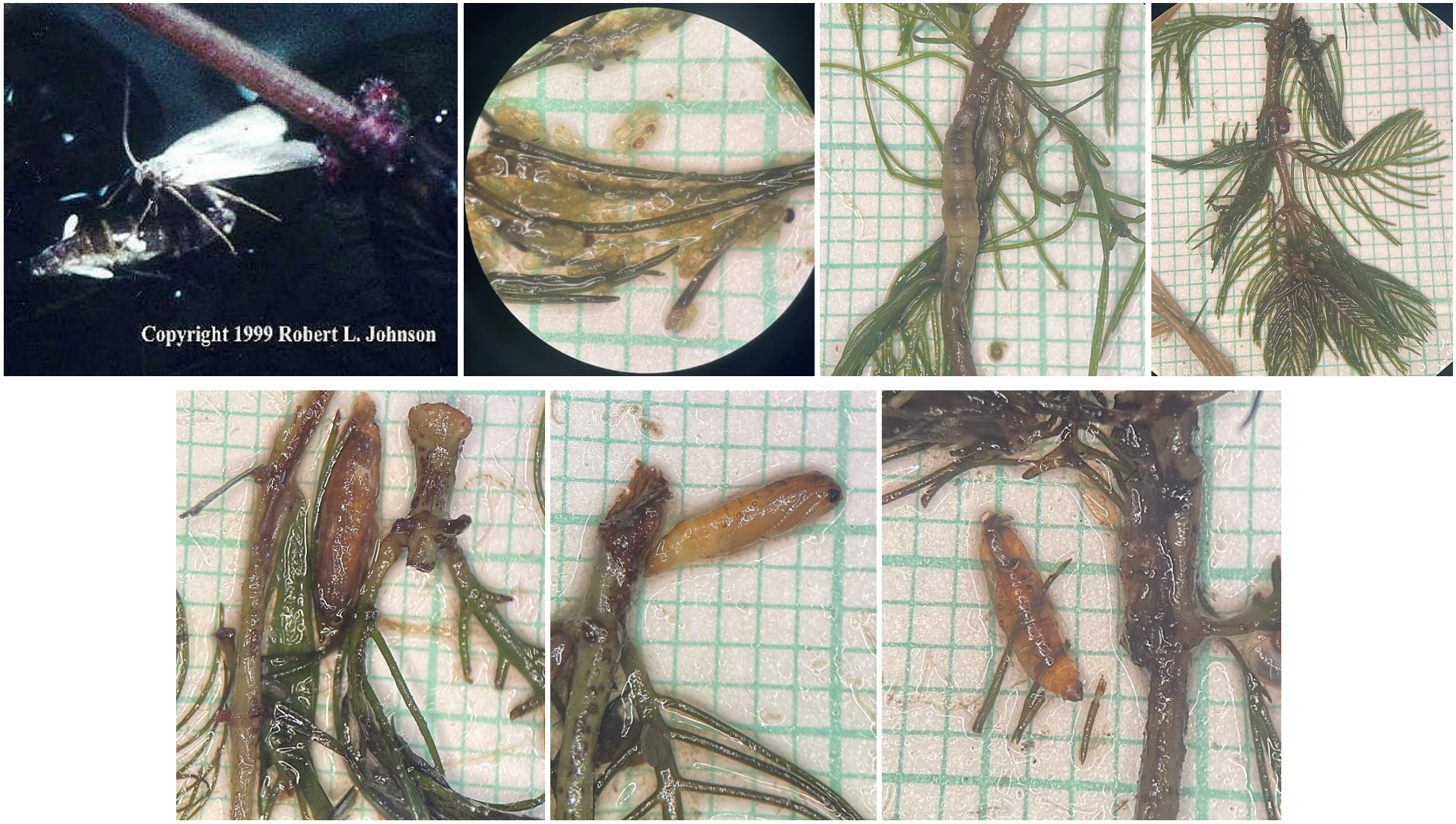

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Methods

In 2023, we continued using past sampling locations of herbivore populations and damage to assess the effectiveness of the weevil and the moth in limiting the growth of Eurasian watermilfoil (Figure 5). In 2017, an additional location at Bemus Bay (BB) was added to help monitor the 2017 herbicide application in this area. In 2023, we collected plants at 13 out of 15 historic sites during our survey (Table 1).

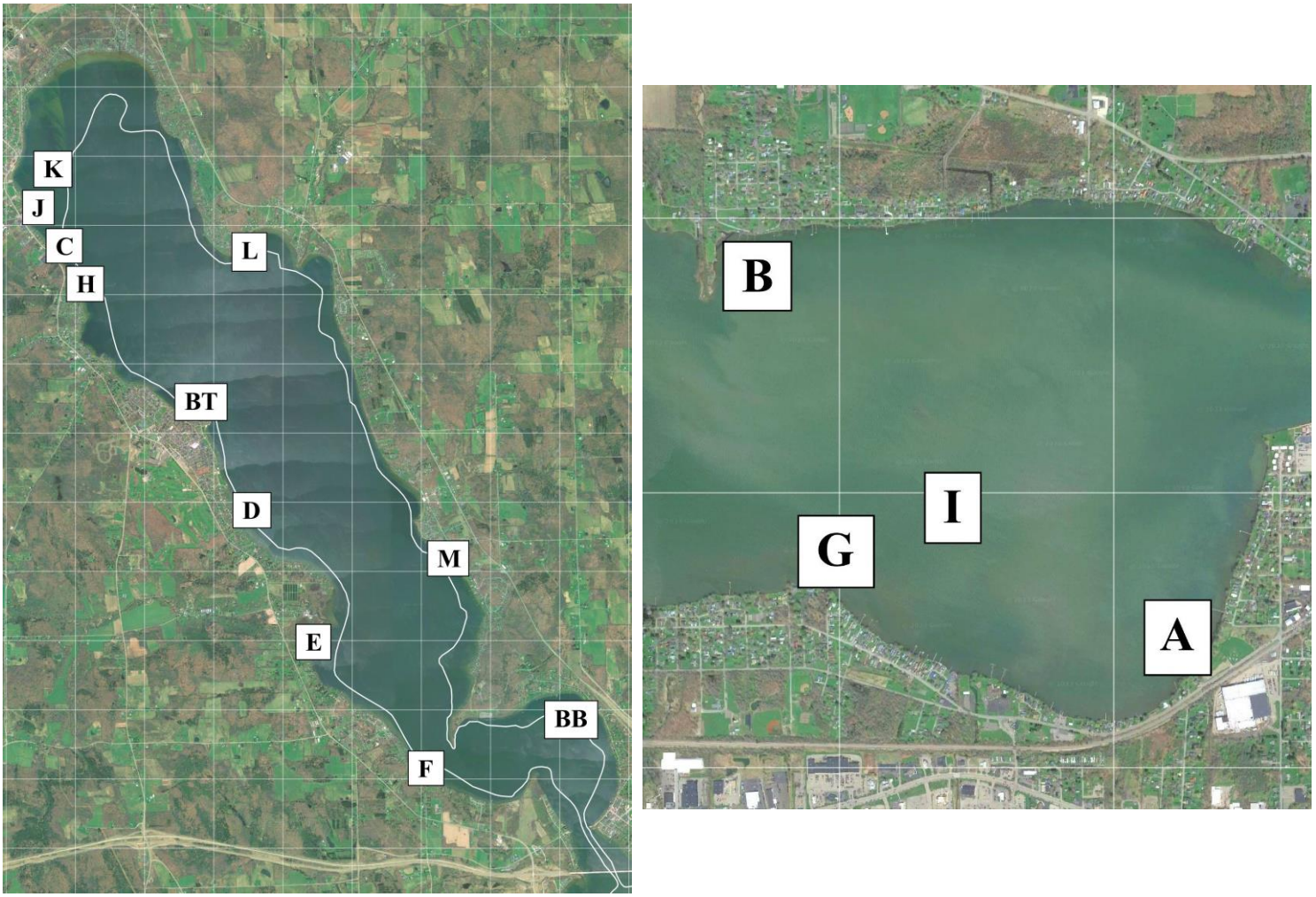

Figure 5. These maps show the Chautauqua Lake historic locations where we collect Eurasian watermilfoil apical stems and measure herbivore presence and damage on Eurasian watermilfoil.

Our herbivore sampling procedure used the double-headed rake-toss drag method to randomly sample plants at each location (Figure 6). In the boat, 25 apical stems measuring 25 centimeters in length of Eurasian watermilfoil were collected. If a significant amount of Eurasian watermilfoil was present, five plant samples were taken from each rake-toss until there were 25 samples. This allowed for a greater variety of plant samples taken from the collection area. While collecting Eurasian watermilfoil stems, crew members discarded any apical stems showing mechanical damage, such as those cut off by a boat propeller or an apical stem that showed a flower bud. Each apical stem was placed in an individually labeled zip lock bag and stored in a cooler for transport back to our lab.

In the laboratory, we refrigerated the apical stems for up to three weeks for examination. If we could not analyze the samples in three weeks, they were frozen for later analysis. At the time of examination, each apical stem was placed under a stereoscopic dissecting microscope for evaluation. If the samples were frozen, the stems would be thawed before assessment. Dissection of the entire stem allowed complete determination of the number and types of herbivores. Evidence of herbivore presence, such as retreats, cocoons, and pupal chambers, along with plant tissue damage, such as leaflet damage, stem mining, and a missing or grazed apical meristem, were observed and recorded.

The microscope examiner recorded all life stages (eggs, larvae, pupae, and adults) for every weevil or moth found on each stem. We qualified and quantified all Eurasian watermilfoil tissue damage using a consistent scoring system developed in our laboratory. The number of weevils and moths per apical stem was calculated, including individuals in all life stages. Using a standard protocol, we determined which herbivores were responsible for the types of damage, and estimated the amount of plant damage caused by each herbivore. Results were recorded in an Excel spreadsheet.

Figure 6. Macrophyte sample on a dual-headed rake (left) and two apical stems of Eurasian watermilfoil, one that is undamaged while the other shows extensive damage (right).

Results and Discussion

On June 21, July 19, and 20, 2023, Rooney's Aquatic Biologists continued to monitor insect herbivore densities and evaluate the damage to Eurasian watermilfoil growing in Chautauqua Lake at all 15 historic locations. The 2017 – 2022 macrophyte (plant) surveys show that there has been a decrease in biomass (g/m^2) for *Myriophyllum spicatum* (Eurasian watermilfoil) lake-wide (Figure 7). There were 263 apical stems collected in 2022 compared to 213 apical stems collected in 2023 (Johnson *et al*. 2023). Out of the 15 historic locations, we could not collect Eurasian watermilfoil at locations F (Woodlawn) and M (Maple Springs). We were also not able to collect all 25 apical meristems at locations A (Burtis Bay), D (Chautauqua), G (Lakewood), I (Burtis Bay), and BB (Bemus Bay) due to a lack of plants (Table 1).

In 2023, the invertebrate herbivore survey concentrated on the presence and density of the weevil *Euhrychiopsis lecontei*, and the moth, *Acentria ephemerella*. The locations with the highest densities of weevils and moths were E (Whitney Bay), with 1.68 weevils and 5.20 moths found per apical stem, J (Lakeside Park), with 1.52 weevils per apical stem, and C (Camp Merz) with 0.48 moths per apical stem (Table 1).

Since 2002, there has been a decrease in the density of weevils per apical stem at all 15 historic locations (Johnson *et al*. 2023). Some of these lower population densities might be attributed to the fact that there were fewer Eurasian watermilfoil stems found at many locations (Table 1). While in the field, locations J (Lakeside Park), K (Mayville), and BT (Bell Tower) were the only historical locations that had a Sparse (S), or Medium (M) amount of Eurasian watermilfoil to collect. The other 12 locations either had a Zero (0), Trace (T), or Sparse (S) amount of Eurasian watermilfoil to collect. Due to this significantly low biomass (Figure 7), finding enough specimens to collect was extremely difficult. We had to throw more rakes and spend more time trying to find plants in each location. These smaller stands of Eurasian watermilfoil would create more competition between the weevils and other herbivores (Figure 8). This lack of Eurasian watermilfoil may make it difficult for weevils to propagate, and there would be less viable material for egg-laying substrate (Johnson *et al.* 2009, Johnson *et al.* 2008A). From our observations of changing aquatic macrophyte growth and corresponding insect herbivore population densities on Chautauqua Lake, we believe this lake-wide weevil population decline is also related to food quality. As food quality declines, insect reproduction quickly declines (Johnson *et al.* 2023).

Another potential cause for this decline in the population of weevils could be mechanical harvesting, which is the primary management used to remove excessive plant growth from the lake. Removing growing macrophytes by cutting does remove herbivores from the lake. However, the herbivores figured out how to persist in making harvesting a non-factor, since this has occurred since 1952. Mechanical harvesting leaves a rooted cut stubble in the lake sediment that regrows with lush new habitat to aid rapid insect reproduction. Additionally, the insects can move to areas that are not managed and quickly move back to renewed habitats (Johnson *et al.* 2023).

Lastly, weevil population densities could be declining in certain areas of Chautauqua Lake due to the recent use of herbicides (Figure 9). Locations A (Burtis Bay), B (Greenhurst Point), G (Lakewood), I (Burtis Bay), and BB (Bemus Bay) have been greatly affected by the various herbicide applications since 2017. Protection from the total elimination of plant species in these locations must be the top consideration in the long-term management of the lake. Macrophyte growth remains a stabilizing force supporting water clarity and repelling excessive cyanobacteria growth/harmful algae blooms (HABs). The accepted scientific theory of alternative stable states predicts that shallow lakes with high nutrient concentrations can likely switch from a clear state, where rooted aquatic plants dominate, to a turbid state controlled by phytoplankton, often concentrated with HABs (Bachmann *et al*. 2002, Balls *et al*. 1989, Carpenter *et al*. 1999, Carpenter and Lodge 1986, Didham *et al*. 2005, Genkai-Kato and Carpenter 2005, Hilt and Gross 2008, Jackson 2003, Janse 2008, Janssen *et al*. 2014, Jeppesen *et al*. 1997, Jeppesen *et al*. 2012, Ludwig *et al.* 1997, Pakdel *et al*. 2013, Scheffer 2001, Scheffer and Carpenter 2003, Scheffer *et al*. 2001, Scheffer *et al.* 1992, Scheffer *et al.* 1993, Scheffer *et al*. 1997, Van Donk and Van de Bund 2002, Van Nes *et al*. 2002, Verhofstad and Bakker 2019, Wang *et al.* 2009). Loss of macrophytes from the littoral zone in shallow Chautauqua Lake will allow for an increase in unrestricted wind-driven waves, forcing bottom sediment re-suspension and shoreline erosion, dramatically increasing nutrient loading into the water column (Getsinger *et*

al. 1982, Jackson 2003, Peretyatko *et al*. 2007, Roelke *et al*. 2007, Scheffer 2001, Takamura *et al.* 2003). This eutrophic (very nutrient-rich) lake is the ideal candidate for either a macrophyte (clear state) or an algae-dominated (turbid state) waterbody. For Chautauqua Lake to remain a healthy ecosystem with good water clarity, it requires a diverse macrophyte-dominated littoral zone that competes against an overabundance of HABs. If an overabundance of HABs persists in locations A, B, G, I, and BB, the weevil, along with all other macroinvertebrates, will not be able to grow and reproduce if there are no plants (Figures 7 and 9).

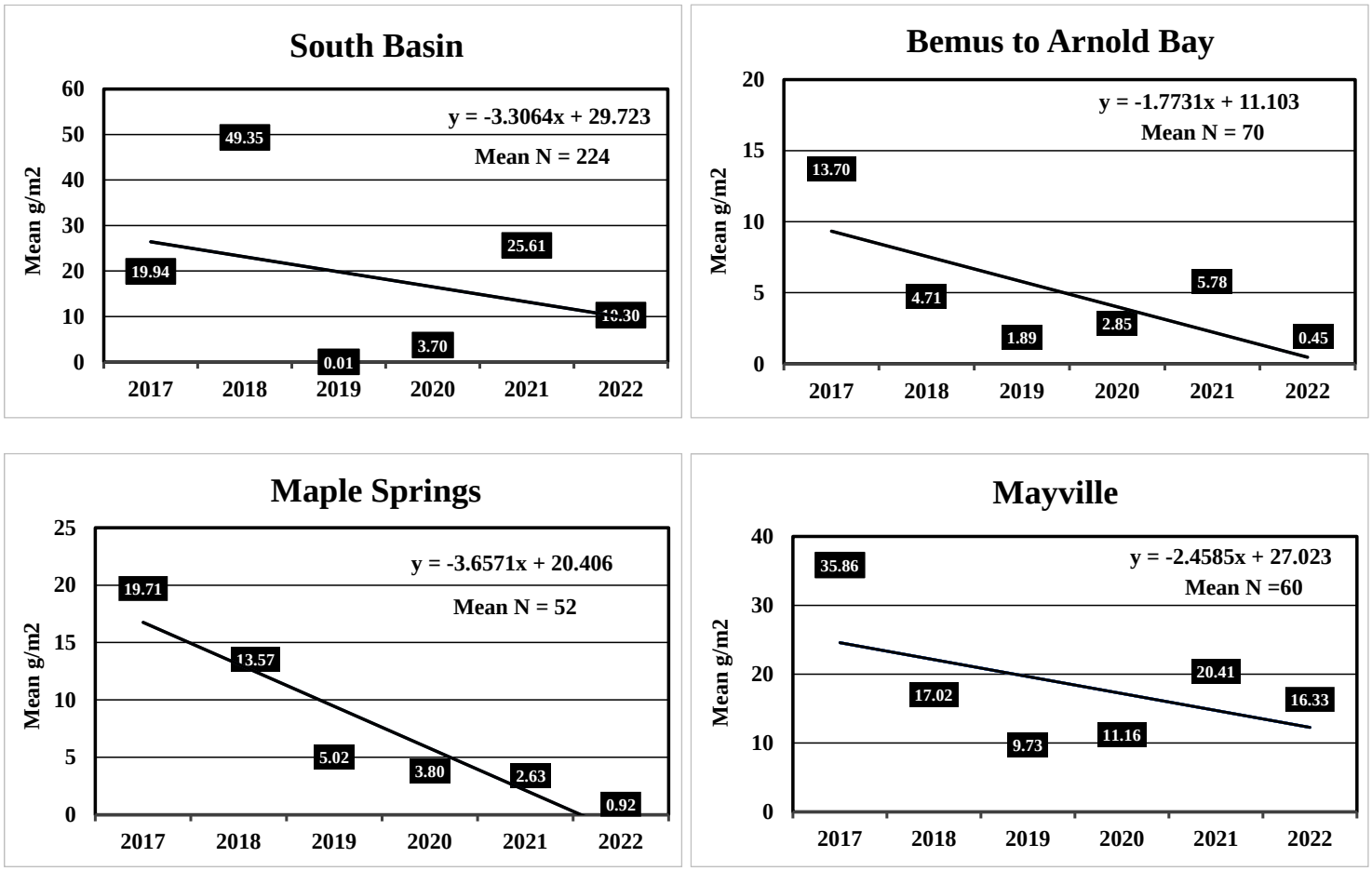

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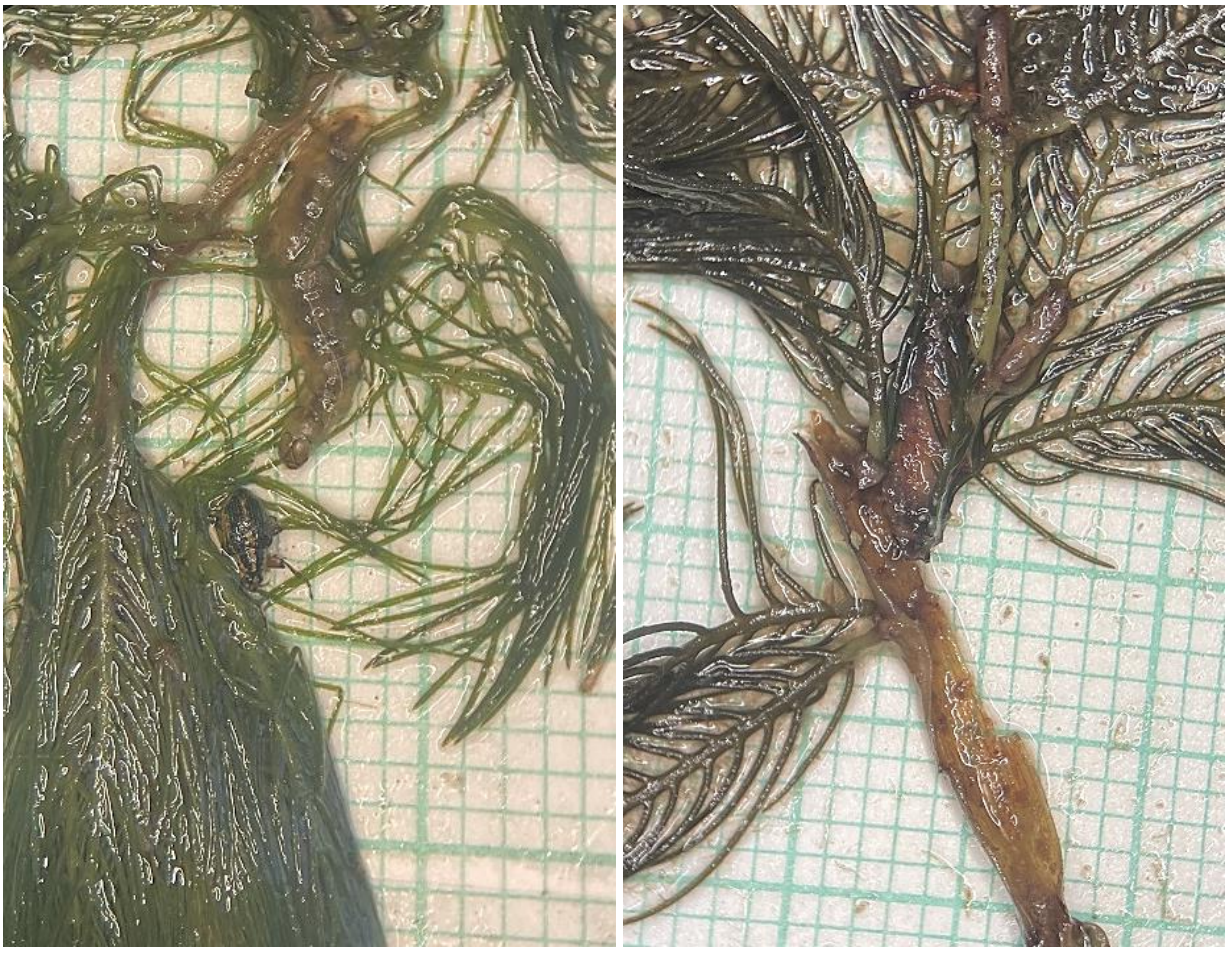
Table 1. The mean number of weevils and moths, which includes all life stages (eggs, larvae, pupae, and adults), was recorded for Eurasian watermilfoil apical stems at Chautauqua Lake on June 21, July 19, and 20, 2023.

Lake area	Plot	Date	NAD27 X cord EAST 17T	NAD27 Y cord NORTH	Number of apical stems	Number of Weevils	Number of Moths	Weevils per apical stem mean	Weevil (SE)	Moths per apical stem mean	Moth (SE)
Burtis Bay	A	7/19/2023	641227	4662467	7	2	0	0.29	0.15	0.00	0.00
Greenhurst Point	B	6/21/2023	639645	4663836	25	0	3	0.00	0.00	0.12	0.07
Camp Merz	C	7/20/2023	624826	4676501	25	3	12	0.12	0.09	0.48	0.13
Chautauqua	D	7/20/2023	627411	4672791	1	0	0	0.00	0.00	0.00	0.00
Whitney Bay	E	7/19/2023	628355	4670952	25	42	130	1.68	0.49	5.20	4.05
Woodlawn	F	NA	630016	4669103	NA	NA	NA	NA	NA	NA	NA
Lakewood	G	7/19/2023	639953	4662724	2	0	0	0.00	0.00	0.00	0.00
Lighthouse Point	H	7/20/2023	624881	4676416	25	3	10	0.12	0.09	0.40	0.12
Burtis Bay	I	7/19/2023	640412	4662940	2	0	0	0.00	0.00	0.00	0.00
Lakeside Park	J	7/20/2023	624389	4677437	25	38	2	1.52	0.55	0.08	0.06
Mayville	K	7/20/2023	624592	4677640	25	5	1	0.20	0.08	0.04	0.04
Dewittville Bay	L	7/20/2023	627425	4676677	25	6	3	0.24	0.12	0.12	0.07
Maple Springs	M	NA	630335	4672218	NA	NA	NA	NA	NA	NA	NA
Bell Tower	BT	7/20/2023	626900	4674200	25	18	2	0.72	0.27	0.08	0.06
Bemus Bay	BB	6/21/2023	632300	4670000	1	0	0	0.00	0.00	0.00	0.00



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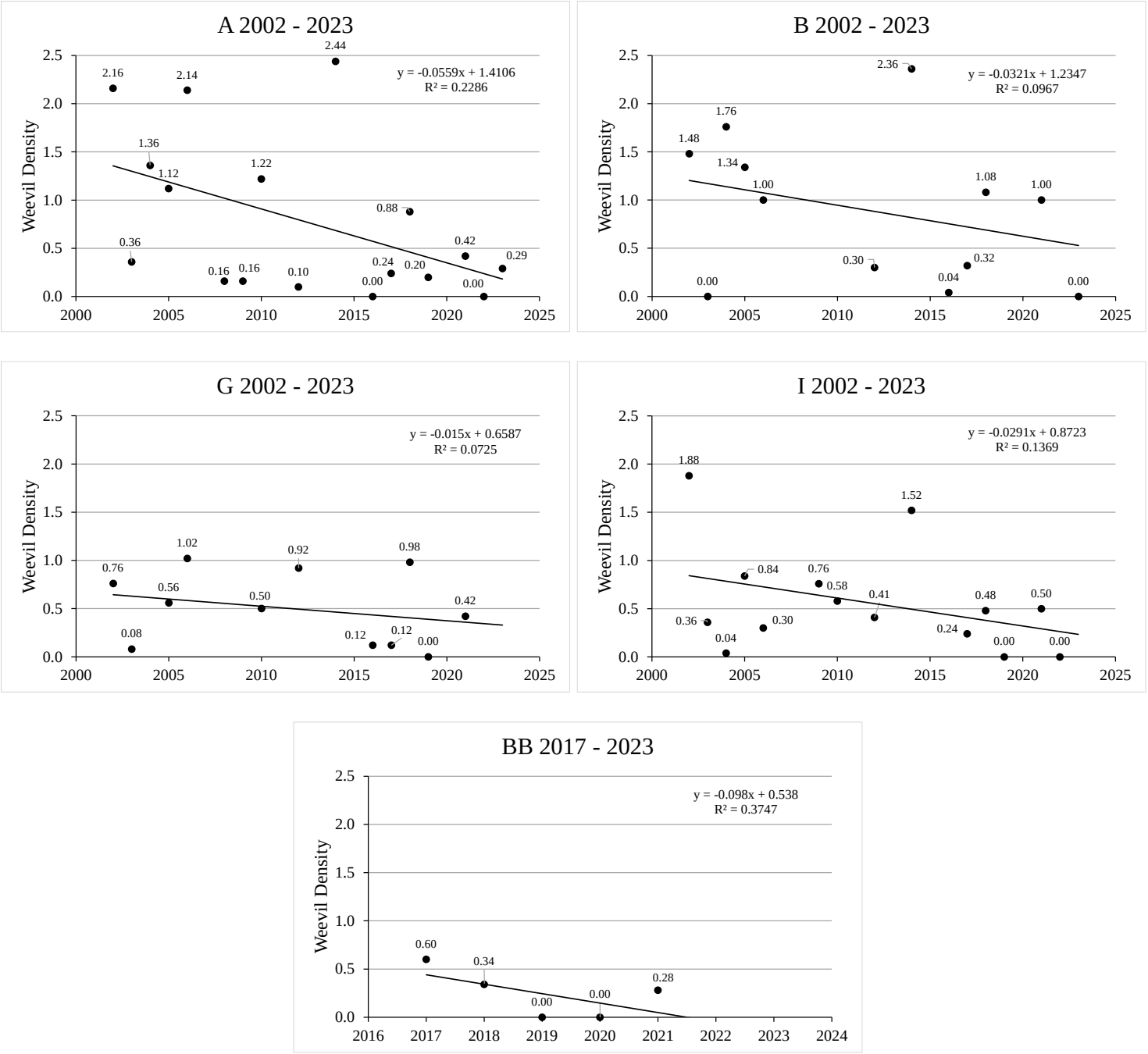

Figure 9. Number of weevils per apical stem of Eurasian watermilfoil (Weevil Density) at four locations in the south basin (A, B, G, and I) and one location in Bemus Bay (BB) of Chautauqua Lake. These locations could be experiencing a decline in weevil density due to the recent use of herbicides. The wholesale elimination of macrophytes in these areas of the lake would make it difficult for the weevils to survive. Each data point is the mean weevil findings on 25 or 50 individual stems.

Other herbivores found feeding on Eurasian watermilfoil in Chautauqua Lake include the midge, *Cricotopus myriophylli* and two caddisflies, including the critical long-horn caddis, *Nectopsyche albida* (Walker) and *Setodes grandis* (small caddis) also known as *Leptocerus americanus* or *Setodes americana* (Banks 1899, Johnson *et al*. 2019A, Johnson *et al.* 2012, Johnson *et al.* 2008). We noted the small caddis in high densities on Eurasian watermilfoil in the 2018 – 2020 surveys (Johnson *et al*. 2020A, 2020, 2019C, 2019B, 2019A, and 2019). From 2018 – 2020, the small caddis aided the weevil and moth in removing Eurasian watermilfoil from large acreages in the area south of Maple Springs and north of Long Point on the eastern side of the lake. High populations of these small caddis have been feeding on watermilfoil in the area (Figure 10). This lake area has a lower density of Eurasian watermilfoil, but higher populations of native species, particularly coontail. This dense native growth has improved water clarity, and critical habitat for fish and macroinvertebrates while decreasing wind-driven re-suspension of bottom sediments that would increase turbidity and add nutrients to the water column (Johnson *et al*. 2023).

Over the last two years, we have observed a drastic decrease in the number of caddisflies on our plant samples from the lake. In 2022 and 2023, only 37 and 30 small caddisflies were found on Eurasian watermilfoil. Historically, the small caddis would be found primarily in the north basin (Johnson *et al.* 2021A, 2020A, 2019C). This recent decrease is likely due to the lack of plant material in areas like Maple Springs and Mayville (Figure 7). The higher caddis populations from 2018 – 2020 would have caused greater competition between the species, and, therefore, may have heavily damaged the Eurasian watermilfoil in these lake areas (Figure 10).

During the macrophyte and herbivore surveys, we would historically find the Walker caddis in the south basin, which has been treated with various herbicides since 2017. There has also been a decrease in the presence of the Walker caddis, which we have not observed in Chautauqua Lake since 2021 (Johnson *et al*. 2021A). The number of Walker caddisflies on a single stem influences feeding rates and plant growth. More caddisflies per stem appear to compete with each other, eating less per individual, and producing fewer fecal pellets/hour per caddis. More than four caddisflies feeding on a stem show severe negative influences on plant growth, significantly reducing plant mass to a point where there is less plant material than the experiment started with (Johnson *et al*. 2023).

With the recent decline of the weevil and both caddis species, stakeholders should consider if the recent increase in herbicide use contributes to declining invertebrate populations (Figures 7 and 9). The wholesale elimination of plants creates an unsuitable environment for these herbivores, which is not sustainable for the long-term management of the lake. Conserving and encouraging these natural, biological control agents will control the excessive plant growth in the lake and can aid in lowering management costs (Havel et al. 2017).

Figure 10. A high density of small caddisflies was found feeding on Eurasian watermilfoil in 2021.

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