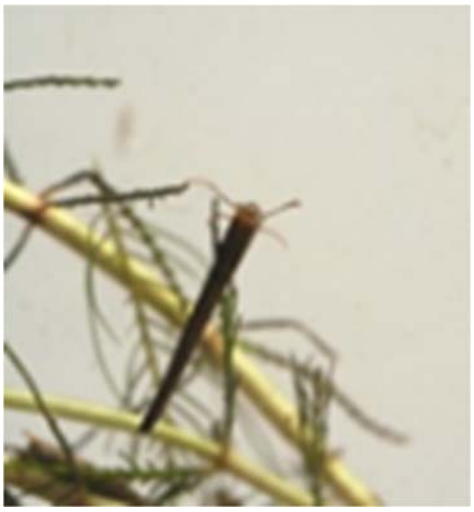
2022 Report on Invertebrate Herbivores in Chautauqua Lake



Caddis *Nectopsyche albida*

Weevil *Euhrychiopsis lecontei*

Moth *Acentria ephemerella*

Apical Stems of Herbivore Damaged Watermilfoil

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COVER

The top left shows the caddis larva *Nectopsyche albida* feeding on Eurasian watermilfoil.

At the top right is the adult weevil *Euhrychiopsis lecontei* on Eurasian watermilfoil.

The bottom left is a caterpillar of the pyralid moth *Acentria ephemerella.*

The bottom right exhibits herbivore damage to the apical meristem of Eurasian watermilfoil (burgundy red apical stem).

Racine-Johnson Aquatic Ecologists 2023

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Introduction

This report summarizes the findings of our Summer 2022 survey of invertebrate herbivores feeding on *Myriophyllum spicatum* (Eurasian watermilfoil) in Chautauqua Lake, conducted on July 13 and 14, 2022. We depict this information in tables and figures to provide current information on the herbivore populations as part of the 2002 – 2022 long-term dataset documenting those populations and subsequent plant damage. The report will include a discussion of the results of the 21-year study emphasizing important findings from the long-term 21-year research **(Johnson et al. 2002 – 2021)**.

The study design setup in 2002 and 2003 assessed whether the invertebrate herbivores *Acentria ephemerella* (a pyralid moth) and *Euhrychiopsis lecontei* (an aquatic weevil) could limit the growth of Eurasian watermilfoil in the lake. To accomplish this, 14 locations within the lake's littoral zone were identified, and the resident herbivores were sampled from 2002 through 2022. 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)**. Research at Chautauqua Lake would add to our knowledge of Eurasian watermilfoil management influenced by insect herbivores. In 2017, an additional location at Bemus Bay (BB) was added to the 14 historical lake locations to assess any effect on invertebrates that a 2017 and future herbicide applications targeting macrophytes in the lake might have. Over the same time, in-depth aquatic macrophyte data was recorded to assess the presence and abundance of individual plant species within the lake's littoral zone.

In 2022, we visited all 15 of the 15 historical sites during our survey; however, several locations lacked the presence of Eurasian watermilfoil due to 2022 herbicide applications, and without that habitat, there were no insect populations to evaluate. No data was collected from these barren areas of the lake's littoral zone. Eurasian watermilfoil was present in a few other locations; however, few or no insect herbivores were found, resulting in a herbivore density of 0 **(Table 1)**. Populations of insect herbivores increase and decrease with the plant mass and quality available for food, shelter, and reproduction. Healthy food quality is essential and determines population densities. The weevil, *Euhrychiopsis*, is "host specific" to the native *Myriophyllum sibiricum* (northern watermilfoil) but prefers the non-native Eurasian watermilfoil. The weevil requires these watermilfoils to reproduce and feed on to survive. The documented loss of Eurasian watermilfoil from recent herbicide applications can be associated with significant declines in lake weevil populations **(Havel *et al.* 2017)**. Chautauqua Lake areas treated with herbicides show a much lower occurrence or a lack of invertebrate populations. We believe this is primarily due to the loss of habitat. Other possible reasons for decreased populations include mechanical harvesting, invertebrate competition, dense algal blooms, and previous overwintering conditions that removed macrophytes or changed interspecific competition.

In 2021 we saw a significant increase in weevils and moths on Eurasian watermilfoil at locations that received herbicide applications from 2017 – 2020 south of Long Point compared to untreated areas. In 2021 the herbicide treatment with Endothall at the southeast end of the lake did not affect plant growth. We saw no efficacy of the herbicide **(Johnson *et al.* 2021)**. Macrophytes and water clarity increased (very reduced HABs) in the south basin, allowing invertebrates to return and reproduce. We recorded that weevil increase in the spring of 2021. Protection from the wholesale elimination of plant species from the littoral areas must be a top consideration in the long-term management of the lake. The continued loss of macrophytes from large sections of the south basin shrinks the littoral zone resulting in a decline of macroinvertebrates, water clarity, and an increase in the duration of cyanobacterial blooms.

Invertebrate Survey Methods

In 2022, we continued using past invertebrate herbivore data collection locations to sample Eurasian watermilfoil for the evaluation of herbivore populations and herbivore damage **(Figure 1)**.

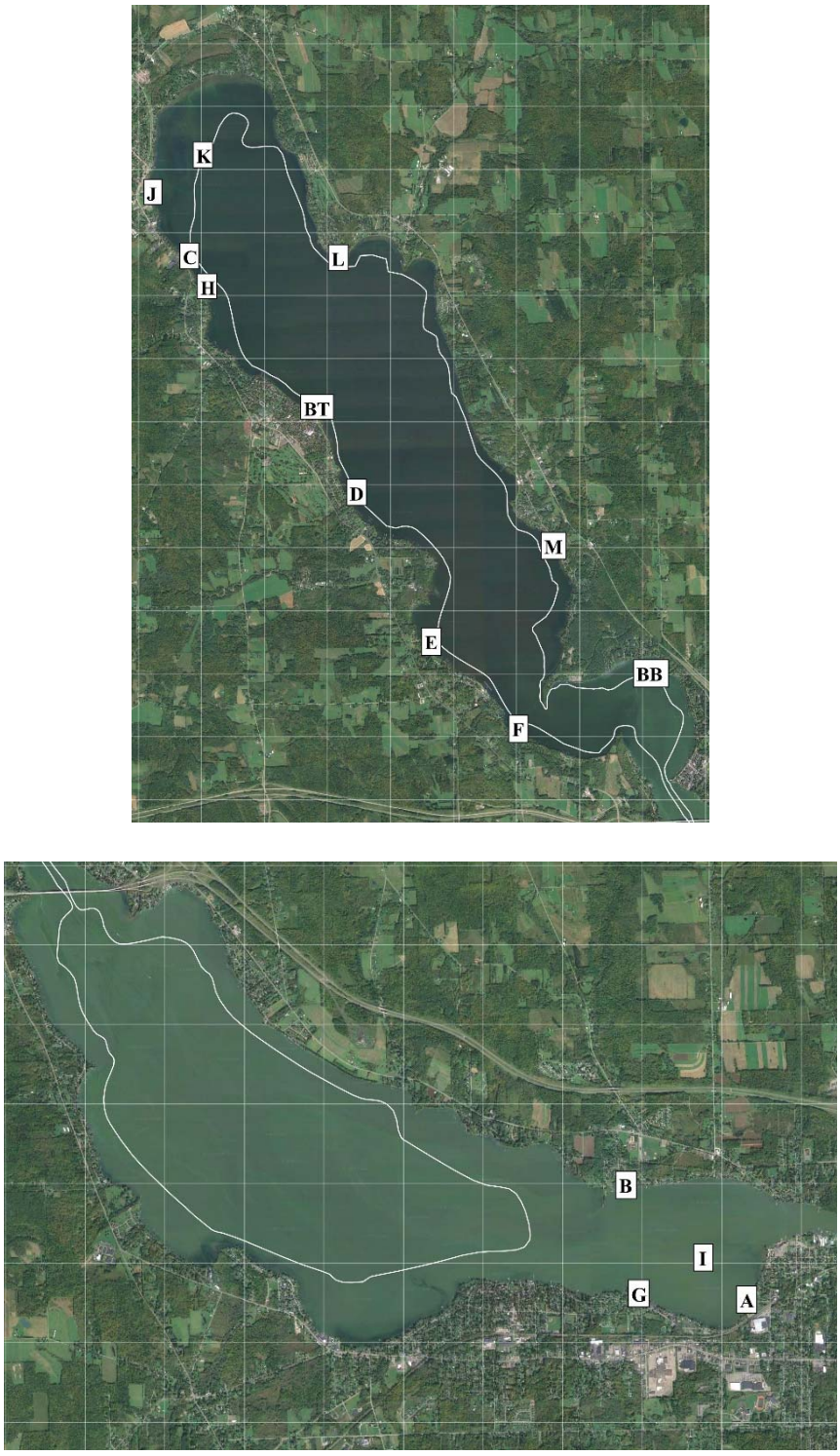


Figure 1. These maps show the Chautauqua Lake historic locations where we collect Eurasian watermilfoil apical stems and measure herbivore presence and damage on Eurasian watermilfoil.

Our herbivore sampling procedure used the double-headed rake-toss drag method to randomly sample plants at each location. In the boat, 25 apical stems of Eurasian watermilfoil, yet to flower, measured 25 centimeters in length, were collected. 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 for evaluation. Dissection of the entire stem allowed complete determination of the number and types of herbivores. Evidence of herbivore presence, like retreats, cocoons, and/or pupal chambers, along with plant tissue damage like 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 moth or weevil 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 moths and weevils per apical stem was calculated, including individuals in all life stages. Using a standard protocol, we determine which herbivores were responsible for the types of damage, and we can estimate the amount of plant damage caused by each herbivore. Results were recorded in a database.

Results 2022 Invertebrate Survey

On July 13 and 14, aquatic biologists Melanie Rooney and Vanessa Covert conducted an invertebrate herbivore survey concentrating on the presence and density of the weevil *Euhrychiopsis lecontei* and the moth *Acentria ephemerella* on Eurasian watermilfoil at historical locations within Chautauqua Lake. Their monitoring was possible using Paul Stage's Maple Springs Lakeside Inn Bed and Breakfast pontoon boat.

All 15 locations were sampled, with 25 apical meristems of watermilfoil collected from all but five sites. Two areas had no watermilfoil plants, BB in Bemus Bay and G in Lakewood. Location B at Greenhurst Point had one meristem, D at Chautauqua two, and A at Burtis had ten meristems. Weevil densities ranged from 0 to 1.24 per apical meristem, and moths from 0 to 0.44. The observation of insects in general and our herbivores would be expected to be very low in the areas with watermilfoil habitat absent. We would not expect any weevils in 2022. A significant percentage of locations in 2022 that have low, or no weevil densities are from Long Point southward into the south basin.

The locations with the highest densities of weevils and moths in 2022 are **E (Whitney Bay)**, with 1.24 weevils and 0.44 moths per meristem, **L (Dewittville Bay),** with 1.20 weevils and 0.35 moths per meristem, **BT (Bell Tower)** with 0.88 weevils and 0.04 moths per meristem, **H (Lighthouse Point)** with 0.68 and 0.19 moths per meristem and **M (Maple Springs)** with 0.60 weevils and 0.08 moths per meristem **(Table 1)**.

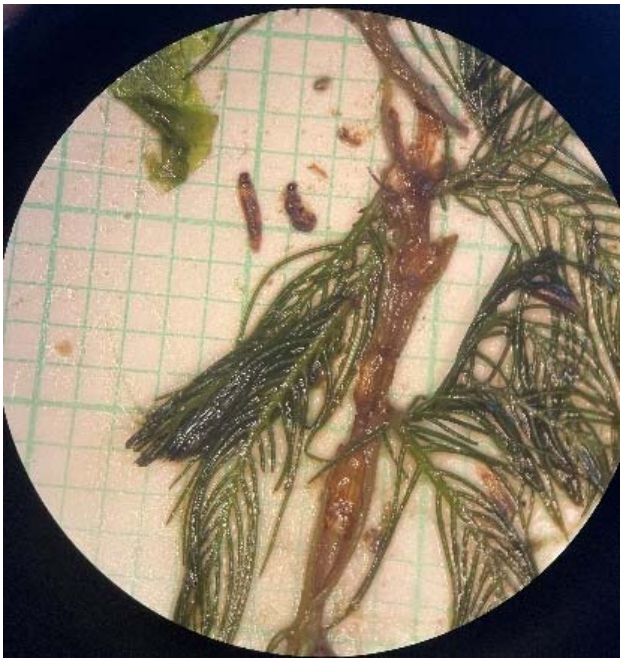
These densities are high and cause significant damage to Eurasian watermilfoil. One crucial observation is that in all five of these locations, the collection point for the last ten years is located at an increased distance further from the shoreline and at a more significant water depth than the original historical GPS points chosen at the beginning of this study. Eurasian watermilfoil has decreased or been eliminated at the close-to-shore areas of those locations, and we suggest that is due to sustained insect feeding. We have noted this loss of watermilfoil at the original nearshore areas that had recorded high densities of weevils and or moths in Lake Bonaparte and Cayuga Lake, where we have measured herbivores on Eurasian watermilfoil over many years. Conserving and encouraging natural biological control agents can aid in lowering management costs by insect biological control of excessive plant growth in the lake **(Havel *et al.* 2017)**.

Following are this year's results **(Table 1)** and photos of herbivores, life stages, and Eurasian watermilfoil damage from the 2022 analysis **(Figure 2)** and the previous year's analysis, 2021 **(Figures 3, 4, 5)**.

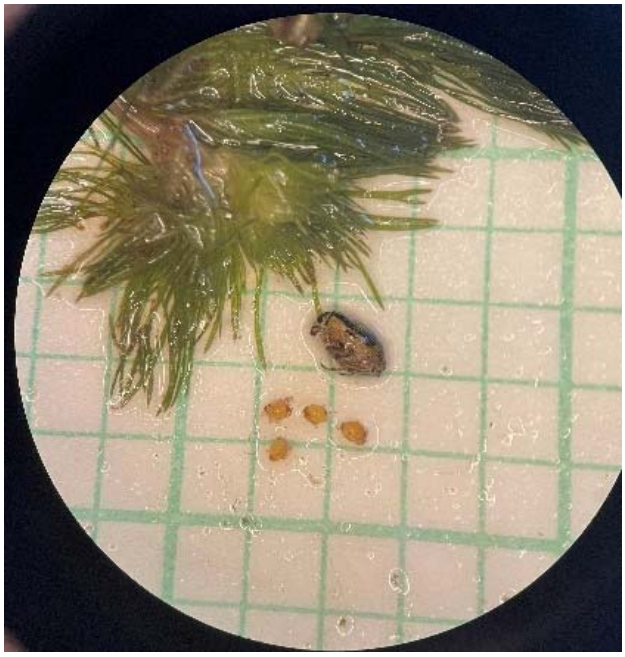
Adding the 2022 herbivore apical stem results to past results, we created graphs of weevil densities derived from data collected from the historical locations covering the time from 2002 through 2022 **(Figures 6, 7, 8, 9)** to follow in the Discussion section.

Table 1. Summary of results by microscope analysis of the July 13-14, 2022, survey. N/A means data is not available because no Eurasian watermilfoil was present.

Lake area	Plot	NAD27 X EAST 17T	NAD27 Y NORTH	Number of apical stems	Weevil Numbers	Moth Numbers	Weevils per apical stem	Weevil (SE)	Moths per apical stem	Moth (SE)
Burtis Bay	A	641227	4662467	10	0	0	0	0	0	0
Greenhurst Point	B	639645	4663836	1	N/A	N/A	N/A	N/A	N/A	N/A
Camp Merz	C	624826	4676501	25	1	2	0.04	0.04	0.08	0.06
Chautauqua	D	627411	4672791	2	N/A	N/A	N/A	N/A	N/A	N/A
Whitney Bay	E	628355	4670952	25	31	11	1.24	0.38	0.44	0.14
Woodlawn	F	630016	4669103	25	0	0	0	0	0	0
Lakewood	G	639953	4662724	0	N/A	N/A	N/A	N/A	N/A	N/A
Lighthouse Point	H	624881	4676416	25	17	5	0.68	0.19	0.2	0.08
Burtis Bay	I	640412	4662940	25	0	1	0	0	0.04	0.04
Lakeside Park	J	624389	4677437	25	4	1	0.16	0.09	0.04	0.04
Mayville	K	624592	4677640	25	3	2	0.12	0.09	0.08	0.06
Dewittville Bay	L	627425	4676677	25	30	7	1.2	0.35	0.28	0.14
Maple Springs	M	630335	4672218	25	15	2	0.6	0.26	0.08	0.08
Bell Tower	BT	626900	4674200	25	22	1	0.88	0.31	0.04	0.04
Bemus Bay	BB	632300	4670000	0	N/A	N/A	N/A	N/A	N/A	N/A



Weevil larvae caused stem mining damage.



Adult weevil and 4 weevil eggs are present.

Adult weevil and larva in the center.

Acentria larva in pupa at the cutoff growing tip.

Figure 2. Herbivore presence and damage photos from the 2022 analysis.

Discussion

In this final report for 2022 of herbivory on Eurasian watermilfoil, we analyze all collected herbivore data from 2002 through 2022 at Chautauqua Lake and report changes in the density of invertebrate herbivores in areas of the lake and the lake as a whole. We will contrast weevil presence and populations with our past measures of plant species mass. We use data referenced in our reports on Chautauqua Lake from 2002 through 2021, of which most of the reports are filed with the Chautauqua Lake Association and listed in the reference section of this report.

Chautauqua Lake's herbivory by the weevil and aquatic moth is still an overwhelmingly effective control of the growth of Eurasian watermilfoil, which has been well documented for over 20 years. The herbivores collectively limit the plant's elongation toward the lake's surface, thereby preventing flowering and surface matting by early June.

Figure 3. The two pictorials above show the weevil, *Euhrychiopsis lecontei*, on the left, and on the right the moth, *Acentria ephemerella*. These pictorials show the weevil and the moth causing extensive damage to *Myriophyllum spicatum* (Eurasian watermilfoil).

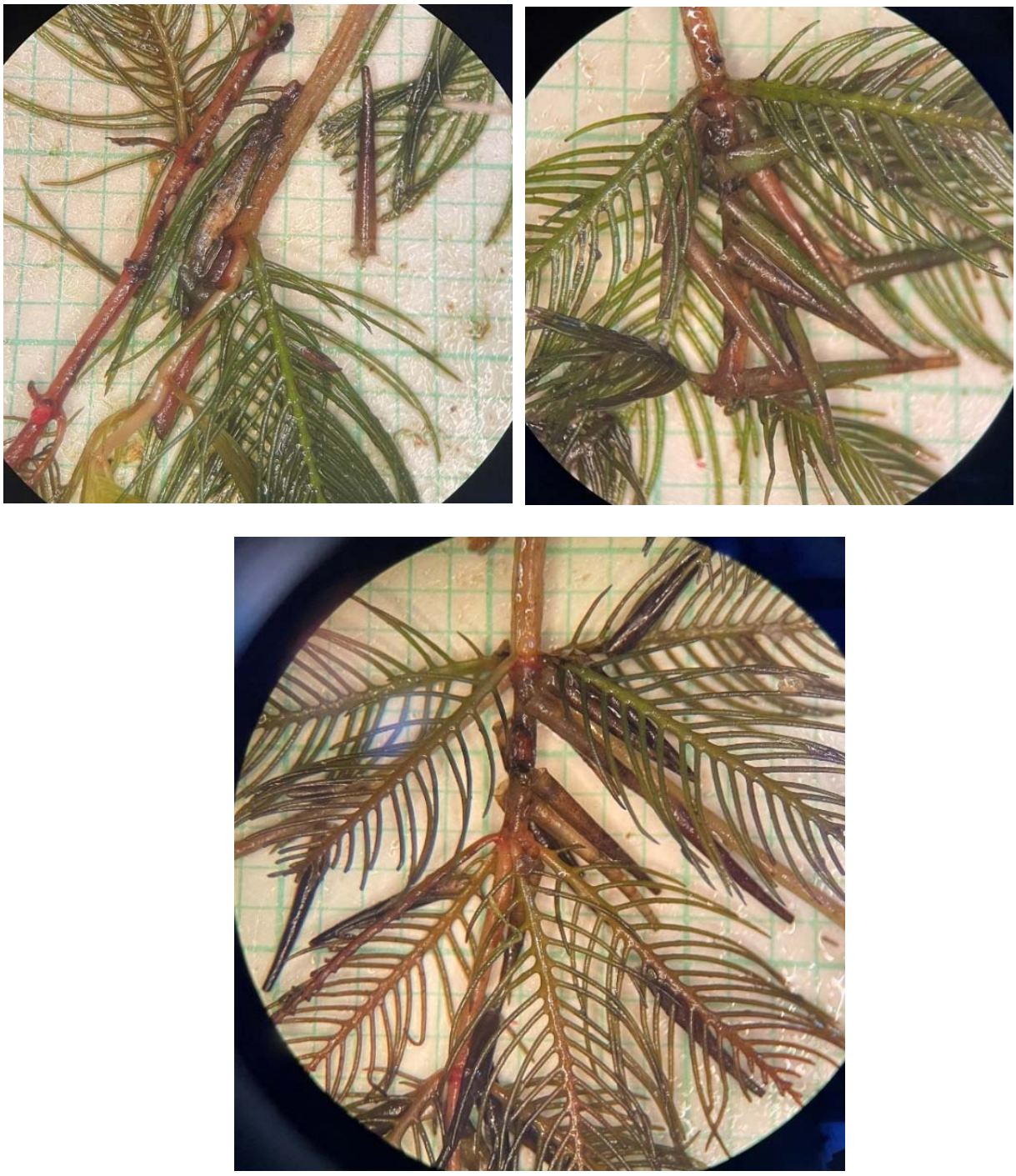


Figure 4. The top left photo shows the moth pupae, *Acentria ephemerella*, in a cocoon using the leaves of Eurasian watermilfoil as it transforms into an adult. Top right and bottom photos show the caddis, *Setodes grandis*, damaging and consuming the apical stem of Eurasian watermilfoil.

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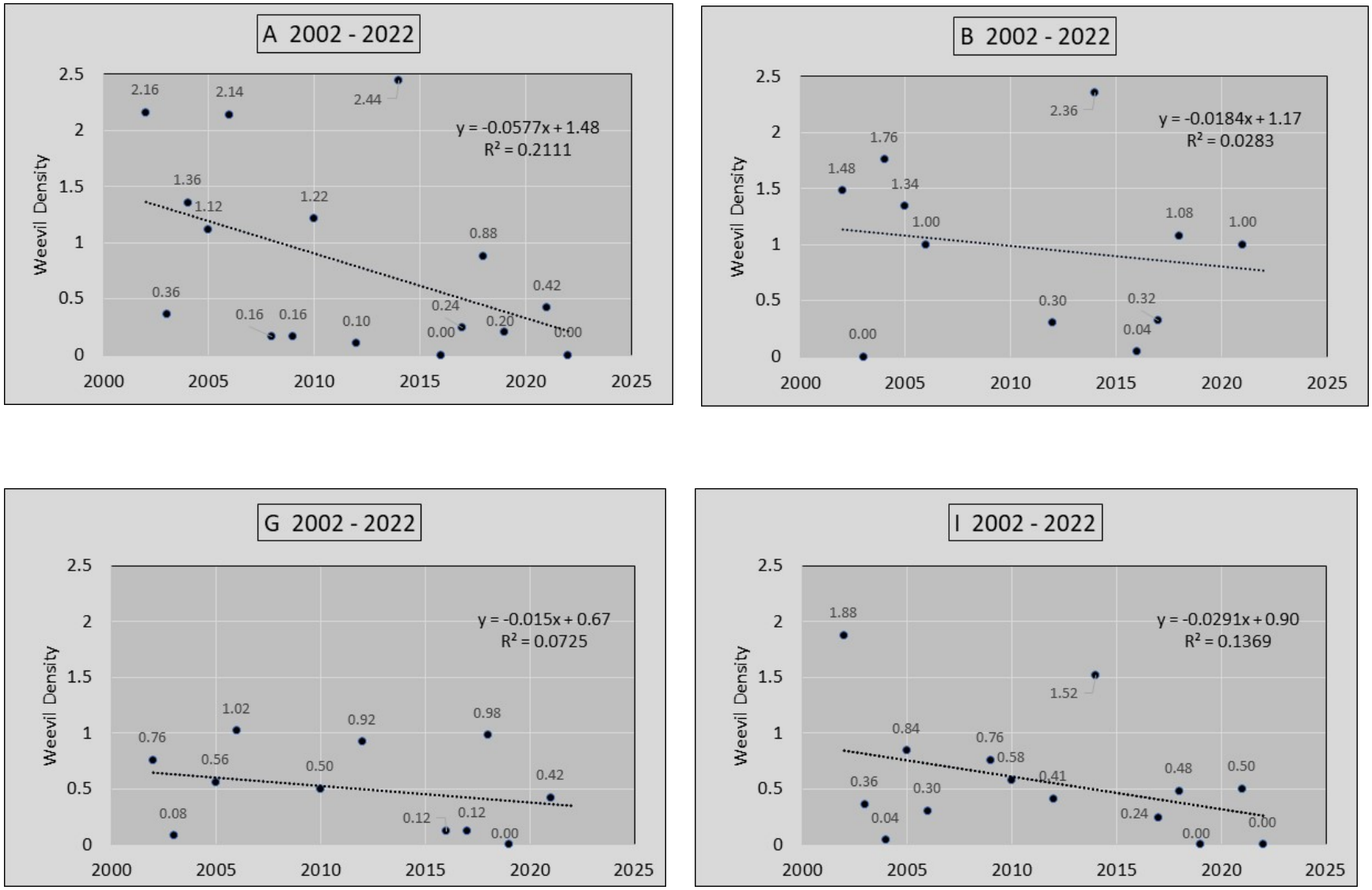
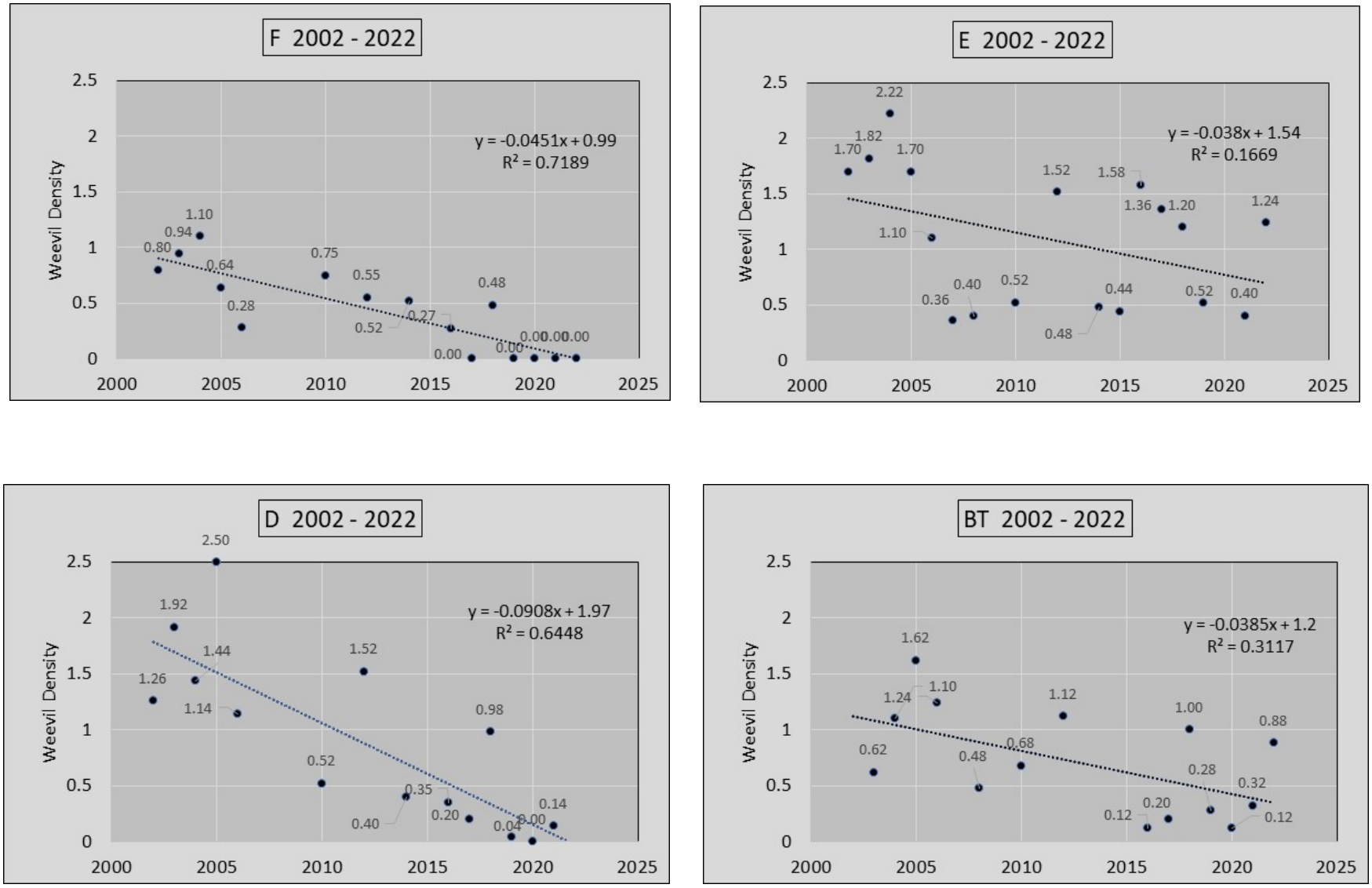


Figure 6. Number of weevils per apical meristem of Eurasian watermilfoil (Weevil Density) at four locations in the south basin of Chautauqua Lake over 21 years. Each data point is the mean weevil findings on 25 or 50 individual meristems.



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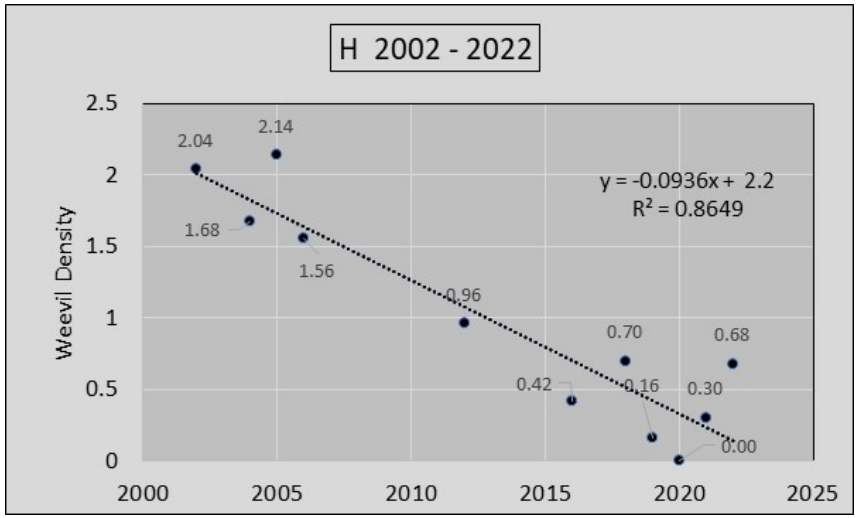

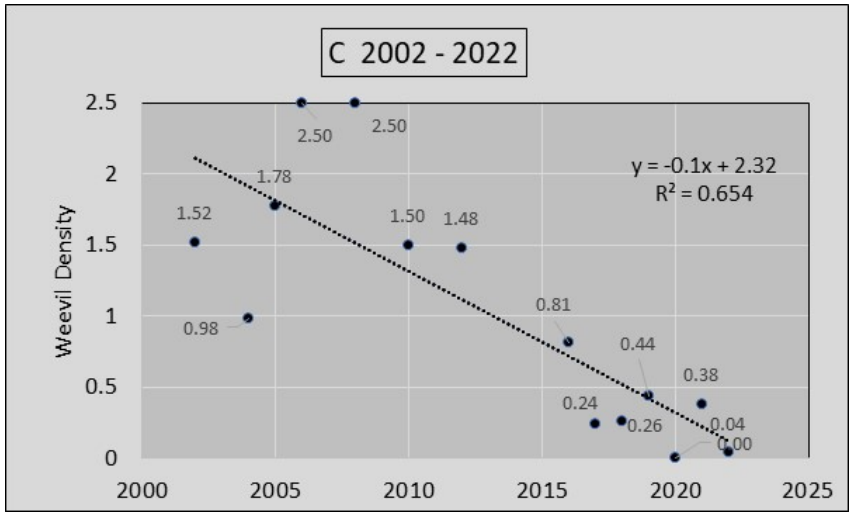

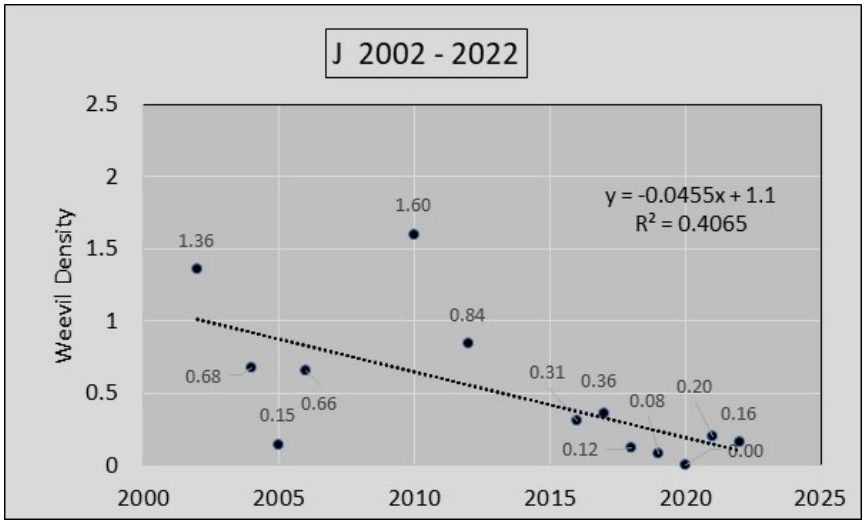

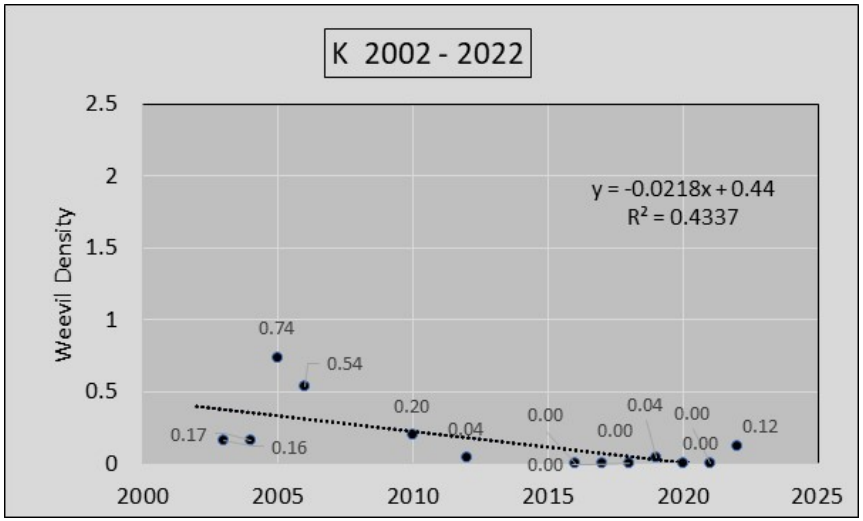

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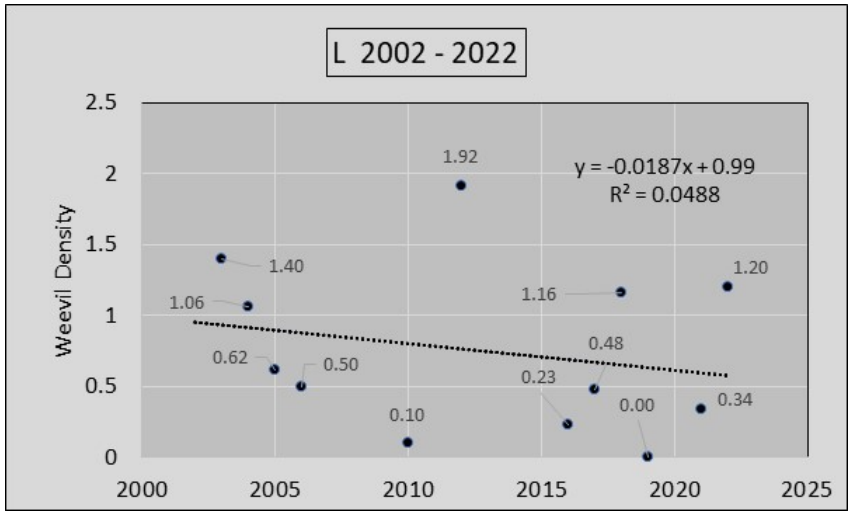

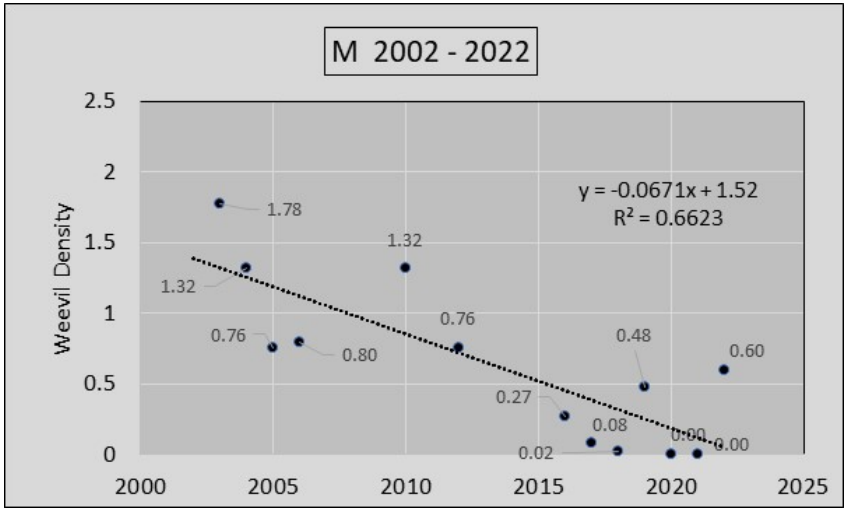

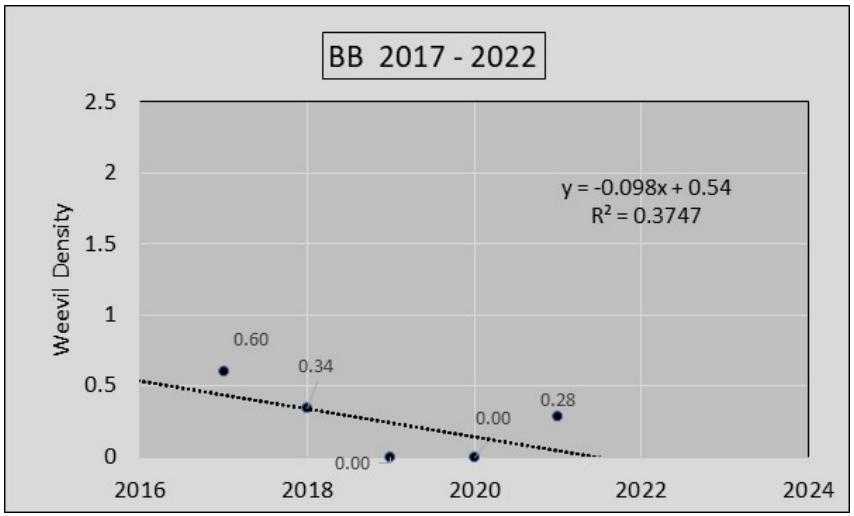

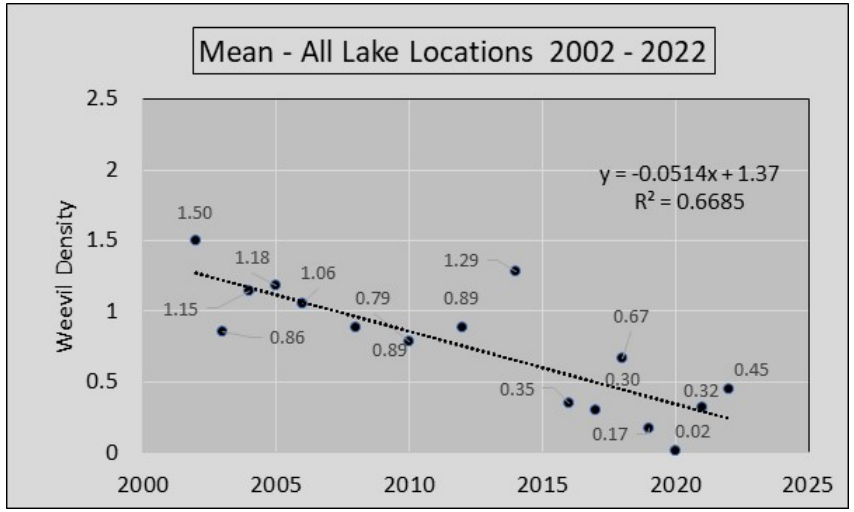

Figure 9. Number of weevils per apical meristem of Eurasian watermilfoil (Weevil Density) at three locations on the east side of the north basin of Chautauqua Lake over 21 years. Each data point is the mean weevil findings on 25 or 50 individual meristems. The fourth graph combines all 14 location means for each year, giving one yearly weevil density.

The preceding graphs **(Figures 6 – 9)** show populations of the weevil *Euhrychiopsis lecontei* expressed as weevil density at each of the 14 historical monitoring locations over the span of up to 21 years. The locations are widespread within the lake, each with unique characteristics of shoreline, plant community, water depth, and wave intensity.

Earlier **(Johnson *et al*. 2009),** we defined individual differences in weevil and moth populations at the 14 herbivore monitoring locations around the lake. We include that data here **(Figures 10, 11, 12)** to support observations we made earlier and currently about weevil and moth life cycles, damage to Eurasian watermilfoil, and the validity of the sampling locations chosen. The intense herbivore monitoring schedule through each aquatic plant growing season from 2002 – 2008 **(Figures 10, 11, 12)** gave us the weevil and moth population data to estimate how herbivore populations perform under varying lake locations and conditions.

In **(Figures 10 and 11)** recorded weevil densities depict the normal population growth curves experienced by our weevil sampling of several New York State lakes. Weevil population growth curves increase from early June to peak in mid-July. Then they decrease in August, while Eurasian watermilfoil fitness (health) declines due to decay from herbivory and maturity.

We also averaged the 2002 - 2008 moth (*Acentria*) density data from Chautauqua Lake. The moth graph **(Figure 12)** suggests differing moth densities around the lake. Still, it confirms that the moth population growth sequence appears to follow a definite life cycle pattern we observed in the earlier lake and laboratory studies. Again, as with weevil populations, the moth numbers show significant differences around the lake, which we believe are related to the diversity of the macrophyte communities and the growth stage of macrophytes. Young healthy-growing plants provide the most nutritious food for herbivores allowing rapid growth and reproduction.

The long-term data sets of herbivores and aquatic macrophytes collected at Chautauqua Lake over 21 years offer an opportunity to make valid conclusions backed by years of carefully recorded measures. Observing the weevil density results at the 14 sampling locations over this period **(Figures 6, 7, 8, 9),** it is clear that a change has taken place. While each site has a unique history each year, it is undeniable that this data shows that weevil populations (weevil densities) are declining in the lake. Speculating on possible causes of this long-term decline, the recent experimentation to eliminate macrophytes with various herbicides is likely not one. Although a case can be made in the short term that removing macrophyte habitat has decreased finding herbivores in the south basin **(Figure 6)**.

One potential cause for this decline in the population of weevils could be mechanical harvesting, the main management used to remove excessive plant growth from the lake. Removing growing macrophytes by cutting does remove herbivores from the lake however, weevils, moths, and caddis have been in the lake as long as mechanical harvesting has been applied. The herbivores figured out long ago how to persist in making harvesting a non-factor. 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. Another

possible cause can be competition from other herbivores. While we observe insect population changes year to year and from location to location, there does not appear to be any trend. We further do not see any meaningful predation by small fish species that could reduce weevils, and we discuss that in the following pages.

Our observations in lakes in NY, experimentation in the laboratory, and raising herbivores to large populations in captivity indicate that the most efficient way to produce large numbers of weevils, moths, or caddis is to provide the highest quality of aquatic plant growth (food) possible. As soon as food quality declines, insect reproduction quickly declines. 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 related to food quality.

While not as dramatic, we can point to (**Figure 13)** which describes the trendline for Eurasian watermilfoil abundance (biomass) in Chautauqua Lake using data points for years from 2003 through 2021, where we used the rake-toss drag method to evaluate plant biomass. The measure used for **(Figures 13 and 14)** is the % of locations sampled each year where an M (medium) or a D (dense) value was observed, and the number of each was added to produce a value for the year. Medium and dense values were used because they are biomass values with plants visible from the lake surface under clear conditions and are easily found with a rake-toss drag or grapple hook. Sparse (S) and trace (T) values are extremely small quantities, and most observers would declare those lake bottom areas reporting (S) and (T) not to have rooted plants.

The trendline or best-fit line for the data describing Eurasian watermilfoil abundance (biomass) from 2003 to 2021 shows a slight decline. This is a conservative estimate as data on plant biomass was not collected in the early years of 2002 and 2006, when Eurasian watermilfoil biomass was at very high values (R. Johnson's observation). However, this data shows a decline or, at best no change in Eurasian watermilfoil abundance (biomass) over this long period. This is contrary to what many often hear about lake plant management. Concern that an "invasive" will "takeover" the lake plant community and push out native plants. The Eurasian watermilfoil graph **(Figure 13)** and the trendline graph for native species **(Figure 14)** indicate that a "takeover" by Eurasian watermilfoil is not and should not be a concern for Chautauqua Lake stakeholders.

Our yearly observations since 2002 show Chautauqua Lake has the presence of a suite of five insect herbivores that all feed on Eurasian watermilfoil, with some beginning in the early spring and others continuing into the late fall. This continued damage by insects of this plant species is evident each year. It would appear that the non-native Eurasian watermilfoil in Chautauqua Lake lost its ability to dominate the aquatic plant community long ago and has lost out to native species. As the plant species' health and food quality decline, we would expect herbivore populations to decrease. We suggest lower food quality (low available nutrients) of the Eurasian watermilfoil, which continues to degrade as the reason for the lake's overall decline of weevil populations **(Figures 6, 7, 8, 9)**.

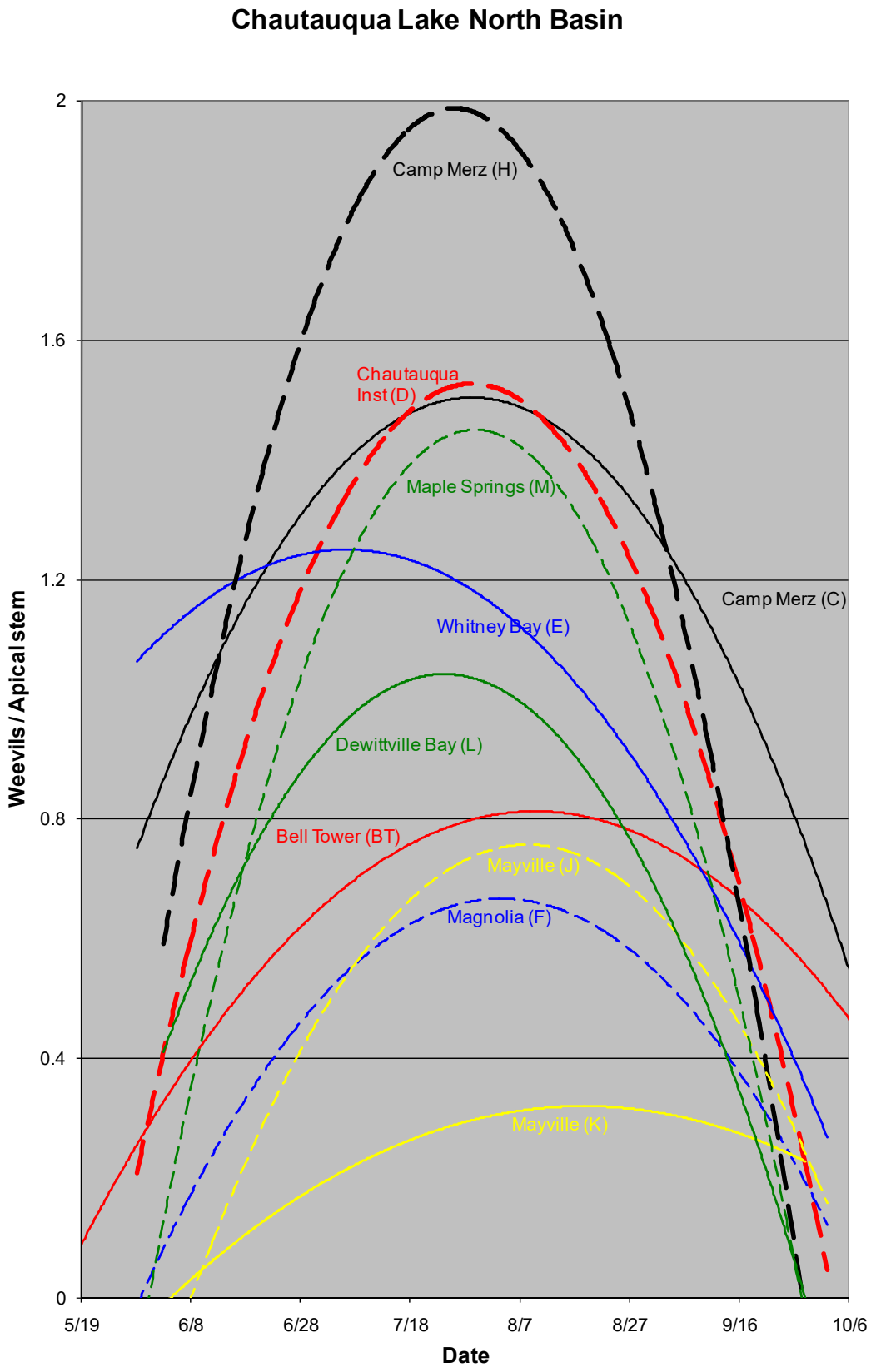

Figure 10. Summary of estimated weevil populations from 2002-2008 for Chautauqua Lake's north basin. Curves are averages of aggregated 2002 – 2008 data for the locations.

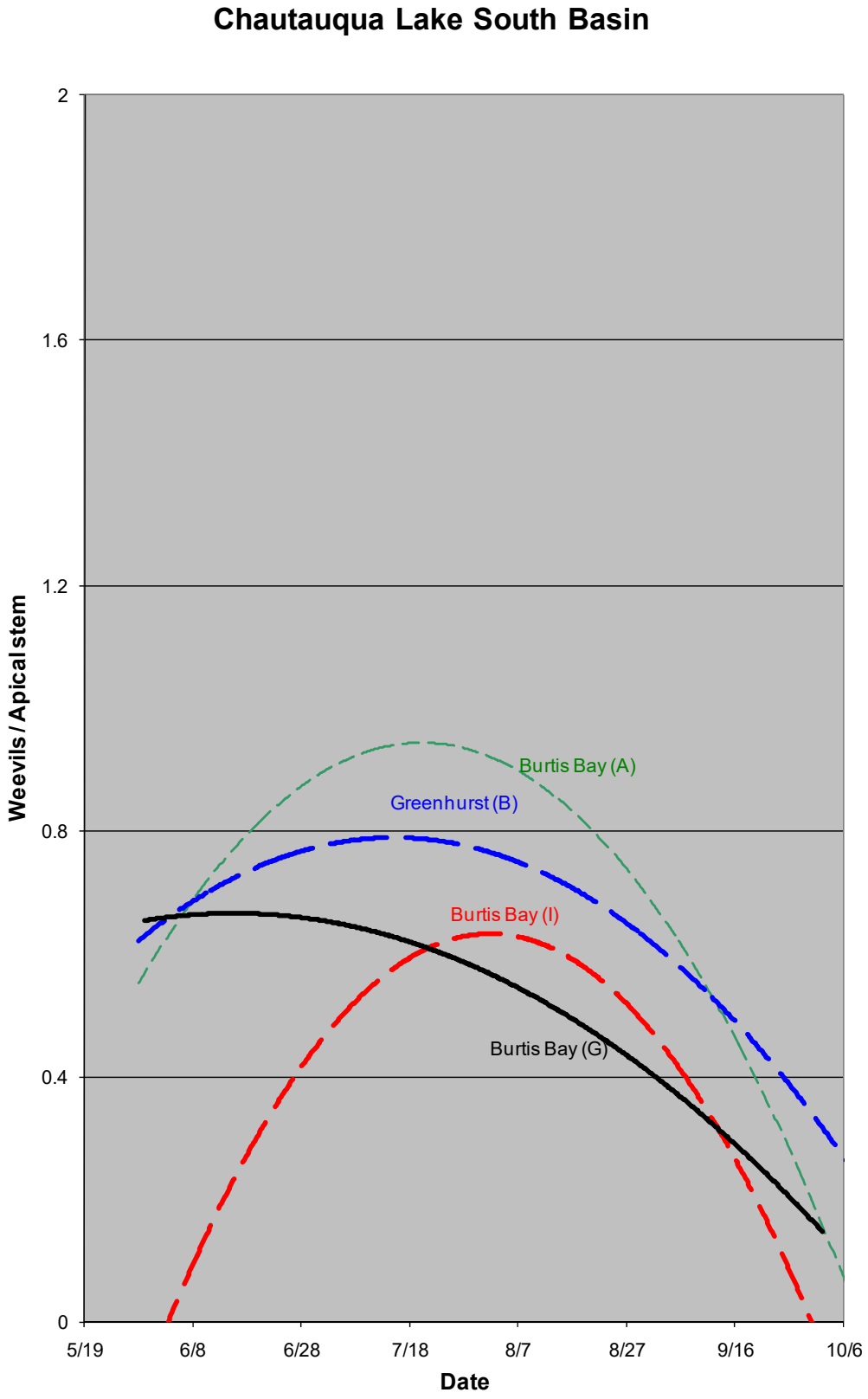

Figure 11. Summary of estimated weevil populations from 2002-2008 for Chautauqua Lake's south basin. Curves are averages of aggregated 2002 – 2008 data for the locations.

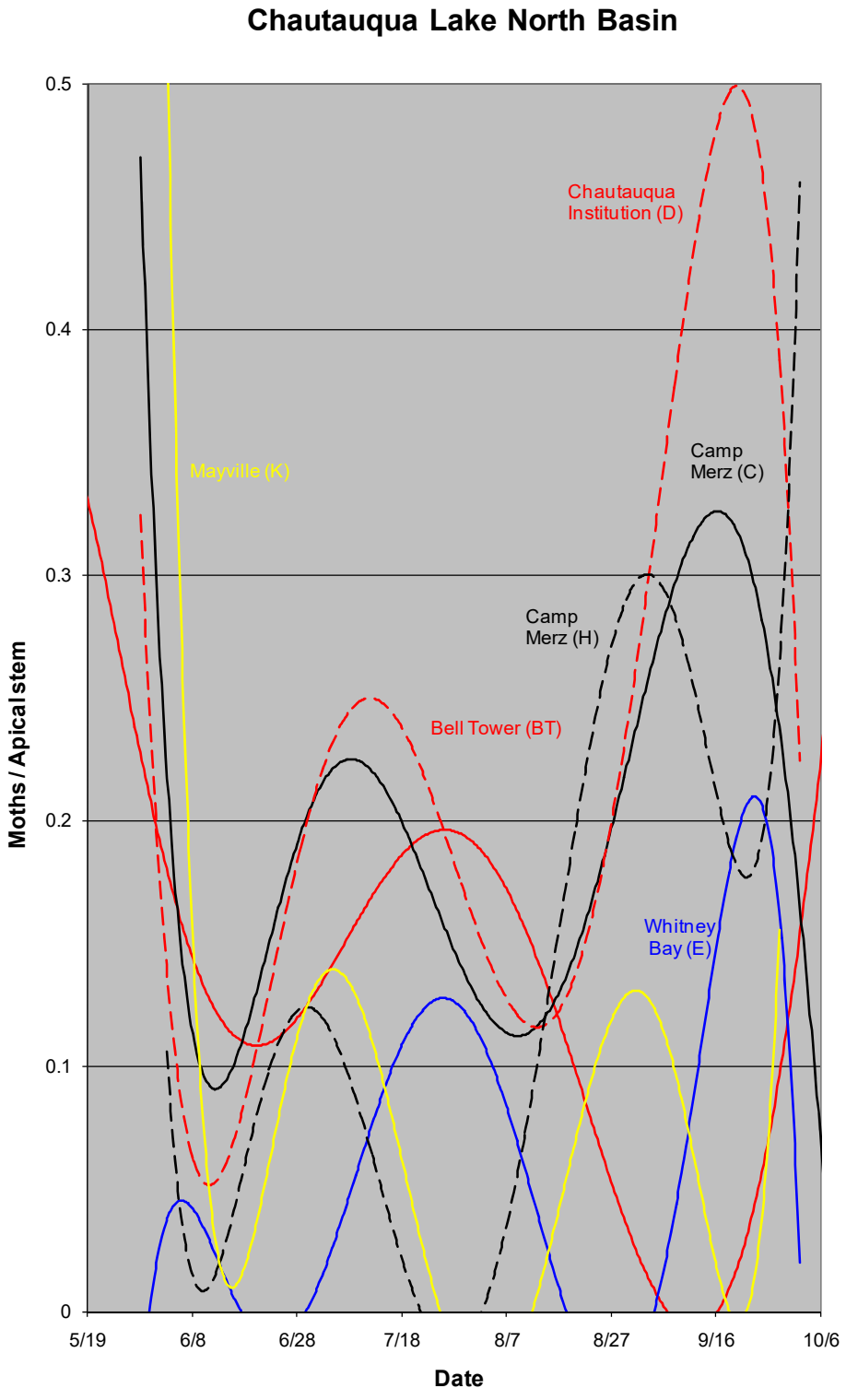

Figure 12. Summary of estimated moth populations from 2002-2008 using a best-fit line graph for Chautauqua Lake's north basin. Curves are averages of aggregated 2002 – 2008 data for the locations.

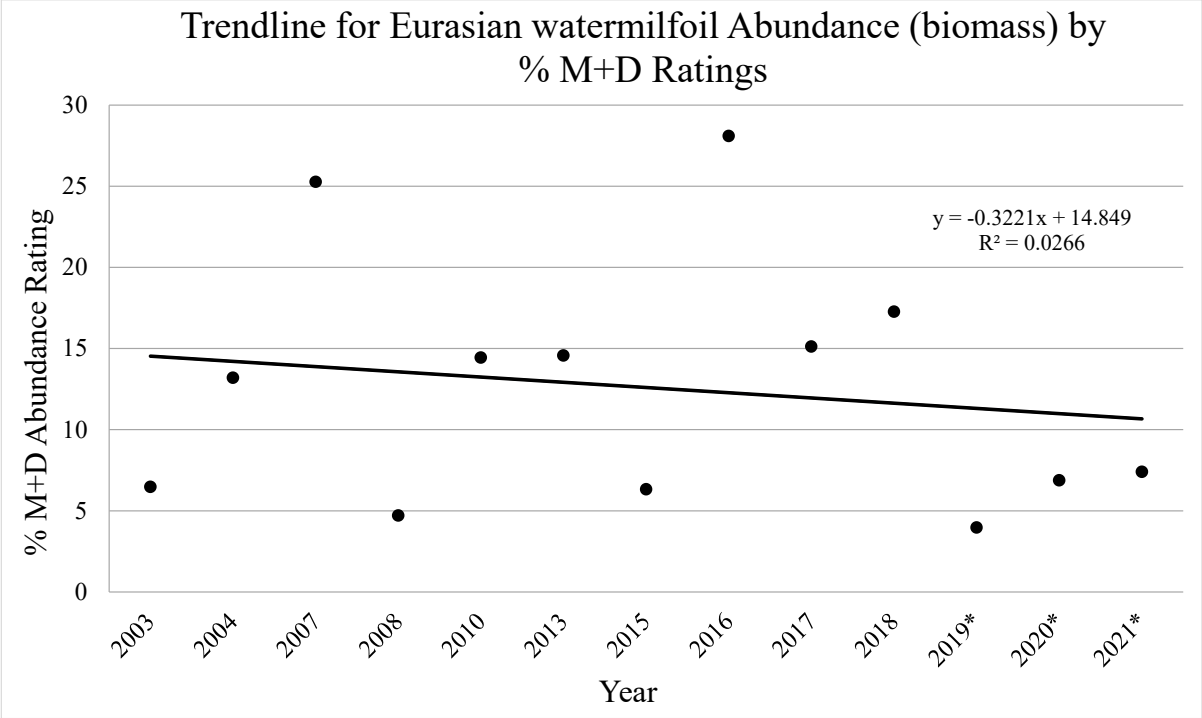

Figure 13. Percentage of Medium and Dense abundance ratings for *Myriophyllum spicatum* (Eurasian watermilfoil) from 2003 – 2021. The 2019 – 2021* data points of locations influenced by the Spring 2019 herbicide application in the south basin were removed from the analysis to eliminate potential bias caused by the herbicide application.

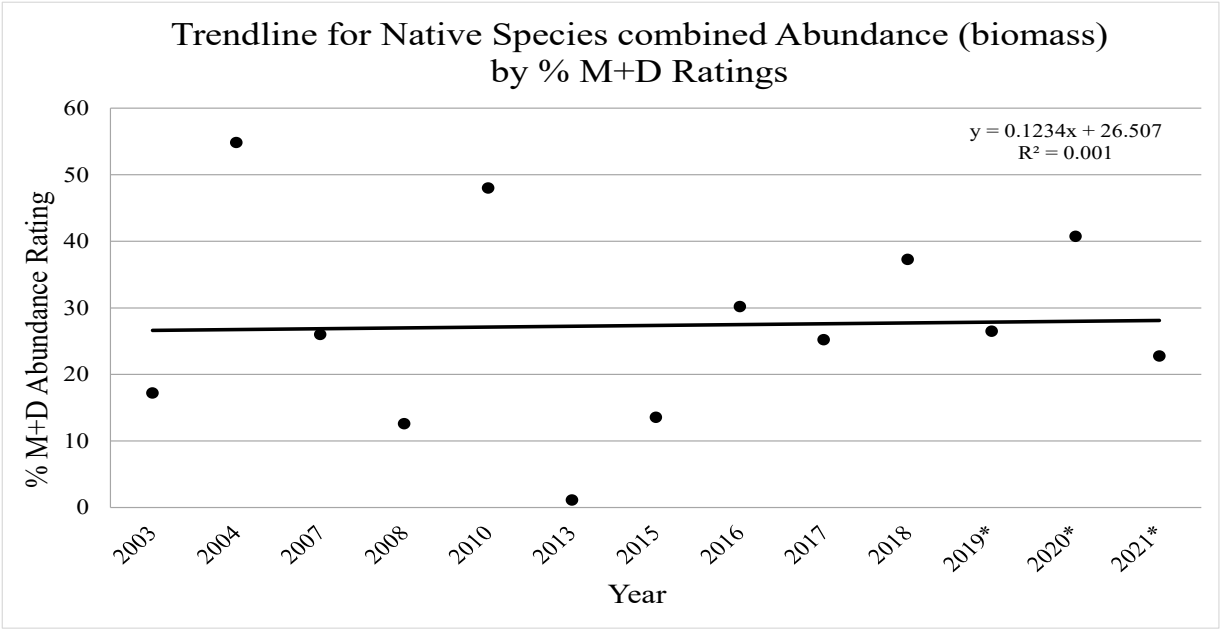

Figure 14. Percentage of Medium and Dense abundance ratings for Native species combined from 2003 – 2021. The 2019 – 2021* data points of locations influenced by the Spring 2019 herbicide application in the south basin were removed from the analysis to eliminate potential bias caused by the herbicide application.

Relationship of fish and watermilfoil herbivores

Several studies have suggested that sunfish predation on watermilfoil herbivores may interfere with watermilfoil control by insect herbivory **(Newbrough 1993, Sutter and Newman 1997, Newman and Biesboer 2000, Ward 2002, Newman *et al*. 2001, Newman 2004, Lord 2004, Ward and Newman 2006)**. While these studies strongly suggest that high sunfish populations limit herbivore populations, the resulting connection to watermilfoil growth control may not be strong. The following graphs (Figure 16) display our data from five NY lakes. All the lakes (except for Skaneateles, which has few watermilfoil plants and, therefore few herbivores) show a sizeable sunfish population, and all have sizeable herbivore populations. Using our electrofishing and herbivore density results from several lakes in NY, we show sunfish abundance having little influence at depressing populations of moths or weevils over a wide range of fish densities that might influence predation on Eurasian watermilfoil by these herbivores. This suggests that high sunfish abundance, although a factor is not an impediment to successful biological control of watermilfoil and that we need to explore and understand this complex interaction. It is likely due to the ability of insect herbivores to overcome predation by fish, insects, and mechanical harvesting as long as a healthy macrophyte ecosystem perseveres as a habitat.

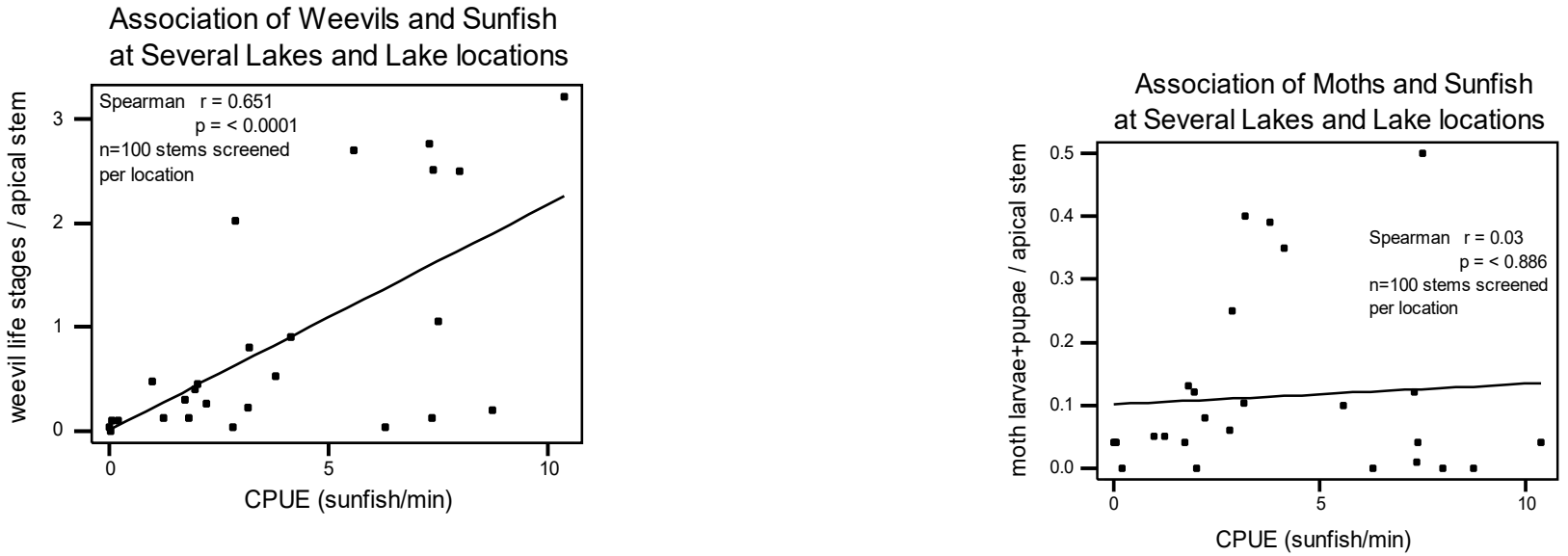

Figure 15. Relationship of *Acentria ephemerella* and *Euhrychiopsis lecontei* densities to sunfish abundance (measured as Catch per Unit Effort) in several lakes in New York.

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* also known as *Leptocerus americanus* or *Setodes americana* **(Banks 1899, Johnson *et al.* 2019A, Johnson *et al.* 2012, Johnson *et al.* 2008)**. We noted this caddis, *S. grandis*, in high densities on Eurasian watermilfoil in the 2018 – 2020 surveys **(Johnson *et al*. 2020A, 2020, 2019C, 2019B, 2019A, and 2019)**. Christopher Ecker and Janis Bowman of Jamestown Community College recorded this species earlier in 2007 as *Setodes sp.* and/or *Leptocerus sp.* in a "Chautauqua Lake 2007 Macroinvertebrate Biodiversity Assessment" **(Johnson *et al.* 2008)**.

These native caddisflies are a biological control of many plant species, including the non-native macrophytes Eurasian watermilfoil and curly-leaf pondweed. In Chautauqua Lake, caddisflies tend to lay eggs in late spring and require flowering Eurasian watermilfoil or curly-leaf pondweed to appear at the lake's surface to provide a suitable habitat to stick their eggs on for a successful hatch **(Figure 16)**. 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 **(Figure 16)**. Both caddis species begin consuming from the bottom of the plant, working their way up the stem and eventually defoliating it **(Figure 16)**. The healthy plant growth of Eurasian watermilfoil decreases rapidly when there is a minimum of four caddisflies on the stem **(Johnson *et al.* 2012)**.

Figure 16. *Nectopsyche albida* (Walker) or "Ghost caddis" present in the hundreds in the plant collection tray from one rake toss drag. Stripped, heavily damaged Eurasian watermilfoil (upper left) and a closeup of the caddis species (lower left). Required curly-leaf pondweed in early spring at lower right.

Eurasian watermilfoil, well-established and widespread in Chautauqua Lake, 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* 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, *E. lecontei*, 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. 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 watermilfoil apical tips. 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. The larvae pupate and prepare a pupation chamber further down the stem of the watermilfoil. An adult eventually emerges from the chamber to lay more eggs or swim to shore to overwinter if it is late summer.

The moth, *A. ephemerella*, displays similar life cycle patterns to the weevil. The annual populations of the moth, *A. ephemerella*, 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 and lay clutches of 100 to 300 eggs in late June. 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. Once these eggs hatch, the larvae overwinter on plant stems as various larvae instars or stages **(Johnson and Blossey 2002)**.

The caddis, *Nectopsyche albida* (Walker), recorded in Chautauqua Lake as early as 1937, resides as a specimen in the Illinois Museum of Natural History **(Glover and Floyd 2004)**. In Chautauqua Lake, caddisflies tend to lay strands of eggs in small groups in late spring until early fall, with the greatest numbers laid in the late spring through early summer. To complete the egg-laying part of their life cycle, *N. albida* requires watermilfoil and curly-leaf pondweed emerged flowers to guarantee a large egg hatch to replenish their population. Larvae appear to require a full year for development, suggesting that they need aquatic plants to survive 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)**. Both caddis species strip the leaves from watermilfoil throughout the year in Chautauqua Lake.

In recent years, the caddis, *Setodes grandis* has 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 recently. This lake area has a lower density of 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.

This invertebrate herbivory prevents watermilfoil from breaking the lake's water surface and flowering while causing the entire plant to decay through the season. The extremely large 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 that decision must be reinforced. Prohibiting herbicide usage in crucial fish habitats specifically used for spawning and nursery is paramount, as suggested earlier in areas like Tom's Point, Whitney Bay, and Irwins Bay **(Luensman *et al*. 1990).**

To conclude this 2022 report on invertebrate herbivores, we want to highlight the biological herbivore control that we do not have a systematic sampling protocol developed as we have for the weevil and moth. That is the caddisfly *Nectopsyche albida* we have observed throughout our research on the lake. I refer you to the 2012 report **(Johnson *et al*. 2012)** "Chautauqua Lake's Insect Herbivory by Caddis, Moths, and Weevils on Macrophytes." The Chautauqua Lake Management Commission (CLMC) requested the project, and the research was carried out by Racine-Johnson Aquatic Ecologists beginning in 2009. We were to define the role that Eurasian watermilfoil (*Myriophyllum spicatum*) and native insect herbivores play in the ecology of Chautauqua Lake, focusing on the insects eating Eurasian watermilfoil and how that herbivory can and is influencing aquatic plant community structure.

We researched this caddis' role in the aquatic plant community by designing and conducting experiments in the Department of Ecology and Evolutionary Biology at Cornell University. We collected data detailing *N. albida* feeding rates on several aquatic plant species in the laboratory and continued our long-term recording of herbivore densities within Chautauqua Lake. Additionally, we conducted an extensive literature search on caddisflies. This information should serve as a caddis herbivory baseline that suggests the potential of native insect biological control of aquatic plant growth in Chautauqua Lake while the Chautauqua Lake community continues to consider and implement options to manage excessive plant growth in the lake.

Major Findings

- While overall plant densities in 2007 and 2009 were similar, the plant community composition was more ecologically valuable in 2009. Non-natives, especially Eurasian watermilfoil, dominated the plant community before increased insect herbivory in late 2007. However, the dominant species that returned in highest abundance in 2009 following the caddis herbivory were natives, such as *Najas guadalupensis*, *Elodea sp.*, and *Potamogeton pusillus* **(Johnson *et al*. 2012)**. This suggests the effectiveness of the insect herbivores as a means of eco-friendly biological management of unwanted non-native plant growth.

- Sizes of caddis collected and measured from Chautauqua Lake show caddisflies continue to grow between September-December, which indicates this insect herbivore exerts a biological control on late summer-early fall growth of aquatic plants **(Figure 17)**.

- Greenhouse experiments evaluating caddis-feeding rates indicate variable feeding rates on different plant species. Retardation of plant growth and production of caddis fecal pellets suggest Eurasian watermilfoil and elodea are preferred species, while other plants (*Zosterella dubia aka Heteranthera dubia)* and *Potamogeton crispus*) show less impact by caddis herbivory **(Table 3, Figure 18)**.

- The number of caddisflies on a single stem influences caddis feeding rates and plant growth. More caddisflies per stem appear to compete with each other eating less per individual, thereby 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 **(Table 4, Figure 19)**.

- Larger caddisflies appear to feed less efficiently than smaller caddis; however, the trend is limited. We need more trials to describe how feeding rates vary for different-sized caddis **(Table 5, Figure 20)**.

- Extrapolation of our laboratory feeding trial results and Chautauqua Lake plant abundance data by rake-toss drag suggests an estimate of the number of caddis present to result in the plant biomass reduction observed in 2007 and carrying over into 2008. A conservative estimate is between 0.5-3 billion caddisflies present to produce observed plant loss. Still, it could easily have been much greater in the Burtis Bay-Greenhurst/Sunnyside area in the summer/fall of 2007.

- We compiled an extensive list of caddis references and background literature (References).

Major observations of caddisflies in Chautauqua Lake:

- Thirteen different caddisflies identified to at least genus during 2007 insect studies exist in Chautauqua Lake **(Johnson *et al.* 2008)**.
- Reports and observations indicate that caddisflies are widespread throughout Chautauqua Lake.
- Generally, caddisflies are herbivores that use various aquatic plants as a source of food and shelter.
- Caddis larvae build cases out of materials available to them in their environment (e.g., aquatic plants, sand, sticks, gravel, or leaves), and we often identify to genus by the size, composition, and shape of the larval case.
- One species, *Nectopsyche albida* (Walker), was found in high numbers in 2007 and 2008 and was likely partially responsible for the current low levels of Eurasian watermilfoil in the Burtis Bay-Greenhurst/Sunnyside area during that period. This species strips milfoil of its leaves, starting from the bottom, working up, and defoliates the plant.
- Chautauqua Lake specimens of *N. albida* were collected and preserved in 1937 and are located in the Illinois Museum of Natural History **(Glover and Floyd, 2004**).
- In the early summer of 2007, large numbers of *N. albida* larvae traveled in waves from the deeper middle portions of Burtis Bay towards the shoreline, feeding as they moved. Later in the summer and early fall, the larvae moved back to the deeper portions of the bay. This movement was consistent with that observed by **Tozer *et al*. 1981**.

- Two caddisflies, including N. *albida* (Walker) and Setodes grandis known as *Leptocerus americanus* or *Setodes americana* **(Banks 1899, Johnson *et al.* 2019A, Johnson *et al.* 2012, Johnson *et al.* 2008),** are major herbivores in the lake. We noted this caddis, *S. grandis*, in high densities on Eurasian watermilfoil in the 2018 – 2020 surveys **(Johnson *et al*. 2020A, 2020, 2019C, 2019B, 2019A, and 2019).**
- Christopher Ecker and Janis Bowman of Jamestown Community College recorded Setodes grandis earlier in 2007 as *Setodes sp.* (**Johnson *et al.* 2008**).

Description of *Nectopsyche albida*'s habits and life history:

- Key features for identification of *N. albida* larvae include: 1) a longitudinal black "V" shaped pattern found only on the head capsule and 2) the absence of well-developed swimming hairs on the metathoracic legs. Additionally, 3) the absence of gills on the thorax and abdomen **(Haddock 1977)**, and 4) a trumpet-shaped case consisting of fine sand grains, clay, and plant material **(Glover and Floyd, 2004; Tozer *et al*. 1981)**.
- The insect lays strands of eggs in small groups of 5-25 eggs across lateral shoots of aquatic vegetation protruding above the water's surface. The time until eggs are hatching depends on water temperature, and the average number of eggs per female was 250 **(Tozer *et al*. 1981).**
- Assuming that peak laying of eggs coincides with peak adult emergence, then egg laying occurs as early as late spring and as late as early fall, with the greatest numbers being laid in the late spring through early summer **(Tozer *et al*. 1981).**
- Larvae appear to require a full year for development **(Tozer *et al*. 1981)**, suggesting that they need aquatic plants to eat overwinter and that the first plant species reaching the surface in the spring may be critically important for maintaining high numbers of this species. In 2007, the watermilfoil in Burtis Bay-Greenhurst/Sunnyside canopied in May likely providing extensive egg-laying substrate required to produce large numbers of summer 2007 feeding individuals and emerging adults the following spring of 2008.
- In pond studies, larvae fed on milfoil, *Potamogeton*, and *Nitella* (the only plants making up the pond plant community), suggesting that they are opportunistic, taking advantage of the plant species present **(Tozer *et al.* 1981)**. Experts classify this genus of caddis either as shredder herbivores or collector-gatherers **(Glover and Floyd, 2004)**.
- Adults at emergence begin swarming after sunset with males performing horizontal "figure-8" patterns 10-15cm above the water surface **(Tozer *et al.* 1981)**.

As chemical treatments can have numerous unintended effects, including the destruction of non-nuisance plants and animals, this biological control method exploits natural predator-prey relations in targeted control of these aquatic macrophytes. Thus, one hero of these studies is an individual member species of the caddisfly genus, *Nectopsyche albida*, also known as the "ghost caddis." We describe with this report that, in lieu of effectively untargeted chemical treatments and as an addition to shoreline mechanical harvesting, this particular caddisfly species is often a potent, targeted control of the non-native nuisance plant, Eurasian watermilfoil (*Myriophyllum spicatum*).

Scientific papers well document that flowering aquatic plant species serve as food for aquatic invertebrates, including moths and caddis, in the larval stage of their development **(Berg, 1949)**. These caddis larvae might even depend on the presence of *Myriophyllum* because the plant maintains live shoot and leaf tissue below the ice through the winter, whereas many common aquatic plants do not exhibit such perennial robustness. Thus, the female readily decides to lay her eggs on the *Myriophyllum* plant canopy because this plant supports the caddis larvae throughout important parts of their lifecycle **(Berg, 1949).**

Researchers identified thirteen caddisfly species during Chautauqua Lake insect studies in 2007 **(Johnson *et al.* 2008)**. The predominant geographical range of our research activities is upstate New York lakes and ponds and routinely includes recording occurrences of insect herbivores. Further, studies also indicate that caddisflies are widespread throughout Chautauqua Lake and feed on aquatic plants and use the latter as a source of shelter. Caddis larvae build cases out of materials (e.g. aquatic plants, sand, sticks, gravel, leaves, or other vegetation) available to them in their environment. They are often identified down to genus by the larval case's size, composition, and shape.

One species in particular, the "ghost caddisfly" species (*Nectopsyche albida* – Walker), appears to be responsible for the bulk of the damage to the non-native watermilfoil plants in Burtis Bay and Greenhurst/Sunnyside. This caddis species strips the watermilfoil of its leaves, starting from the bottom and working up. This specific species of caddisfly was found as early as 1937 in Chautauqua Lake and is preserved in the Illinois Museum of Natural History **(Glover and Floyd, 2004)**. The ghost caddis is easily distinguished from other species of caddisflies **(Tozer *et al*. 1981)**. According to **Denning (1937)**, the ghost caddis larvae are 11mm long and have slightly pigmented heads with inarticulate light spots.

Stands of eggs are laid in small groups of 5-25 eggs across lateral shoots of aquatic vegetation protruding above the water's surface. The time until the hatching of eggs depends on water temperature, and the average number of eggs per female was 250 **(Tozer *et al*. 1981)**. Assuming that peak egg-laying coincides with peak adult emergence, egg-laying occurs as early as late spring and as late as early fall, with the greatest numbers being laid in the late spring through early summer **(Tozer *et al*. 1981)**.

In Chautauqua Lake, our observations indicate late spring as the time of egg laying. Larvae appear to require a full year for development **(Tozer *et al*. 1981)**, 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. In Chautauqua Lake, this can be watermilfoil or *Potamogeton crispus* (curly-leaved pondweed). In 2007, watermilfoil canopied in May and likely provided extensive egg-laying substrate in Burtis Bay-Greenhurst/Sunnyside **(Johnson *et al*. 2008)**.

In pond studies, larvae fed on watermilfoil, *Potamogeton*, and *Nitella* (the only plants making up the pond plant community), suggesting that they are opportunistic, taking advantage of the plant species present **(Tozer *et al*. 1981)**. This genus of caddis is often classified either as "shredder" herbivores or as "collector-gatherers" **(Glover and Floyd, 2004)**. Adults begin swarming after sunset with males performing horizontal "figure-8" patterns 10-15cm above the water surface **(Tozer *et al.* 1981)**. **Colburn et al. (2006)** note that the habitat characteristics of, for example, the caddisfly *P. Canadensis* includes water bodies rich in *Sphagnum sp.*, shrub cover, and low acidity (pH), and there are many stream caddisflies often associated with trout fishing. However, many caddisflies species reside in lakes like Chautauqua, with higher pH **(Johnson *et al*. 2008)**.

Glover *et al*. (2004) note that "within North America, the long-horn caddisfly family *Leptoceridae* contains 8 genera and ~118 species **(Morse 1993)**." They detail the ghost-caddis as below excerpt:

To determine the ghost caddis' sustainability or probability of mass survival given other aquatic predators, the study by **Tozer *et al*. (1981)** determined the impact of large-fish predation on caddisfly. Tozer *et al*. found no traces of Nectopsyche larvae in the guts of two species of predator fish, i.e., largemouth bass and bluegill, both predominant predator fish in northern freshwater.

In contrast**, Schwartz (1961)** notes that caddisfly larvae provide food for sunfish in the fall. Sculpin, minnow, and brown trout also feed on caddisfly, as shown by **Straskraba *et al.* (1966)**. We would expect, therefore, that bodies of water with these fish would provide some challenge to sustaining the *albida* species.

However, **Johnson *et al.* (2008)** note that the predominant predator or large fish species in Chautauqua Lake are trophy muskellunge, walleye, largemouth, and smallmouth bass, given their size and diet of smaller fish, which may present a lesser challenge to the herbivores including the caddisfly larvae. However, pan fish are abundant such as perch, historically crappy, white perch, and sunfish, and likely feed on Chautauqua caddis. In addition, of course, bullhead feed on caddisfly. However, the persistence of several caddis species in Chautauqua suggests their numbers remained high. Since the main source of Eurasian watermilfoil predation by heavy leaf feeding is from caddis larvae, we may conclude that the pest-control efforts via these larvae may remain unhampered by large-fish or pan-fish predation. While it takes place, fish predation appears not to have a huge impact on invertebrate herbivore populations as to cause a decline of herbivores in Chautauqua Lake.

Further supporting this view, **Pearse (1924)** performed a study that specified how much of each prey (caddisfly included) the large predator fish eat in their diets. His research indicates that the total amount of caddisflies eaten by largemouth bass, rock bass, bullhead, etc., is relatively small when presented with alternate foods. Following we include a description and table **(Table 2)** excerpted and reformatted from Pearse, which details the fish preferences with respect to their diets.

"The figures are averages for ten individuals of each species. The first figure gives the average volume of food consumed per day; the second figure gives the average weight of food consumed per day. Both these figures are expressed in percentage of the volume or weight of the body of the fish that ate the food. The third figure gives the average number of food units consumed per day. The data in this table are condensed from eight tables which gave the actual amount consumed by each fish each day and which could not be published on account of the expense involved. Those who desire more detailed information may obtain it from the writer."

Table 2. Showing the food eaten by four species of fishes

	Largemouth Bass			Sunfish/Pumpkinseed			Rock Bass			Yellow Bullhead/Brown Bullhead			
Food	Vol.	Wt.	No.	Vol.	Wt.	No.	Vol.	Wt.	No.	Vol.	Wt.	No.	
Minnows	33.8	34.4	3.4	5.8	6	2.5	5.1	5.1	2.5	14.6	14.8	1.5	
Grasshoppers	3.4	2.9	2	1.3	1.1	2.8	0.7	0.6	1	4.4	3.6	0.7	
Dragion fly nymphs	3.6	3.5	2.3	2.9	3	4.6	4.9	4.9	12.4	4.8	4.6	0.7	
Caddis fly larvae	0	0	0	1.6	1.6	10.4	0.03	0.03	0.03	0.08	0.08	1.9	
Crayfishes	0	0	0	0.03	0.03	0.01	4.8	5.2	2.9	1.5	1.6	0.4	
Amphipods	13.3	14.1	20.1	5	5.5	31.5	4.1	4.3	38	14.5	15.2	16.1	
Snails	0	0	0	9.3	9	62	0.1	0.1	1.1	1.3	1.3	1.1	
Earthworms	19.2	21.1	2.2	?	?	?	3.4	3.7	1.8	31.8	34.5	1.3	

Pearse thus determined that caddisfly larvae rank among the lowest in terms of order of preference of the fish when presented with alternative food including minnows, earthworms, grasshoppers amphipods, and etc. The other Eurasian watermilfoil herbivores may probably rank low in order of preference and their potentially high reproductive rate may compensate predation by fish.

Caddisfly Feeding Trials

We implemented numerous feeding trials in the laboratory at Cornell University in Ithaca to identify life cycle relationships of the caddis fly, *N. albida,* in Chautauqua Lake as well as feeding preferences and rates of plant consumption by this generalist herbivore. To investigate these relationships, we conducted research in the lake in 2009 and the greenhouse in 2009 and 2010. Caddisflies used in greenhouse experiments were ones we collected from Chautauqua Lake to ensure the experiments utilized the caddis species directly feeding in Chautauqua Lake. **Figure 17** displays the size of caddis collected in the lake during different times of the year. **Table 3** and **Figure 18** are summary results from numerous feeding trials (Experiment 1) conducted in the greenhouse to determine aquatic plant species that were most desired for food by the caddis. **Table 4** and **Figure 19** are results from feeding trials (Experiment 2) conducted in the greenhouse to determine the effect of different numbers of caddis flies on plant growth of a single stem. **Table 5** and **Figure 20** are results from feeding trials (Experiments 3 and 4) conducted in the greenhouse to determine how caddis size, as defined by length, influenced feeding rates.

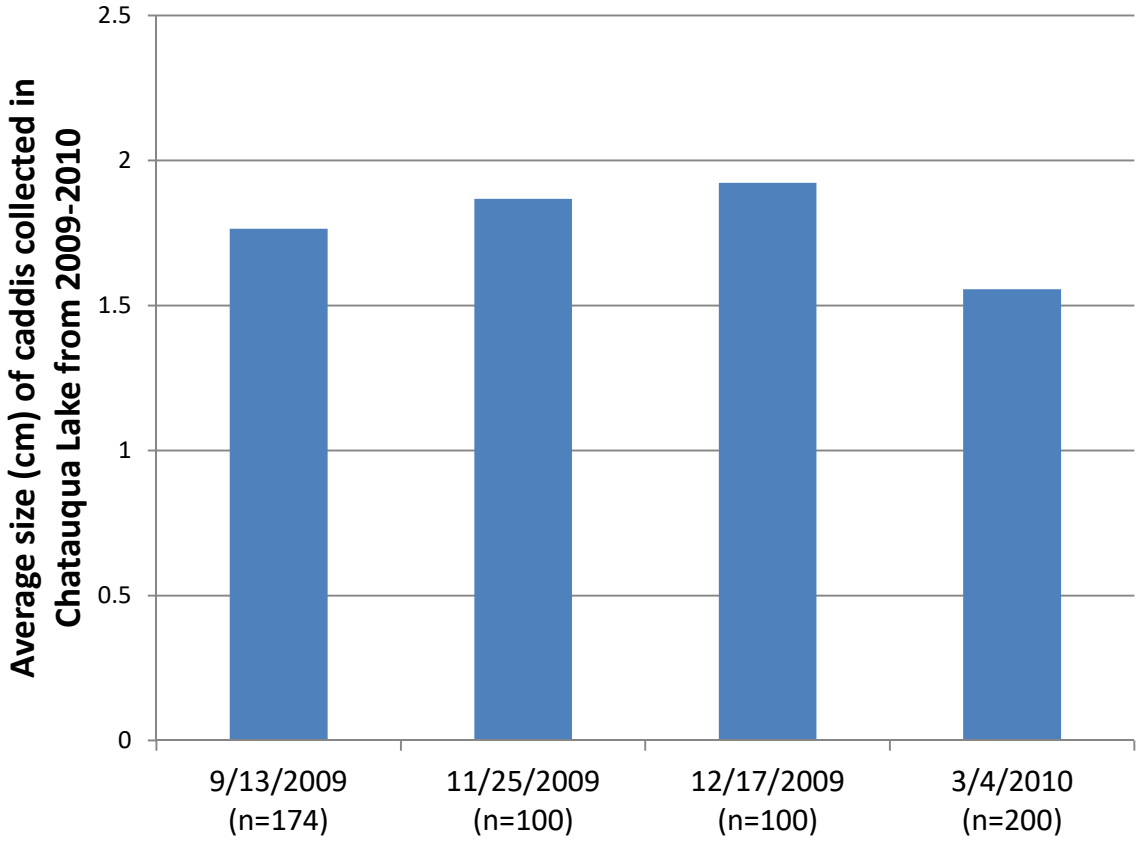

Figure 17. Average size of *N. albida* caddis larvae collected in Chautauqua Lake through Fall 2009 to Spring 2010.

Table 3. Summary results from *N. albida* caddis larvae feeding trials on various plant species. "Growth without caddis – caddis growth (mg Dry Weight)" is (+) where control plants grew more than plants fed on by caddis flies, whereas (-) values indicate plants fed on by caddis larvae grew more than the Control plants. The average number of fecal pellets per hour (mg DW), and fecal weight/per hour (mg DW), are standardized to a rate based on the duration of each experiment. We recorded the average lengths of caddis larvae for different feeding trials as cm. Feeding trials are for a single caddisfly.

Plant species	Chara vulgaris	Egeria densa	Egeria densa	Elodea sp.	Elodea sp.	Elodea sp.	Elodea sp.	Myriophyllum spicatum	Potamogeton crispus	Zosterella dubia
Date of experiment	4/22/2010	3/12/2010	5/13/2010	3/5/2010	3/9/2010	4/5/2010	5/10/2010	4/19/2010	4/12/2010	5/17/2010
Number of replicates	30	24	30	24	24	30	30	30	30	30
Duration of experiment (hrs)	99.00	72.00	92.75	70.50	72.00	91.00	93.50	80.00	90.50	90.50
Growth without caddis (mg DW)	7.79	3.83	8.79	3.95	7.56	12.58	8.81	13.94	1.59	3.86
Growth with caddis (mg DW)	3.68	3.92	8.22	1.07	3.72	12.73	6.60	9.64	2.99	5.30
Difference by feeding (mg DW)	4.11	-0.09	0.57	2.88	3.84	-0.15	2.21	4.30	-1.40	-1.44
Consumption Fecal pellets/hr	0.918	0.352	0.636	0.916	0.836	0.720	1.168	2.110	0.458	0.720
Consumption Fecal weight/hour (mg DW)	0.129	0.194	0.094	0.151	0.197	0.112	0.095	0.187	0.100	0.116
Caddis size as length (cm)	2.12	1.53	1.72	1.63	1.63	1.80	1.97	2.21	1.36	1.95

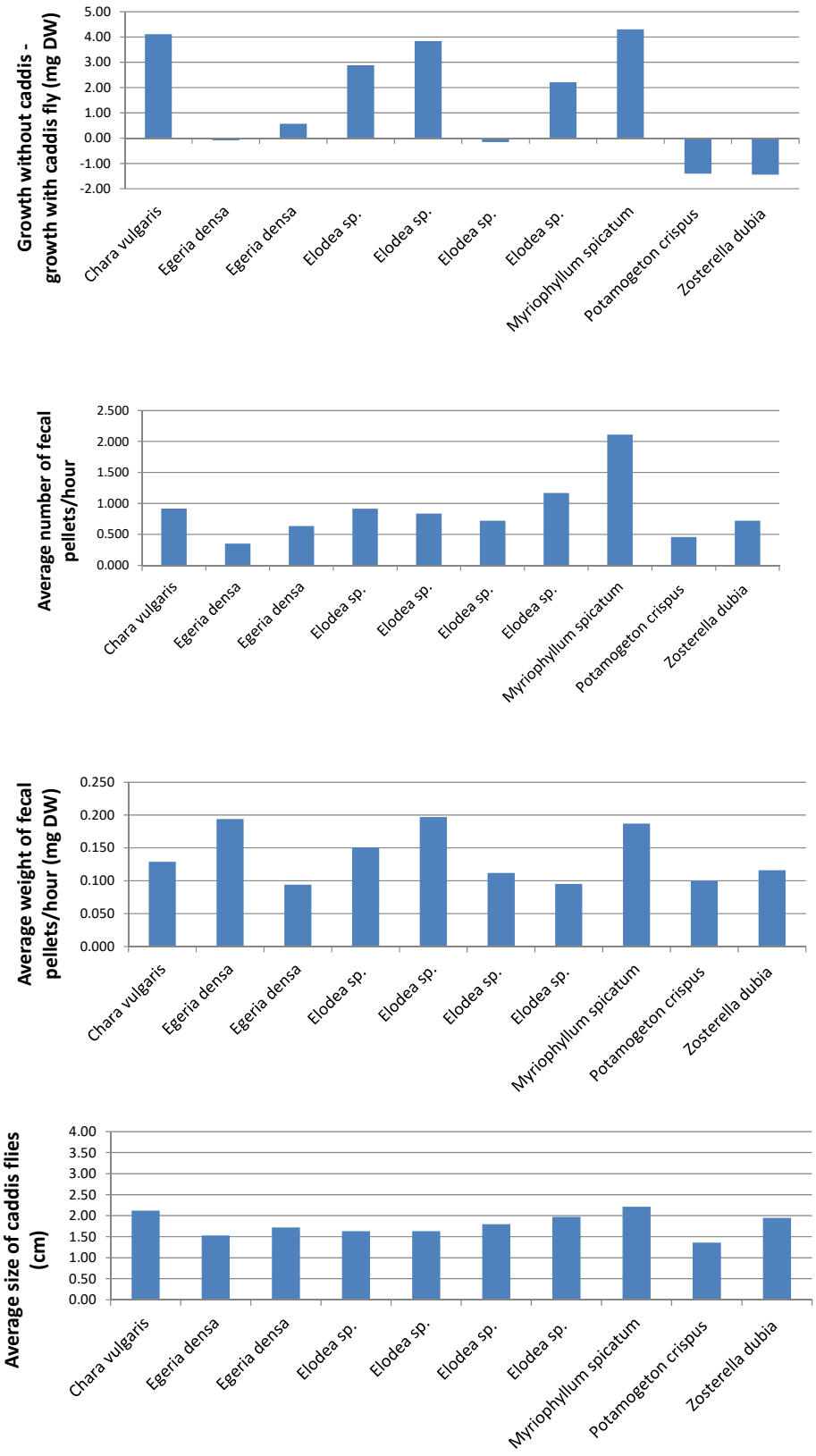

Figure 18. Summary graphs for data taken during *N. albida* caddisfly feeding trials on various aquatic plant species.

Table 4. Number of caddis larvae on a single stem was varied (0, 1, 2, 4, and 16) to determine the effect of caddis density on feeding rates and watermilfoil growth (summary of several trial runs).

Number of caddis on a milfoil stem	Milfoil growth (mg DW)	Fecal pellets/hr	Fecal (pellets/hr) per caddis
0 (control)	4.84	0.06	
1	9.14	1.28	1.28
2	3.15	2.02	1.01
4	-8.49	5.80	1.45
16	-19.88	10.21	0.64

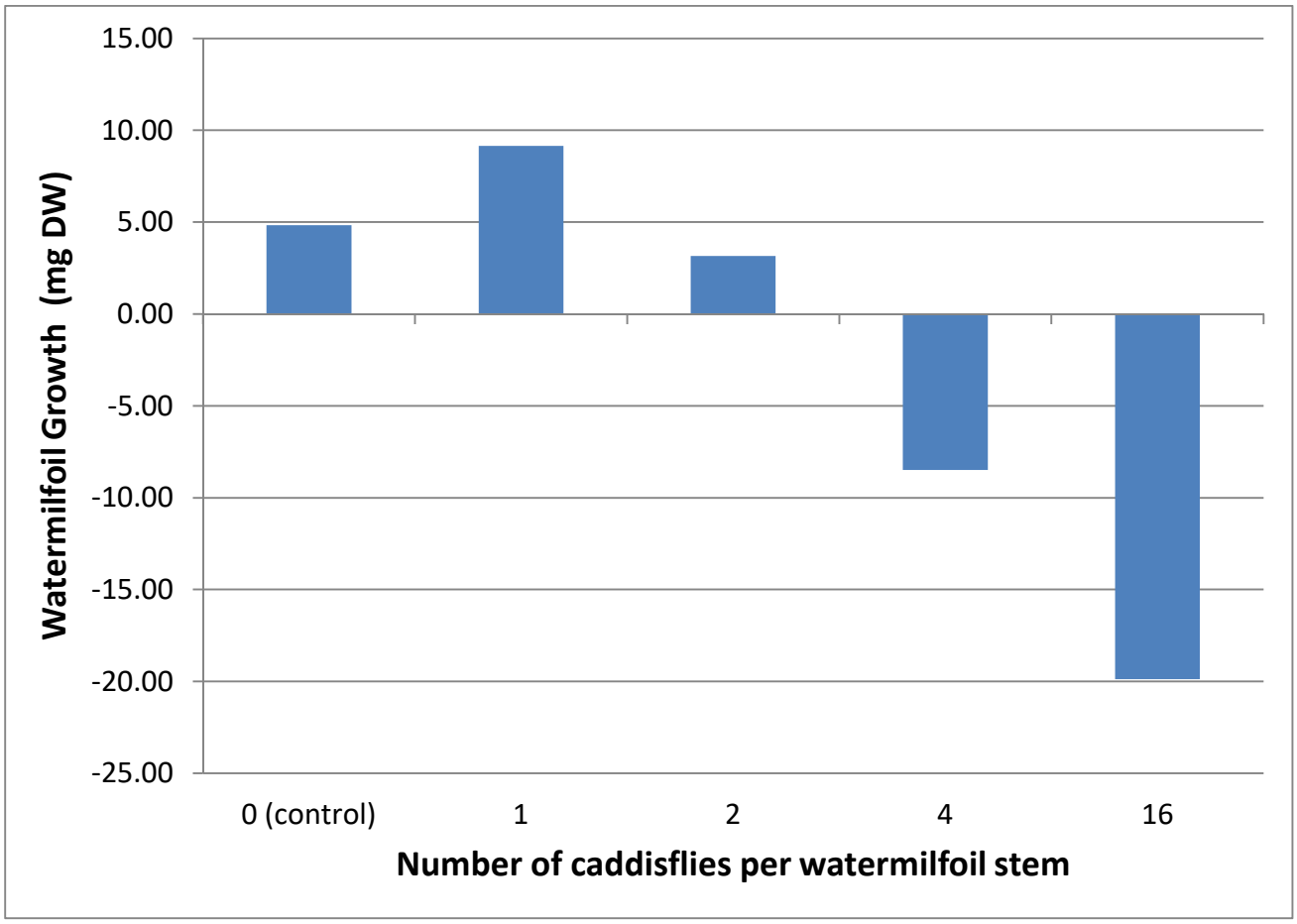

Figure 19. Watermilfoil growth (+), and biomass reduction (-) in mg DW describing plant response to differing numbers of caddisfly herbivores based on Experiment 2 summary data.

Table 5. Average caddis length (cm) added to a single watermilfoil stem, resulting in a number of fecal pellets per hour produced and weight of generated fecal pellets per hour (mg DW) (Summary results from Experiments 3 and 4).

	----- Experiment 3 -----			----- Experiment 4 ------		
Caddis length (cm)	1.72	1.77	1.78	1.93	1.98	2.05
# of Fecal pellets / hour	1.36	1.33	1.07	1.80	1.63	1.28
Fecal weight / hr (mg DW)	0.195	0.191	0.206	0.255	0.252	0.251

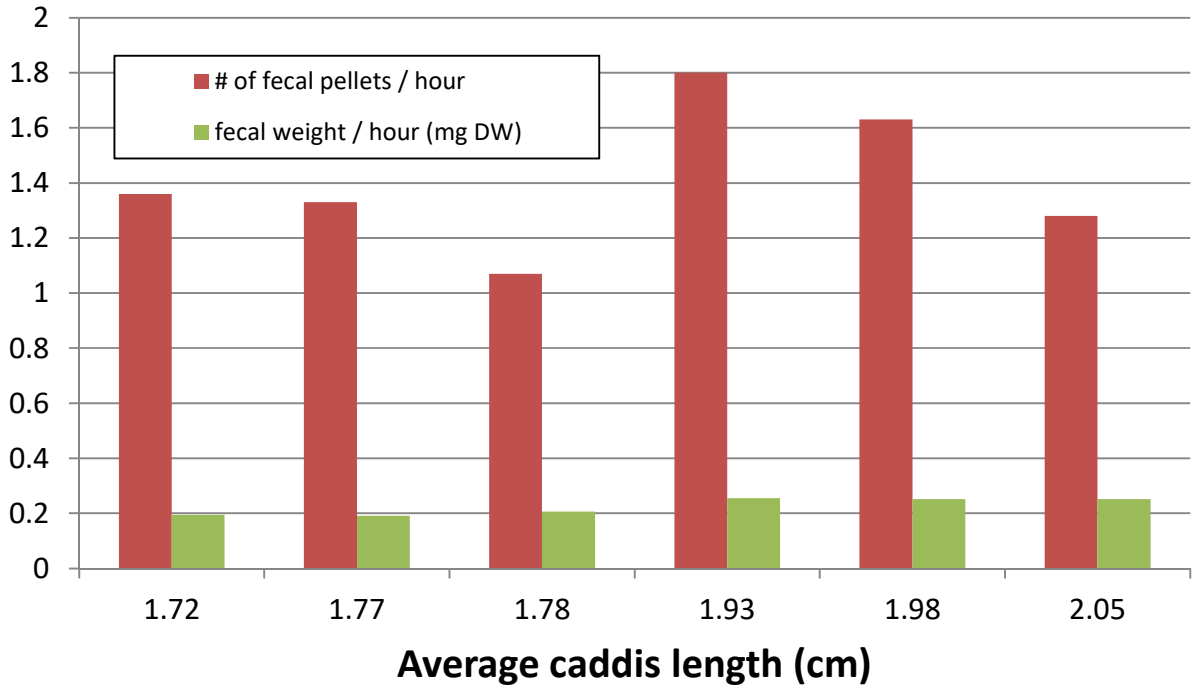

Figure 20. Number of fecal pellets per hour, and the average weight of fecal pellets (mg DW) generated from different size classes of *N. albida* caddis larvae based on results from experiments 3 and 4.

***N. albida* Caddis Density Calculations**

We extrapolated our caddis feeding trial results to suggest a rough estimate of the number of *N. albida* larvae needed to result in the biomass reduction observed in 2007. The average rake-toss abundance value in the Summer of 2007 was a calculated number value of 3.01, an M (medium), falling to 1.78, an S (sparse), in the Fall of 2007 during the natural seasonal decline of aquatic plants in Chautauqua Lake but aided by heavy feeding by caddis. We used our rake-toss drag abundance number to biomass estimates the basis of our rake-toss drag macrophyte sampling method to determine the amount of dry weight consumed by the caddis from Summer-Fall 2007. Our rake-toss drag method was most recently described by our 2021 report to the Chautauqua Lake Association **(Johnson *et al*. 2021).** The approximate weight of plants consumed during this time was 56 grams of dry weight per meter^2 in three months. A conservative approximate feeding rate per caddis of 0.18 mg DW (using the production of fecal pellet DW/hour as a measure) suggested from feeding trial results on watermilfoil and elodea, the dominant Burtis Bay-Greenhurst/Sunnyside plants in 2007 **(Johnson *et al*. 2008)**, follows:

$$\frac{0.18\text{mgDryWeight}}{\text{hour}} * \frac{1\text{g}}{1000\text{mg}} * \frac{24\text{ hours}}{1\text{ day}} * \frac{90\text{ days}}{3\text{ months}} = \textbf{0.39grams of Dry Weight}$$

Assuming a constant feeding rate, a caddis larva can consume approximately 0.39g of dry weight over a period of 3 months. To reduce biomass 56 grams of dry weight, with feeding rates of 0.39g/ Caddis, you would need about 144 caddis larvae per square meter. If we assume the approximate area of the "Burtis Bay/Greenhurst Area" south of the shoals is ~ 800 acres, or 3,237,485m^2. Therefore, 144caddis/m^2 * 3,237,485m^2 = 466,197,849 caddis. Preliminary calculations suggest you need about half a billion caddis in the south end (Burtis Bay-Greenhurst/Sunnyside area) to reduce the biomass observed from the Summer to Fall of 2007 above plant mass removed by mechanical harvesting or natural decay.

The estimate obtained from these extrapolations likely underestimates the number of caddis in the area. During our sampling in the fall of 2007, we first noted large numbers of caddis, often at least 50 caddisflies on single stems of watermilfoil or elodea **(Figure 15, Johnson *et al*. 2008)**. Assuming only 20 stems per square meter (a low density of plants), the number of caddis could have easily been about 1000 per square meter. 1000 caddis per square meter would yield an estimate of more than 3 billion caddis. These estimates assume no competition and that each caddis has an endless food supply. A caddis would not have been able to feed constantly without competition for three months. Feeding rates in the lake were likely much lower, and the number of caddis per square meter was much larger, so conceivably the number of caddis in the entire south end would have been in the billions of caddis.

Therefore, our observations of feeding by caddis, weevils, moths, etc., on their preferred macrophyte, Eurasian watermilfoil, in Chautauqua Lake suggest that a likely result is a significant annual decrease in the growth of this rooted macrophyte year in and year out due to insect herbivory. Considering this potential decrease in excessive growth of Eurasian watermilfoil is essential when evaluating the lake's overall aquatic vegetation management plan.

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