Insect Herbivore Monitoring in Chautauqua Lake 2024

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Cover

The cover photo is of the adult weevil, *Euhrychiopsis lecontei*. This herbivore is showing extensive scaring by consuming the outer 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 – 2024. The project focuses on insect herbivore densities, control of Eurasian watermilfoil, and the restoration of native submersed aquatic plant communities in Chautauqua Lake.

We 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 survey of invertebrate herbivores feeding on *Myriophyllum spicatum* (Eurasian watermilfoil) in Chautauqua Lake, conducted on July 16, 2024. We depict this information in tables and figures to provide current information on the herbivore populations as part of the 2002 – 2024 long-term dataset documenting those populations and subsequent plant damage (Johnson *et al*. 2023 – 2002). The Association's long-term goal is to reduce the impacts of Eurasian watermilfoil on the ecology and recreational uses of the lake.

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 (Johnson *et al.* 2017A). 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, Johnson *et al*. 2012 and 2013). Eurasian watermilfoil growth begins early in the spring. Adult weevils move from shore to the water in late April or early May by using native plants as a bridge to find Eurasian watermilfoil. Once located, the female weevil lays eggs on the Eurasian watermilfoil apical tips (Figure 2). The apical tips must be healthy enough for the adult female, or they might not lay eggs (Johnson *et al*. 2012 and 2013). The eggs hatch as larvae, and start growing by consuming the Eurasian watermilfoil. Generally, these larvae are mining and hollowing out the stems by early June, resulting in the stems' collapse from late June to mid-July. The larvae prepare a pupation chamber further down the stem of the Eurasian watermilfoil, where they pupate into an adult. An adult eventually emerges from the pupal chamber to lay more eggs or swim to shore to overwinter if it is late summer (Figure 2).

The moth displays a life cycle pattern similar to that of the weevil. The annual populations of the moth show mostly two, but sometimes three, peaks in density (Figure 3, Johnson *et al*. 2009). Generally, the overwintering generation of larvae matures through the spring inside the stems of Eurasian watermilfoil. The larvae will grow in the plant by leaf-mining and creating retreats. Once the larva grows to the fifth instar (stage), it will form a cocoon on the host plant. The adult emerges from the cocoon, leaving a case behind (Figure 4). The male moth has wings, and can fly over one mile to find an adult female moth. The female moth only has rudimentary wings and stays almost entirely underwater (Lord *et al*. 2004). The female moth will protrude her abdomen out of the water to release pheromones and find a mate. After reproduction, the female moth will lay clutches of 100 to 300 eggs on the apical stem of Eurasian watermilfoil by late June (Figure 4). These eggs have enough time to hatch into larvae and develop into adults throughout the summer. By late summer, the second-generation adults will lay eggs once again. These larvae will overwinter on the 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 and curly-leaf pondweed 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 24 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 24 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. 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).

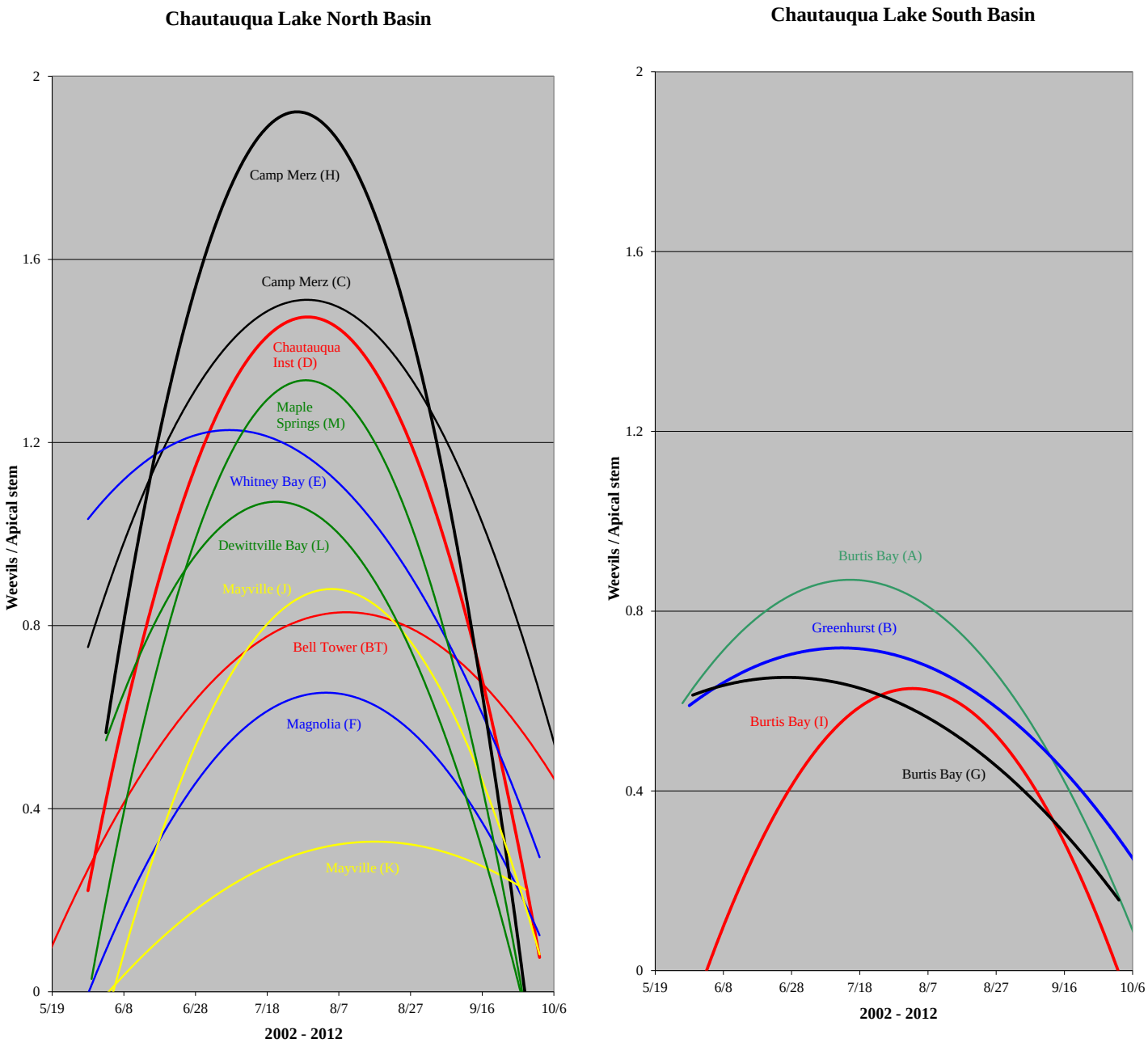


Figure 1. Densities of the weevil, *Euhrychiopsis lecontei*, from Eurasian watermilfoil apical stem surveys for the north basin (left) and the south basin (right) of Chautauqua Lake from 2002 to 2012.

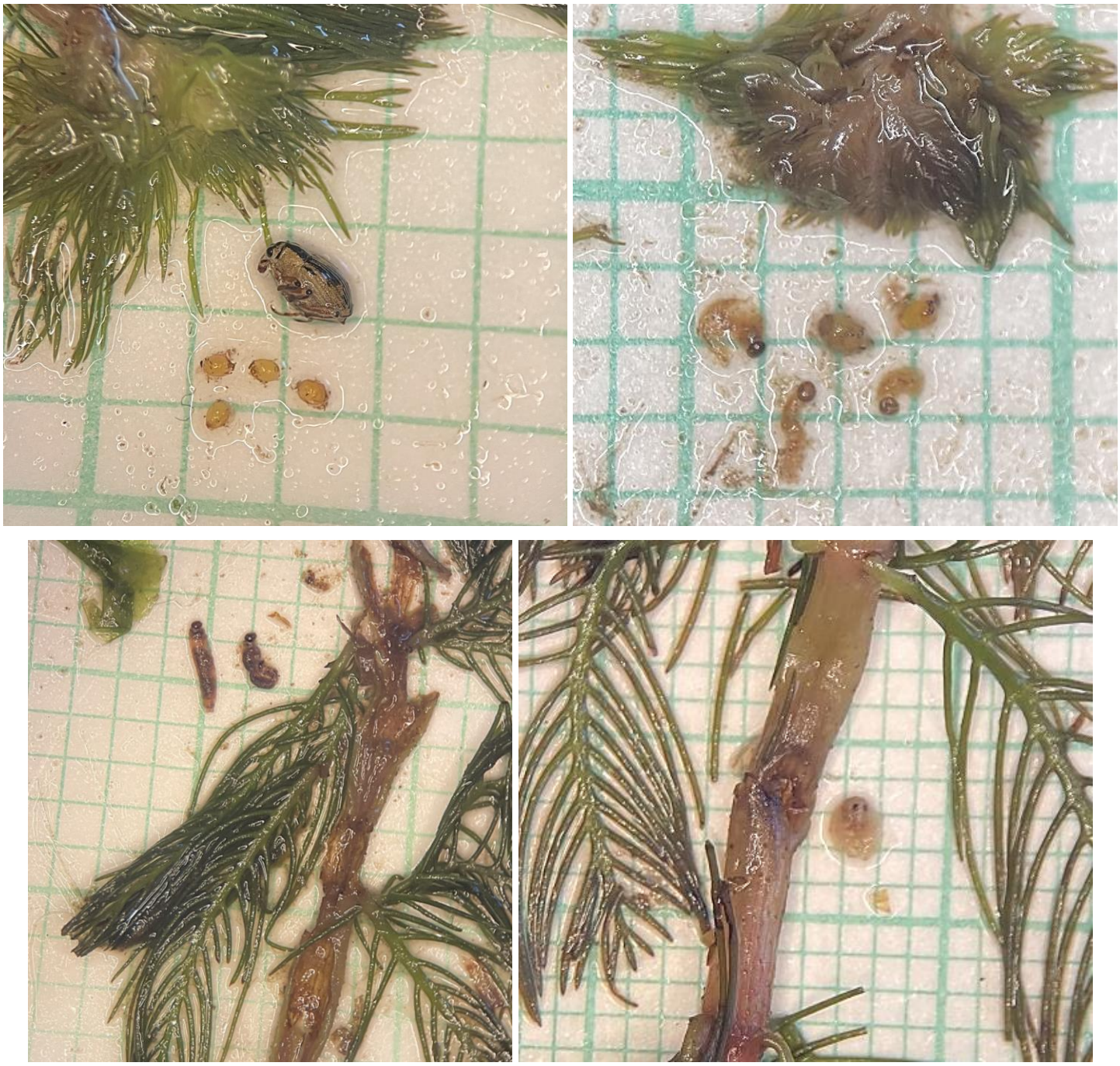


Figure 2. These photos show the life cycle stages of the weevil, *Euhrychiopsis lecontei*. The top left photo shows an adult weevil that laid four eggs on an apical stem of Eurasian watermilfoil. The top right photo shows three weevil larvae that have just hatched with two weevil eggs that have not yet 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.

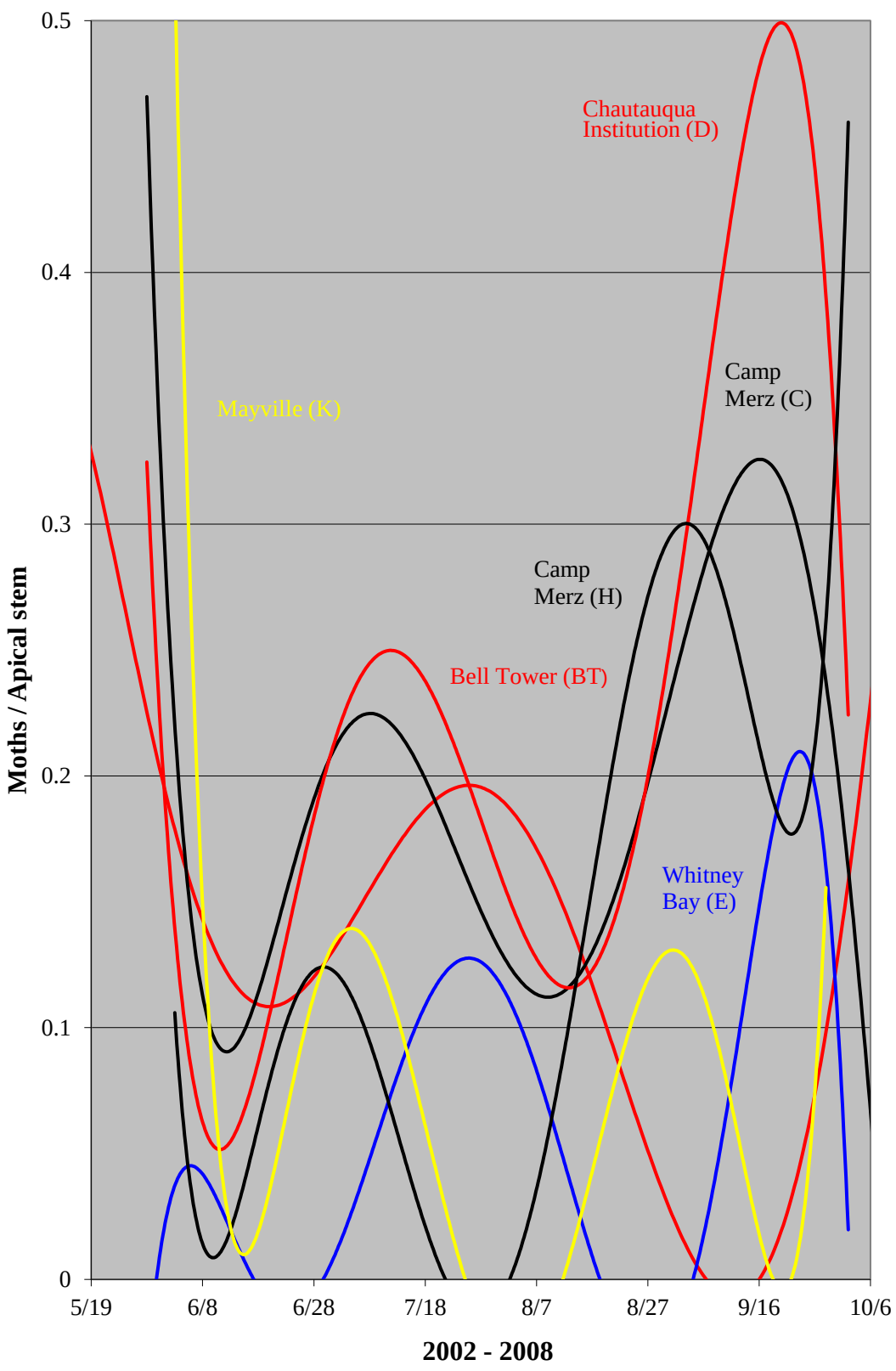


Figure 3. Densities of the moth, *Acentria ephemerella*, from Eurasian watermilfoil apical stem surveys for the north basin of Chautauqua Lake from 2002 to 2008.

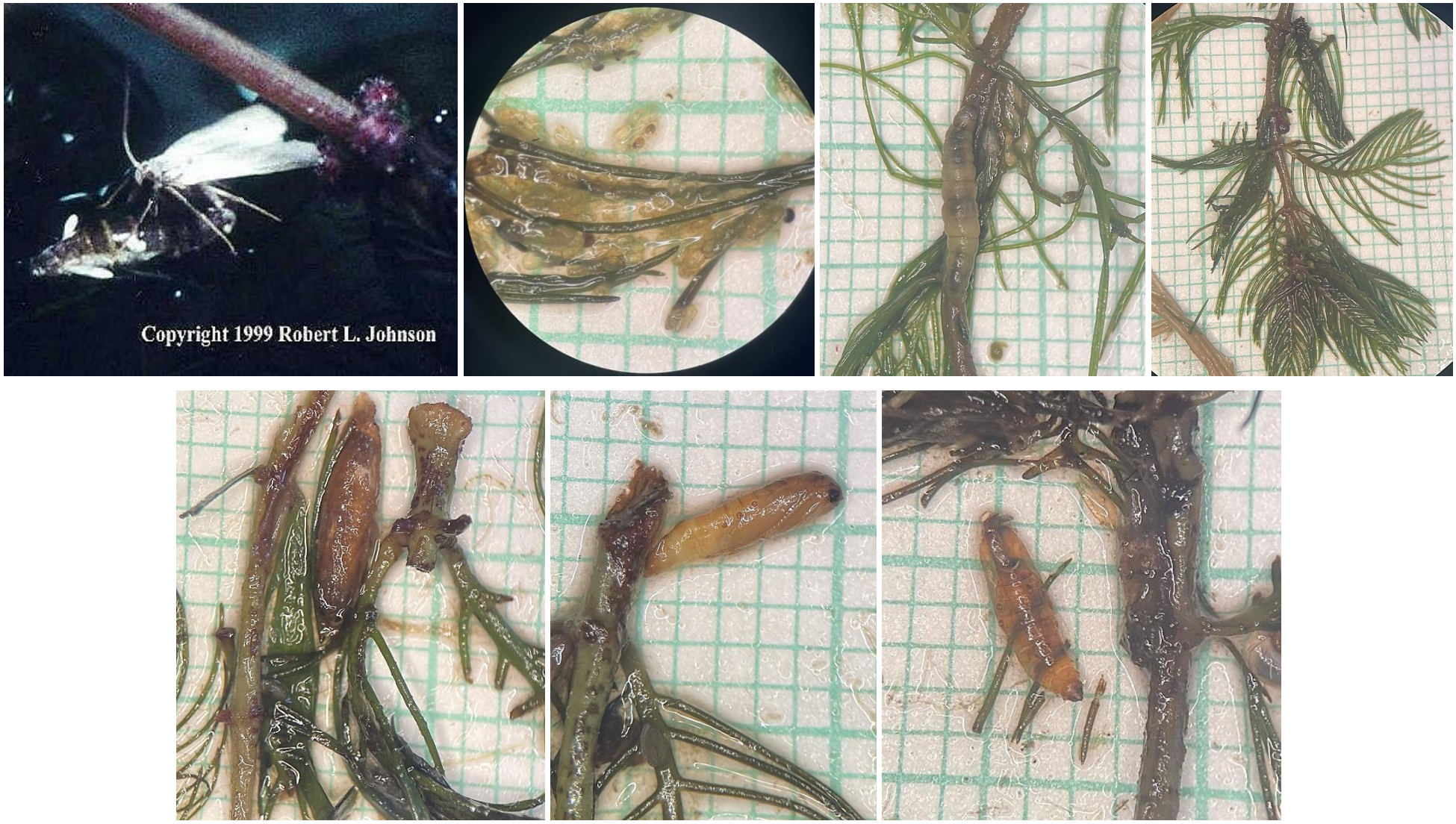


Figure 4. These photos show the life cycle stages of the moth, *Acentria ephemerella*. The top left photo shows two adult moths reproducing. The female moth goes down the Eurasian watermilfoil's stem to lay eggs (top left center). The eggs then develop into larvae (top right center), which will grow and feed on Eurasian watermilfoil by creating retreats (top right). The bottom photos show different stages of the larvae creating a cocoon (left) to develop into an adult (middle) while causing extensive damage to the Eurasian watermilfoil. The adult emerges from the cocoon once fully developed and leaves behind a case (right).

Methods

In 2024, 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 2024, we collected plants at 13 out of 15 historic sites during our survey (Table 2). Locations D and G were not collected due to the lack of Eurasian watermilfoil apical stems.

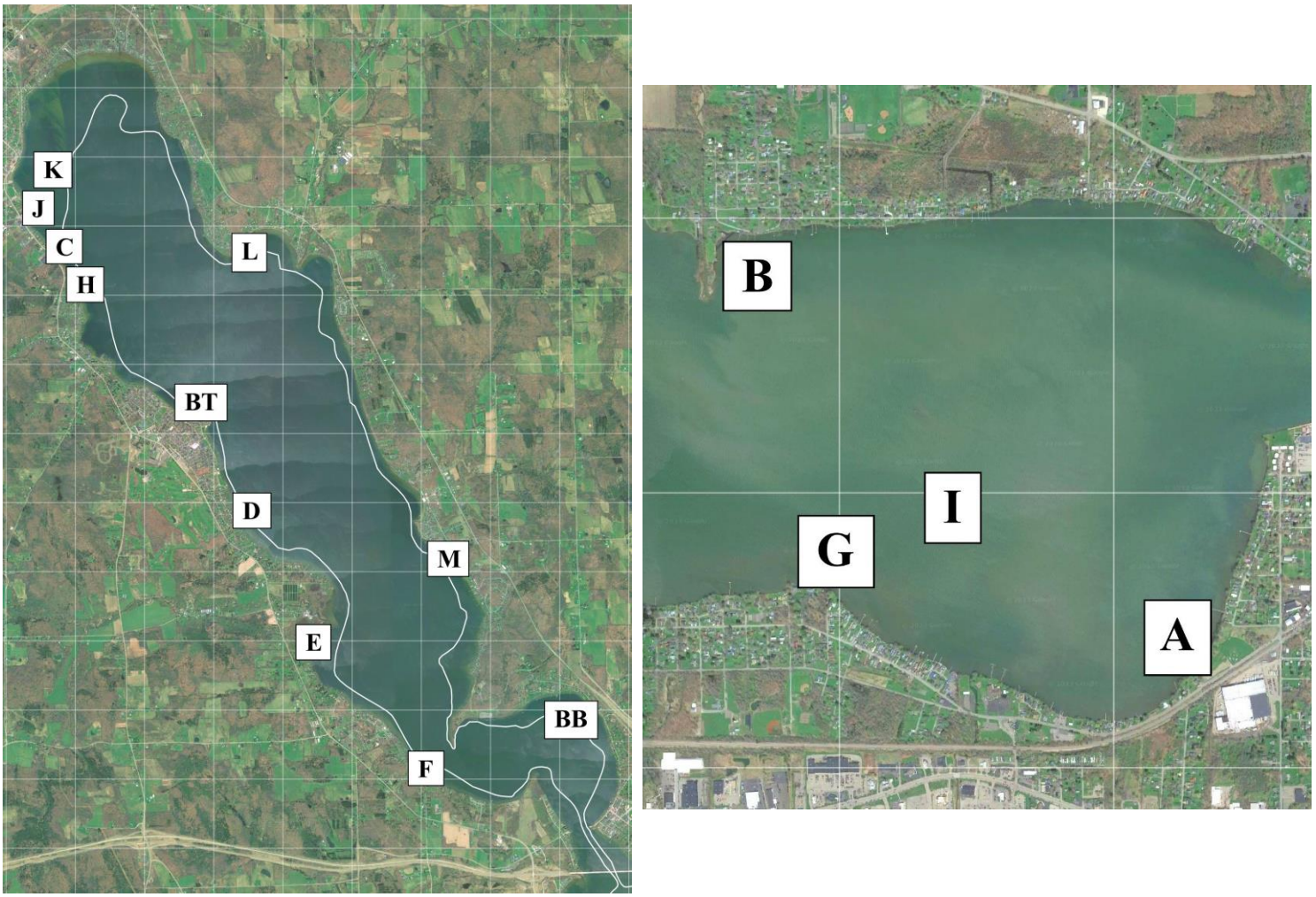


Figure 5. These maps show the Chautauqua Lake historic locations where we collect Eurasian watermilfoil apical stems and measure herbivore presence and damage on Eurasian watermilfoil.

Locations were found using a handheld GPS (NAD27 datum and True North, Table 2). 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 long 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.

Apical stems were refrigerated for up to three weeks until examination in the laboratory. If the samples could not be analyzed 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 at room temperature 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 scaring, leaflet damage, stem mining, and a missing or grazed apical meristem, were observed and recorded. The microscope examiner also recorded all life stages (eggs, larvae, pupae, and adults) for every weevil or moth found on each stem. All Eurasian watermilfoil tissue damage was qualified and quantified 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 7).

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).

Laboratory Data Sheet: Watermilfoil Herbivores and Associated Damage					
Location:	Date of Collection:			Date Examined:	
Location or GPS				Examiner:	
APICAL STEM SAMPLE	**No:**	**No:**	**No:**	**No:**	**No:**
HERBIVORES					
Moth ADULT (#)					
Moth **LARVAE (#)**					
Pupae in cocoons (#)					
Eggs (#)					
Weevil ADULT (#)					
Weevil **LARVAE (#)**					
Pupae in pupal chamber (#)					
EGGS (#)					
Midges non-damaging (#)					
Midges **DAMAGING** Milfoil (#)					
Caddis flies (#)					
Other:Damselfly, Mayflies, etc.					
APICAL MERISTEM DAMAGE					
Healthy apical tip					
Minor (a few leaflets missing)					
Moderate (many leaflets gone)					
Extensive (most grazed/deformed)					
Tip Missing (boat cut,insect, decay)					
STEM DAMAGE					
Healthy Stem					
Minor (1-4 scars or <2cm mined)					
Moderate (>4 scars or 2-4cm mined)					
Extensive (>8 scars or >4cm mined)					
Weevil mining (cm)					
Pupal chambers (# total)					
Scars (# moth, weevil, or other)					
LEAFLET DAMAGE					
Healthy Leaflets					
Minor (leaflets gone in 1-2 locations)					
Moderate (gone, 2-4 locations)					
Extensive (gone, >4 locations)					
Retreats (# total)					
Cocoons (# total)					
APICAL STEM CONDITION					
Clean					
CaCO3 Precipitate					
Algae covered					
Decayed					
COMMENTS					
MOTH LARVAE MEASUREMENTS:	body length / head width	body length / head width	body length / head width	body length / head width	body length / head width
1					
2					
3					
4					

Figure 7. Example of an Excel spreadsheet used to determine herbivore population density and associated damage.

Results and Discussion

On July 16, 2024, Rooney's Aquatic Biologists continued to monitor insect herbivore densities and evaluate the herbivore damage to Eurasian watermilfoil growing in Chautauqua Lake at all 15 historic locations. The 2017 – 2023 macrophyte (plant) surveys show that there has been an overall decrease in biomass (g/m^2) for *Myriophyllum spicatum* (Eurasian watermilfoil) lake-wide (Figure 8). The south basin has the most significant decline over the years due to recent herbicide use and ongoing herbivore activity. Bemus to Arnold Bay has also had a decrease in biomass of Eurasian watermilfoil primarily due to recent herbicide use. On the other hand, there has also been a decrease in the biomass of Eurasian watermilfoil in Maple Springs and Mayville (Figure 8). These areas of the lake have not had recent herbicide use. The most likely reason for this biomass decline is herbivore activity since no other targeted management tool has been used in these areas.

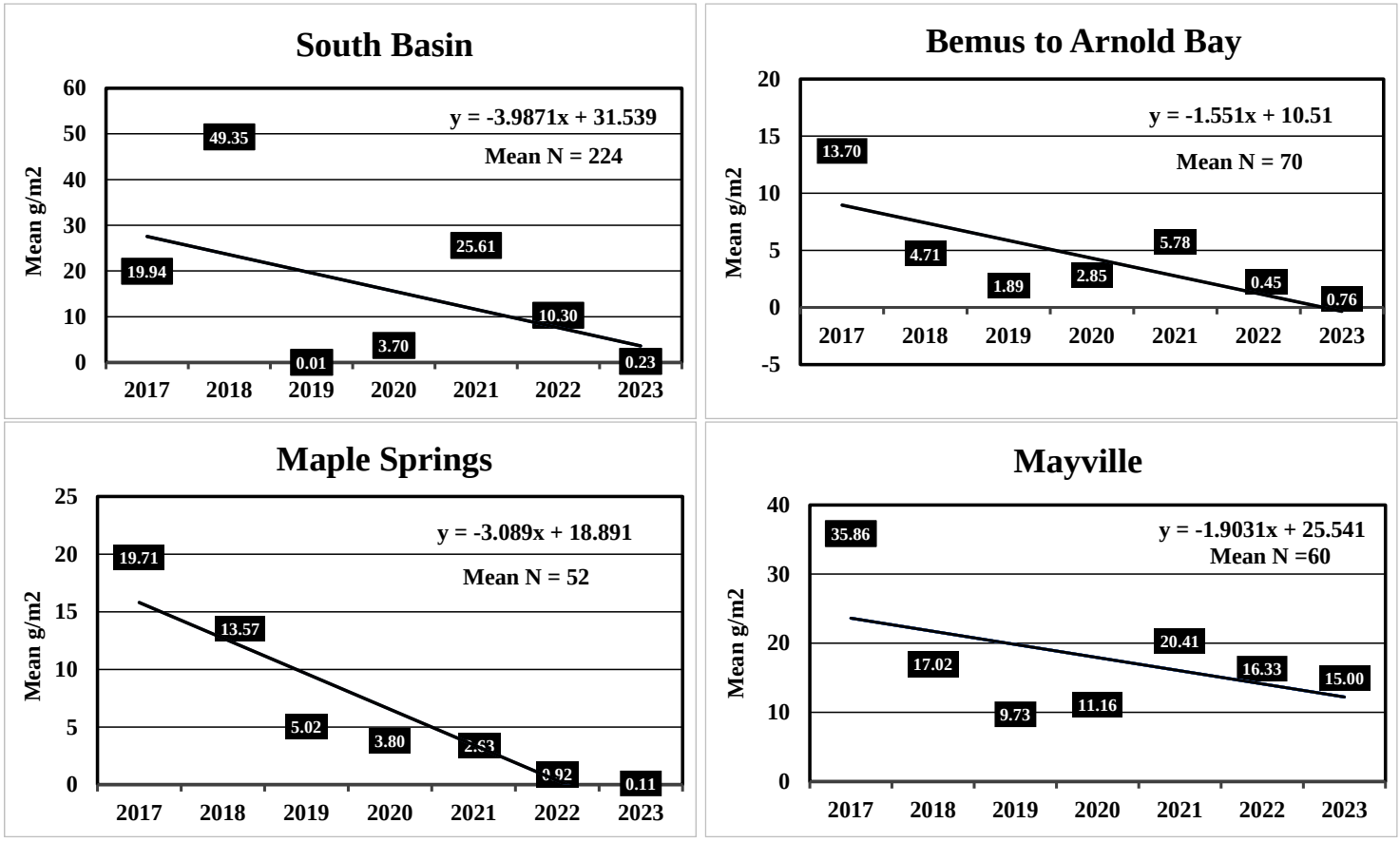
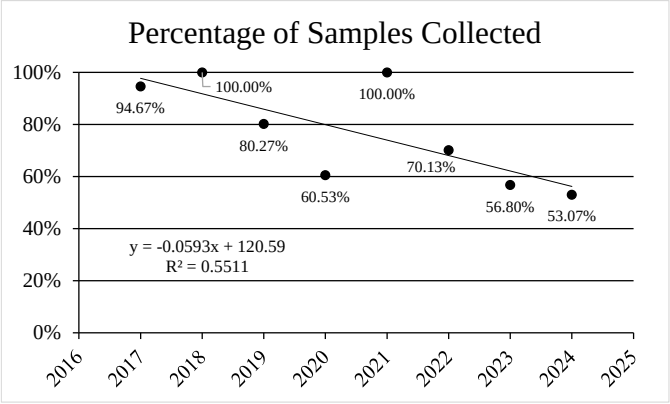


Figure 8. The estimated dry biomass (g/m^2) in the graphs above is calculated from our plant abundance surveys described in our plant survey reports (Johnson *et al*. 2021A – 2017). The graphs above describe the amount (biomass) of *Myriophyllum spicatum* (Eurasian watermilfoil) in the southeast end of the South Basin, Bemus to Arnold Bay, Maple Springs, and Mayville from 2017 to 2023. Note the differing g/m^2 on the left axis. The data points for 2022 – 2023 came from the SUNY Oneonta Biological Field Station report (Lord 2022 and 2024).

This overall decrease of Eurasian watermilfoil has also been apparent in the ability to collect samples for the insect survey lake-wide. Since 2017, with the addition of Bemus Bay (BB), there should be 375 Eurasian watermilfoil samples to collect. Table 1 shows the percentage of Eurasian watermilfoil apical stems collected yearly since 2017. In 2018 and 2021, all 375 samples of Eurasian watermilfoil were collected. Overall, there has been a decrease in the number of Eurasian watermilfoil apical stems collected since 2017 (Table 1). In 2024, we could only collect 53.07% of Eurasian watermilfoil apical stems, the smallest percentage of all the years (Table 1). Out of the 15 historic locations, we could not collect Eurasian watermilfoil samples at locations D (Chautauqua) and G (Lakewood) due to a lack of plants. We were able to collect all 25 apical stems at only five locations: F (Woodlawn), I (Burtis Bay), K (Mayville), BT (Bell Tower), and BB (Bemus Bay) (Table 2). On July 16, 2024, collection was particularly difficult because of low visibility due to the high algae in the water column, and it was a cloudy day with wind gusts up to 35 mph. This could have contributed to the inability to visually see the plants in the water. Crew members had to rely on GPS coordinates and past knowledge of where the plants should be at each location. Samples should be collected on a sunny, non-windy day to have the best chance of finding plants. New locations should also be considered on Chautauqua Lake, if possible. Other areas of the lake may have larger patches of Eurasian watermilfoil that could be sampled.

Table 1. Percentage of Eurasian watermilfoil apical stems collected lake-wide since 2017. There are 25 Eurasian watermilfoil apical stems collected at each of the 15 historic locations for a total of 375 samples.

Year	Possible Tips	Tips Collected	Percentage Collected
2017	375	355	94.67%
2018	375	375	100.00%
2019	375	301	80.27%
2020	375	227	60.53%
2021	375	375	100.00%
2022	375	263	70.13%
2023	375	213	56.80%
2024	375	199	53.07%



The invertebrate herbivore survey concentrated on the presence and density of the weevil *Euhrychiopsis lecontei*, and the moth, *Acentria ephemerella*. In 2024, 49 weevils and 51 moths were found on Eurasian watermilfoil lake-wide. The locations with the highest densities of weevils were E (Whitney Bay), M (Maple Springs), and BT (Bell Tower), with 1.09, 0.67, and 0.68 weevils found per apical stem (Table 2). The locations with the highest densities of moths were E (Whitney Bay) and M (Maple Springs), with 1.64 and 0.50 moths found per apical stem (Table 2).

Over the years, there has been a general decrease in the number of weevils per apical stem at 14 historic locations, with a slight increase in the number of weevils at BB (Bemus Bay) (Figure 9). These lower population densities might be attributed to the fact that there were fewer Eurasian watermilfoil apical stems found at many locations (Tables 1 and 2). Due to this significantly low biomass (Figure 8), finding enough specimens to collect was extremely difficult. We had to throw more rakes and spend more time finding plants in most locations. These smaller stands of Eurasian watermilfoil would also create more competition between the weevils and other herbivores. 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 decline in the weevil population is also related to food quality. Weevils depend on healthy Eurasian watermilfoil to find food and be able to grow. 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 8 and 9).

Table 2. 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 July 16, 2024.

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	7/16/2024	641227	4662467	1	0	0	0.00	0.00	0.00	0.00
Greenhurst Point	B	7/16/2024	639645	4663836	16	4	3	0.25	0.11	0.19	0.14
Camp Merz	C	7/16/2024	624826	4676501	19	0	4	0.00	0.00	0.21	0.16
Chautauqua	D	7/16/2024	627411	4672791	NA	NA	NA	NA	NA	NA	NA
Whitney Bay	E	7/16/2024	628355	4670952	11	12	18	1.09	0.34	1.64	0.61
Woodlawn	F	7/16/2024	630016	4669103	25	2	3	0.08	0.08	0.12	0.09
Lakewood	G	7/16/2024	639953	4662724	NA	NA	NA	NA	NA	NA	NA
Lighthouse Point	H	7/16/2024	624881	4676416	10	0	3	0.00	0.00	0.30	0.15
Burtis Bay	I	7/16/2024	640412	4662940	25	0	3	0.00	0.00	0.12	0.07
Lakeside Park	J	7/16/2024	624389	4677437	10	1	3	0.10	0.10	0.30	0.21
Mayville	K	7/16/2024	624592	4677640	25	4	1	0.16	0.09	0.04	0.04
Dewittville Bay	L	7/16/2024	627425	4676677	1	0	0	0.00	0.00	0.00	0.00
Maple Springs	M	7/16/2024	630335	4672218	6	4	3	0.67	0.67	0.50	0.34
Bell Tower	BT	7/16/2024	626900	4674200	25	17	2	0.68	0.24	0.08	0.06
Bemus Bay	BB	7/16/2024	632300	4670000	25	5	8	0.20	0.12	0.32	0.13

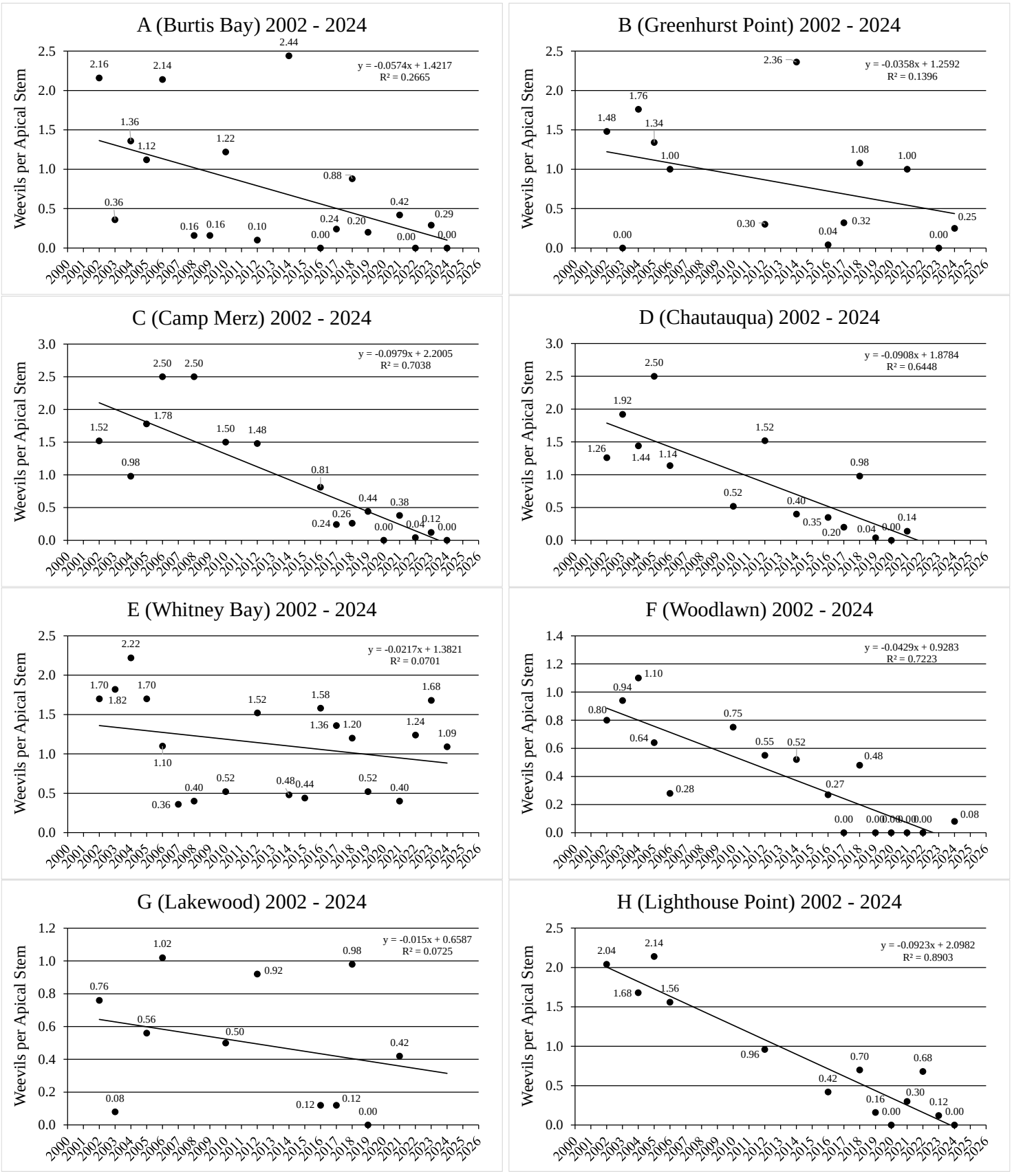


Figure 9. Number of weevils per apical stem of Eurasian watermilfoil at all 15 historic locations of Chautauqua Lake. Note: The y-axis for each graph has a different scale.

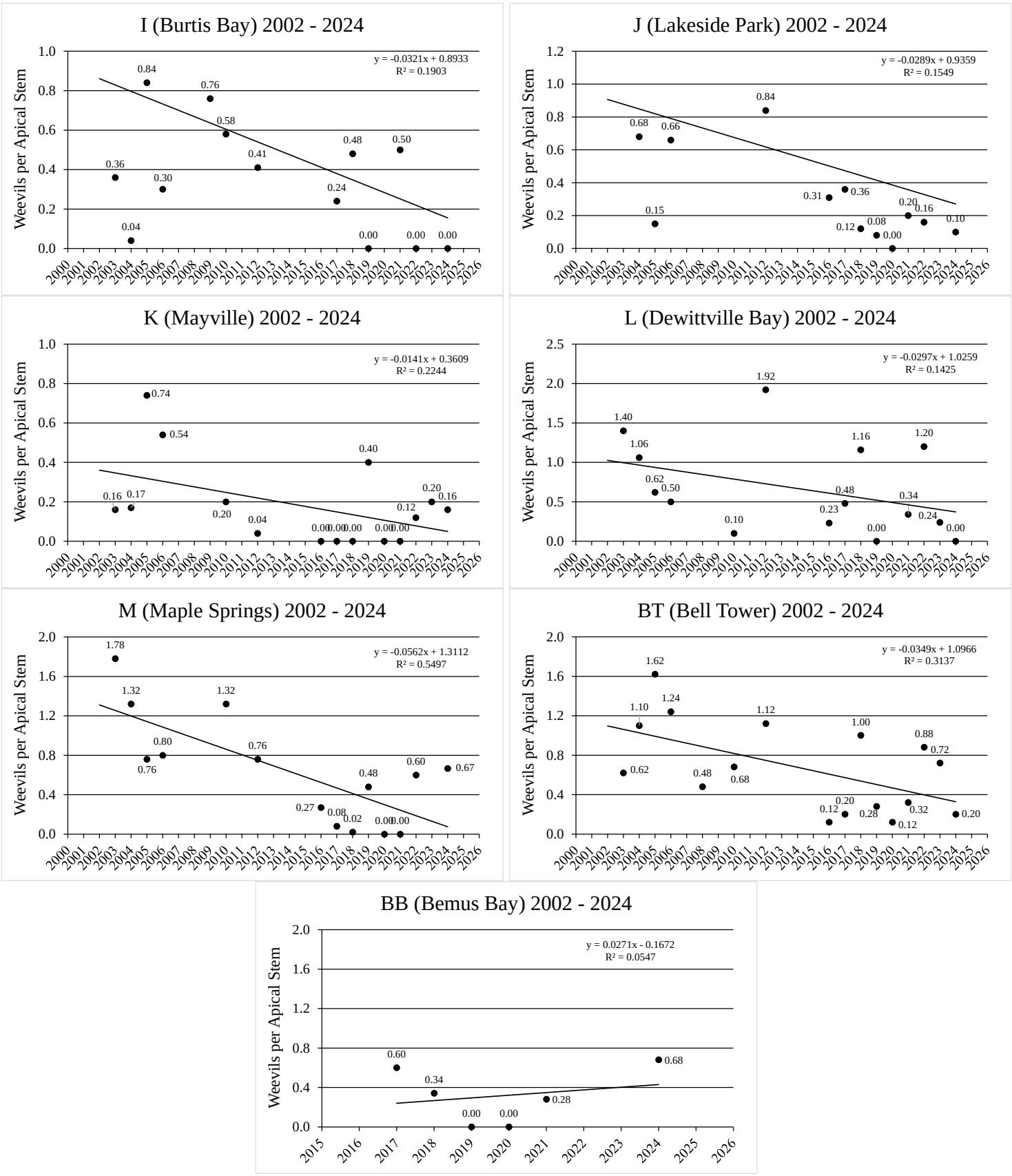


Figure 9 (con't). Number of weevils per apical stem of Eurasian watermilfoil at all 15 historic locations of Chautauqua Lake. Note: The y-axis for each graph has a different scale.

Other herbivores found feeding on Eurasian watermilfoil in Chautauqua Lake include the two caddisflies, 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 – 2021 surveys (Johnson *et al*. 2021A, 2020A, 2020, 2019C, 2019B, 2019A, and 2019). From 2018 – 2021, 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 three years, we have observed a drastic decrease in caddisfly density on our lake plant samples since finding 2,983 caddisflies on June 22, 2021 (Figure 10). In 2022 and 2023, only 37 and 30 small caddisflies were found on Eurasian watermilfoil. There was a slight increase in 2024, with finding 51 small caddisflies lake-wide. 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 8). The higher caddis populations from 2018 – 2021 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 seen since finding one in 2022. 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 and 2012).

With the recent decline of the weevil and both caddis species, stakeholders should consider whether the recent increase in herbicide use contributes to declining invertebrate populations (Figures 8 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, and 2,983 small caddisflies were identified in the herbivore survey conducted on June 22, 2021 (Johnson *et al.* 2021A).

The last herbivore found feeding on Eurasian watermilfoil in Chautauqua Lake is the midge, *Cricotopus myriophylli*. This herbivore is one of the most difficult to identify out of all other herbivores in the lake and has a crisscross, or figure 8 pattern, along its non-segmented body. The midge can create retreats that cause damage to leaves while making scars that cause damage to the stem. Eventually, the apical stem of Eurasian watermilfoil will be consumed. In 2024, two possibly new species of damaging midges were found not only in Chautauqua Lake, but also in nearby Bear Lake and Lake Bonaparte (Rooney and Johnson 2024A and 2024). A total of 44 damaging midges were found lake-wide in Chautauqua Lake. The location with the highest density of damaging midges was BT (Bell Tower), with 1.32 midges found per apical stem. These possibly new damaging midges could be identified by crushing the head capsule and looking at the mouth parts (Lord *et al*. 2004). At this point, laboratory examination of this kind is not obtainable. The first possibly new damaging midge has the figure eight pattern similar to the *Cricotopus myriophylli*, but has body segmentation (Figure 11). The second possibly new damaging midge does not have a figure eight pattern, has body segmentation, and has two distinct brown spots on the head capsule (Figure 12). Visual observations show that these new species damage the Eurasian watermilfoil by creating scars and retreats, similar to the *Cricotopus myriophylli* (Figures 11 and 12).

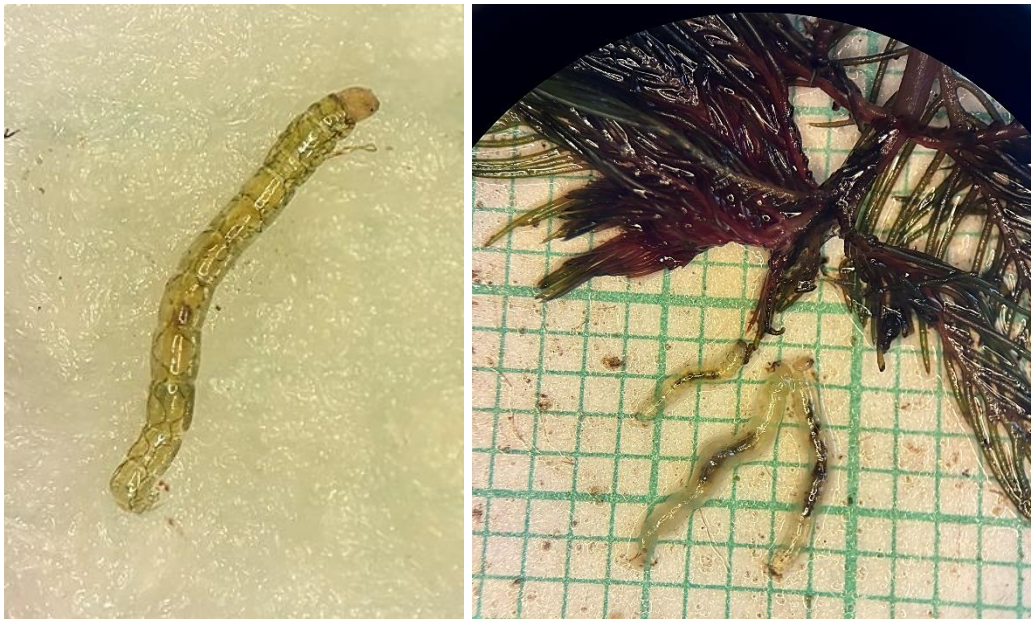


Figure 11. These photos show the possibly new midge species with the figure eight pattern. The left photo shows damage by scaring and creating a retreat to the apical stem of the Eurasian watermilfoil.

Figure 12. The left photo shows the possibly new midge species with two distinct brown spots on the head capsule. This species was found inside a retreat in the leaves of Eurasian watermilfoil (right photo).

One way of quantifying herbivore damage on Eurasian watermilfoil is to count the number of stem and leaf damage, including all scars, pupal chambers, mining, retreats, and cocoons the herbivores create. Determining the specific herbivore that creates stem or leaf damage can be extremely difficult to identify. To rectify this problem, all herbivores have been included to determine overall herbivore stem and leaf damage. Stem damage is determined by counting the amount of all herbivore scaring, along with weevil stem mining and pupal chambers. Leaf damage is determined by counting the number of retreats and cocoons, along with any moth leaf mining. Leaf mining is where a moth will hollow out the inside of an individual leaflet of Eurasian watermilfoil during its different instar stages. Once the number of scars, pupal chambers, mining, retreats, and cocoons has been counted, overall stem and leaf damage can be classified into healthy, minor, moderate, or extensive for each sample (Figure 7). The percentage of each stem and leaf damage category can then be calculated for each location. For example, if 25 stems were collected and 12 stems had a moderate rating, that location would have a 48.00% moderate stem damage rating on Eurasian watermilfoil. Lake-wide stem and leaf damage was also calculated by averaging all 15 historic locations.

Overall, stem and leaf damage in Chautauqua Lake is relatively high. In 2024, only 5.05% of all locations sampled had a healthy stem. The other 94.95% of the samples showed herbivore stem damage. The total moderate and extensive stem damage rating was 37.50% lake-wide (Figure 13). In 2024, only 15.28% of all locations sampled had healthy leaflets. The other 84.72% of the samples showed herbivore leaf damage. The total moderate and extensive leaf damage rating was 44.21% lake-wide (Figure 14). As a whole, these biological control agents in the lake are contributing substantially to the damage of Eurasian watermilfoil. No other means of control or management of Eurasian watermilfoil would be necessary at this time.

By analyzing stem and leaf damage throughout the lake, we can determine where the damage might be most or least significant from year to year. In 2024, location E (Whitney Bay) had the highest number of extensively damaged stems at 72.73% and leaves at 63.64% (Figures 13 and 14). Location E (Whitney Bay) also had the highest number of weevils and moths (Table 2). This allows researchers to see a direct correlation between the number of herbivores compared to the percentage of damage found on the stems and leaves of Eurasian watermilfoil. As the number of herbivores increases, the percentage of stem and leaf damage also increases (Johnson *et al*. 2012 and 2013). This supports the idea of allowing these naturally occurring biological control agents to persist as the most cost-effective way to manage aquatic plants in Chautauqua Lake long term. Wholesale elimination of all plants by using herbicides, specifically in the south basin, will continue to hinder the existence of these essential herbivores (Figures 8 and 9).

Stem Damage Percentages 2024				
	Healthy	Minor	Moderate	Extensive
A	0.00	100.00	0.00	0.00
B	25.00	31.25	31.25	12.50
C	10.53	57.89	10.53	21.05
D	NA	NA	NA	NA
E	0.00	18.18	9.09	72.73
F	0.00	44.00	40.00	16.00
G	NA	NA	NA	NA
H	10.00	80.00	10.00	0.00
I	12.00	64.00	16.00	8.00
J	0.00	40.00	40.00	20.00
K	4.00	76.00	12.00	8.00
L	0.00	100.00	0.00	0.00
M	0.00	33.33	33.33	33.33
BT	0.00	48.00	24.00	28.00
BB	4.17	54.17	25.00	16.67
Lake-wide	5.05	57.45	19.32	18.18

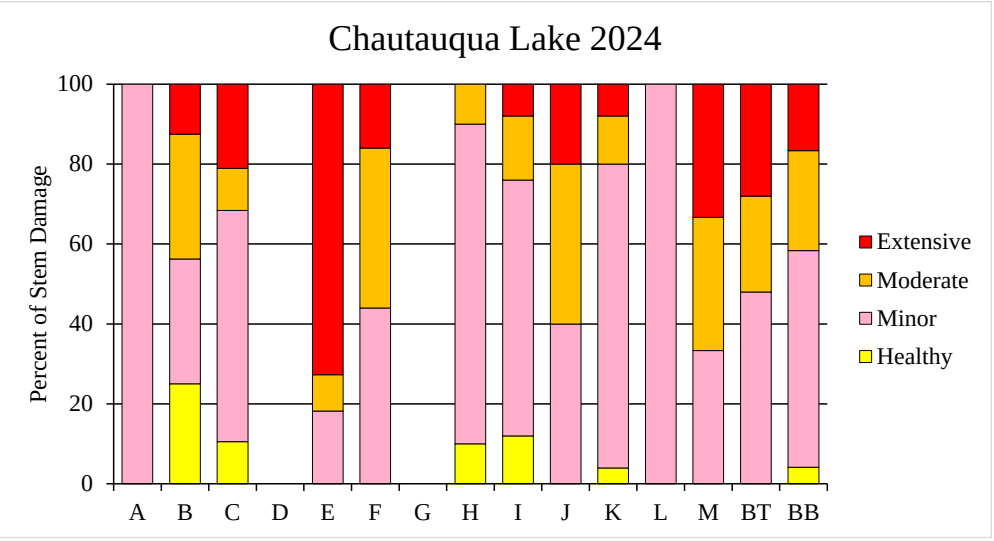


Figure 13. The percentage of stem damage was found for all 15 historic locations in Chautauqua Lake on July 16, 2024. Locations D (Chautauqua) and G (Lakewood) have no data due to a lack of Eurasian watermilfoil.

Leaf Damage Percentages 2024				
	Healthy	Minor	Moderate	Extensive
A	100.00	0.00	0.00	0.00
B	12.50	75.00	12.50	0.00
C	21.05	52.63	15.79	10.53
D	NA	NA	NA	NA
E	9.09	9.09	18.18	63.64
F	4.00	24.00	40.00	32.00
G	NA	NA	NA	NA
H	40.00	50.00	10.00	0.00
I	4.00	68.00	28.00	0.00
J	0.00	10.00	40.00	50.00
K	0.00	16.00	48.00	36.00
L	0.00	100.00	0.00	0.00
M	0.00	50.00	33.33	16.67
BT	0.00	20.00	40.00	40.00
BB	8.00	52.00	32.00	8.00
Lake-wide	15.28	40.52	24.45	19.76

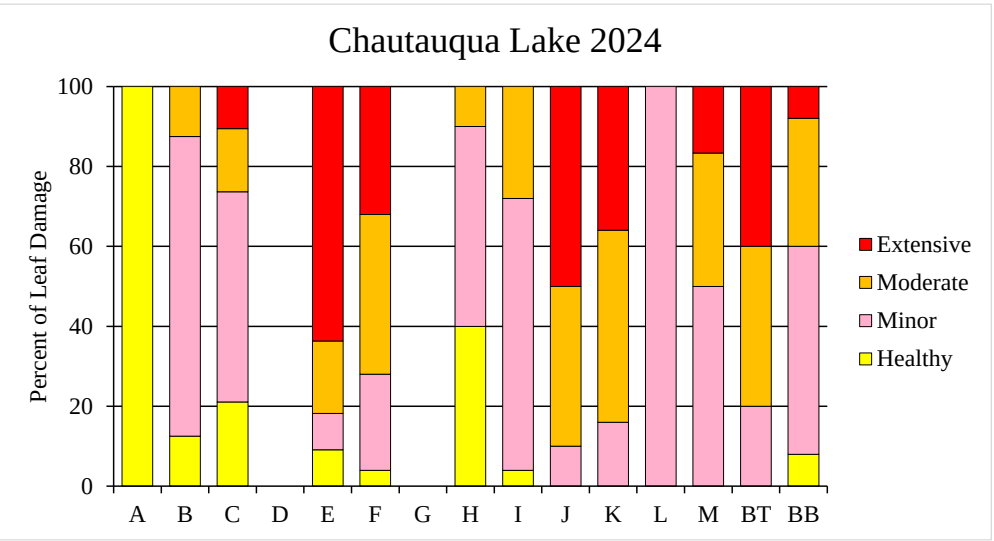


Figure 14. The percentage of leaf damage was found for all 15 historic locations in Chautauqua Lake on July 16, 2024. Locations D (Chautauqua) and G (Lakewood) have no data due to a lack of Eurasian watermilfoil.

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