Monitoring the dynamics of *Galerucella* spp. and purple loosestrife (*Lythrum salicaria*) in the Goodyear Swamp Sanctuary and along the shorelines of Otsego, Weaver, and Youngs Lakes, summer 2007

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INTRODUCTION

Monitoring of the distribution and effectiveness of *Galerucella* spp. populations within Goodyear Swamp Sanctuary as a biocontrol of purple loosestrife (*Lythrum salicaria*) continued through the summer of 2007. Annual spring and fall monitoring of the impact of *Galerucella* spp. on purple loosestrife is updated in this report, as well as Otsego, Weaver, and Youngs Lakes shoreline assessment of beetle distributions. Details of the history of this study can be found in Albright et al. (2004).

L. salicaria is an emergent aquatic plant that was introduced into the United States from Eurasia in the early 19th century (Thomson 1987). Purple loosestrife is an aggressive and highly adaptive invasive species which inhabits wetlands, flood plains, estuaries and irrigation systems. Once established, purple loosestrife often creates monospecific stands, displacing native species including cattails (*Typha* spp.), sedges (*Carex* spp.), bulrushes (*Scirpus* spp.), willows (*Salix* spp.) and horsetails (*Equisetum* spp.). Recent efforts, which include both chemical application and the use of biocontrol methods, have focused on controlling *L. salicaria* where stands impede well-diversified wetland communities (Thomson 1987).

In June 1997, 50 adults each of *Galerucella calmariensis* and *G. pusilla* were introduced into Goodyear Swamp Sanctuary (N42°48.6' W74°53.9), located at the northeastern end of Otsego Lake (Snyder 2006). The beetles were initially released in cages from sites 1 and 2 (Figure 1). In 1998, sites 3-5 were introduced into the study in order to monitor the distribution of *Galerucella* over time to other stands of purple loosestrife (Austin 1998). Sampling sites were established to monitor the qualitative and quantitative effects of the beetles on purple loosestrife and also to examine the extent of any recovery by the native flora (Austin 1997). It was expected that these beetles would lessen the competitive ability of purple loosestrife by feeding upon their meristematic regions, resulting in defoliation, impaired growth, decreased seed production, and increased mortality (Blossey et al. 1994).

In addition to the annual spring and fall monitoring of *Galerucella* spp., *L. salicaria*, and native plants, observations were made at sites along the shoreline of Otsego Lake in order to assess the current distribution of the *Galerucella* spp. from their original point of release in Goodyear Swamp Sanctuary. An observational monitoring program was established at Weaver and Youngs Lakes this year to complement the overall distribution and establishment of *Galerucella* spp. from Goodyear Swamp. The two lakes, located approximately 5 km north of Otsego Lake, are proximal to each other and have large stands of *L. salicaria.*

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METHODS

Goodyear Swamp Sanctuary Monitoring

Spring and fall monitoring were performed according to protocols established by Blossey et al. (1997). Observations of the insects and plants were made within the five $1m^2$ quadrats, marked by four visible stakes (Figure 1).

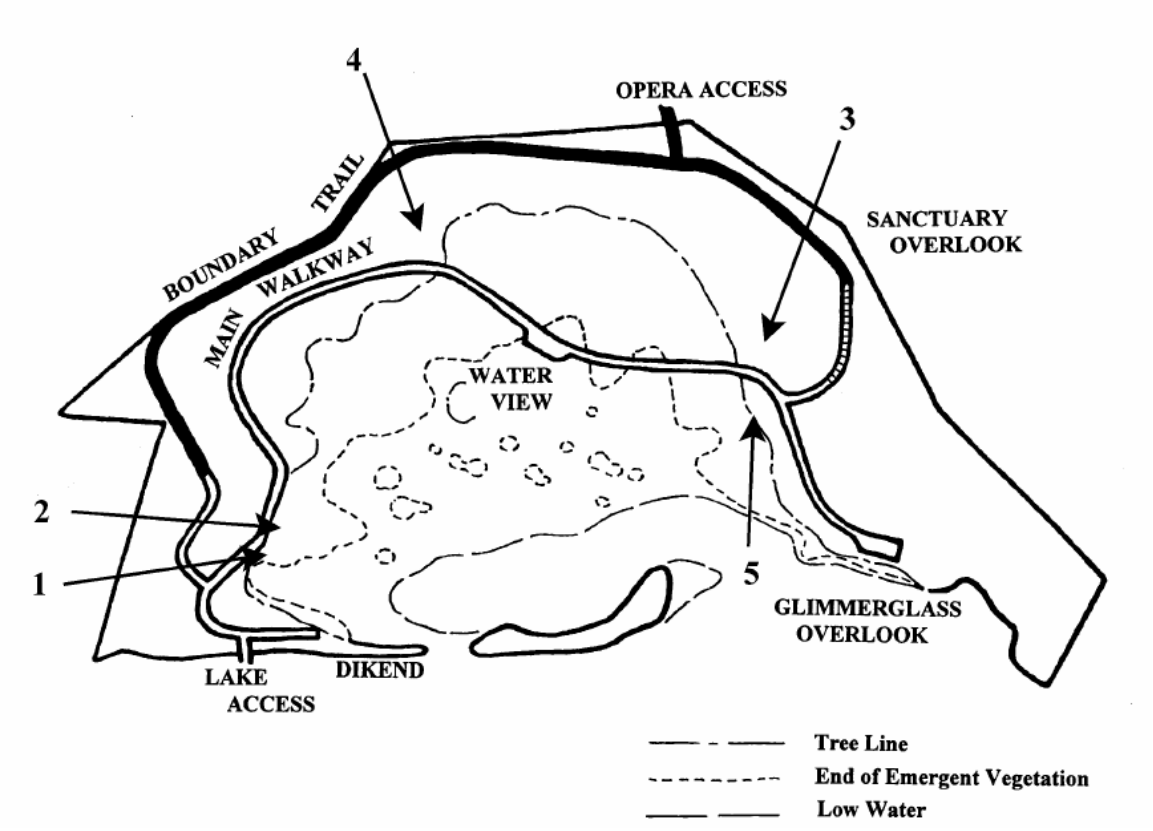

Figure 1. Map of Goodyear Swamp Sanctuary showing sampling sites. Sites 1 and 2 are 1997 *Galerucella* spp. stocking sites; sites 3-5 were established to evaluate the spread of *Galerucella* spp. within the Sanctuary over time.

Spring monitoring, which consisted of five components, was completed on 29 May 2007. This first assessment is typically completed within 2-3 weeks after overwintering adults appear (Blossey 1997). *Galerucella* spp. abundance was estimated in each life stage (egg, larva, adult) according to the established abundance categories (Table 1). The number of stems of *L. salicaria* within each quadrat were counted, and the five tallest were measured. The percent cover of *L. salicaria* and the percent damage attributable to *Galerucella* spp. were both estimated according to established frequency categories. Fall monitoring, which was completed on 9 August 2007, consisted of the same metrics measured in the spring monitoring along with the identification of native plant species and estimation of their percent cover within each quadrat.

Abundance Categories		Frequency Categories		
Number	category	range	category	mid point
0	1	0%	A	0%
1-9	2	1-5%	B	2.50%
10-49	3	5-25%	C	15%
50-99	4	25-50%	D	37.50%
100-499	5	50-75%	E	62.50%
500-1000	6	75-100%	F	87.50%
>1000	7	100%	G	100%

Table 1. Categories prescribed by Blossey's (1997) protocol for reporting abundance and frequency categories.

Otsego Lake-Shore Assessment

Six loosestrife stands around the shoreline of Otsego Lake, described in Table 2 and shown in Figure 2, were monitored for the presence of *Galerucella* spp. and signs of their herbivory. This work was a continuation of work initiated in 2005 (Meehan 2005). Shoreline observations were made in order to gauge the dispersion and establishment of the beetles since their release in Goodyear Swamp Sanctuary in 1997. Once the loosestrife stand is decimated, the beetles have been observed moving from the area, presumably foraging for new stands (Albright 2004).

The lake-shore assessment of *Galerucella* spp. dispersion around the lake was completed on 26 and 27 July 2007. Loosestrife stands were searched for about 5 minutes in order to standardize the search effort where conspicuous populations were not found.

Weaver and Youngs Lake-Shore Assessment

The shoreline of Weaver Lake (Figure 3) was inspected for *Galerucella* spp. presence via johnboat on 3 August 2007. Eight sample sites were established to follow a similar protocol as the Otsego Lake shoreline assessment and for further monitoring (Table 3).

Youngs Lake (Figure 3) was inspected for *Galerucella* spp. by foot on 9 August 2007. Five sample sites were established to follow a similar protocol as the Otsego Lake shoreline assessment and for further monitoring (Table 4).

Table 2. Descriptions and locations of sampling sites of Otsego Lake shoreline 26 and 27 July 2007. Site locations can be seen in Figure 2.

Site 1: N 42º 44.680′ W 74º 53.628′
Site description: East shoreline of Otsego Lake, located opposite Five Mile Point, between a large dead tree that hangs over the water and a dead conifer that was still standing.

Site 2: N 42º 42.354′ W 74º 54.882′
Site description: Southeast shore above the outlet to the Susquehanna River, near a large overhanging willow.

Site 3: N 42º 42.353′ W 74º 55.585′
Site description: Otesaga Country Club, accessed directly across the fairway behind the parking lot.

Site 4: N 42º 42.546′ W 74º 55.448′
Site description: North of the Otesaga Country Club, accessed from boat near the water-walkway.

Site 5: N 42º 43.600′ W 74º 54.992′
Site description: West shoreline at Leatherstocking Creek inlet on Brookwood Point.

Site 6: N 42º 43.898′ W 74º 54.910’
Site description: Sam Smith’s boatyard accessed by vehicle, north of the boat launch area.

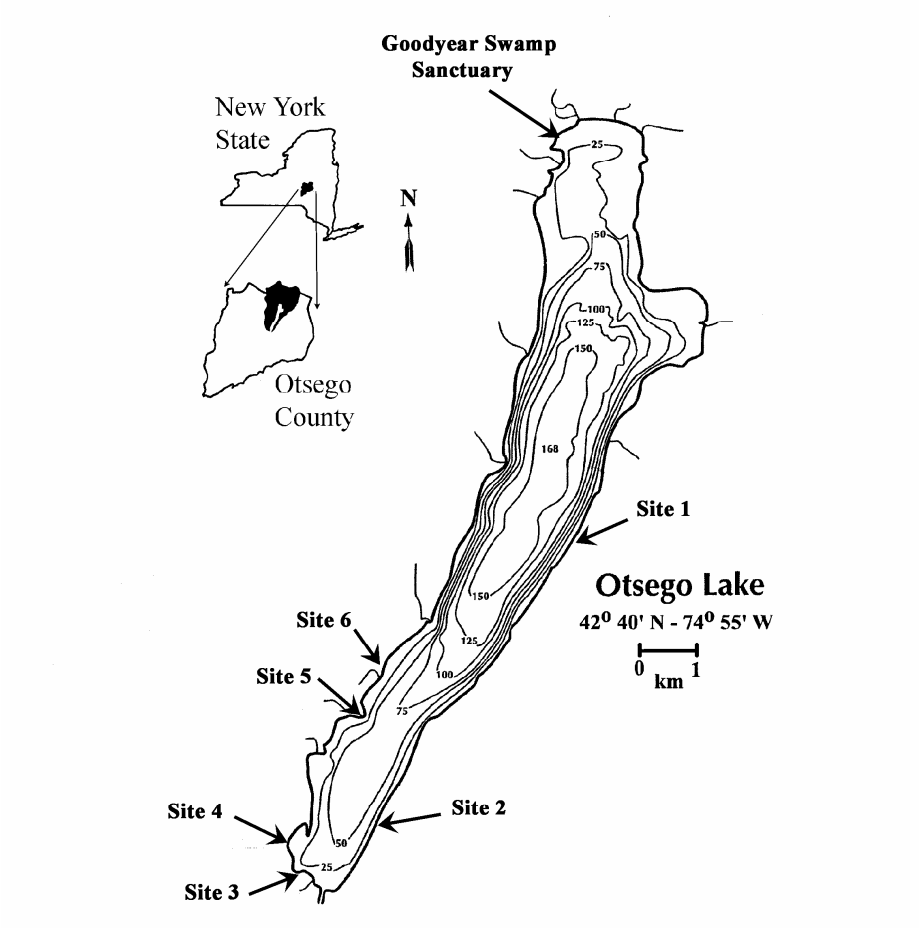

Figure 2. Shoreline sites visited to evaluate loosestrife damage, its vigor and evidence of *Gallerucella* spp. on 26 and 27 July 2007.

Table 3. Exact coordinates of sample sites along the Weaver Lake shoreline, 3 August 2007. Due to ambiguity of the shoreline, site descriptions were not provided. Site locations can be seen on Figure 3.

Site 1:	N 42º 51.058′	W 74º 55.574′
Site 2:	N 42º 51.286′	W 74º 55.614′
Site 3:	N 42º 51.334′	W 74º 55.705′
Site 4:	N 42º 51.397′	W 74º 56.133′
Site 5:	N 42º 51.341′	W 74º 56.336′
Site 6:	N 42º 51.256′	W 74º 56.190
Site 7:	N 42º 51.112′	W 74º 55.963′
Site 8:	N 42º 50.879′	W 74º 55.633′

Table 4. Exact coordinates and site descriptions of sample sites along the Youngs Lake shoreline, 9 August 2007. Site locations can be seen on Figure 3.

Site 1: N 42º 50.530′ W 74º 54.973′
Site description: Immediately left of boat launch, at the beginning of large ash trees.

Site 2: N 42º 50.555′ W 74º 55.208′
Site description: The point which juts into the lake, adjacent to a stream inflow.

Site 3: N 42º 50.582′ W 74º 55.425′
Site description: The beginning of brushy area where a lone ash tree stands.

Site 4: N 42º 50.739′ W 74º 55.231′
Site description: Corner of field, break in the treeline.

Site 5: N 42º 50.628′ W 74º 54.925′
Site description: Approximately 200 ft. right of the main launch area.

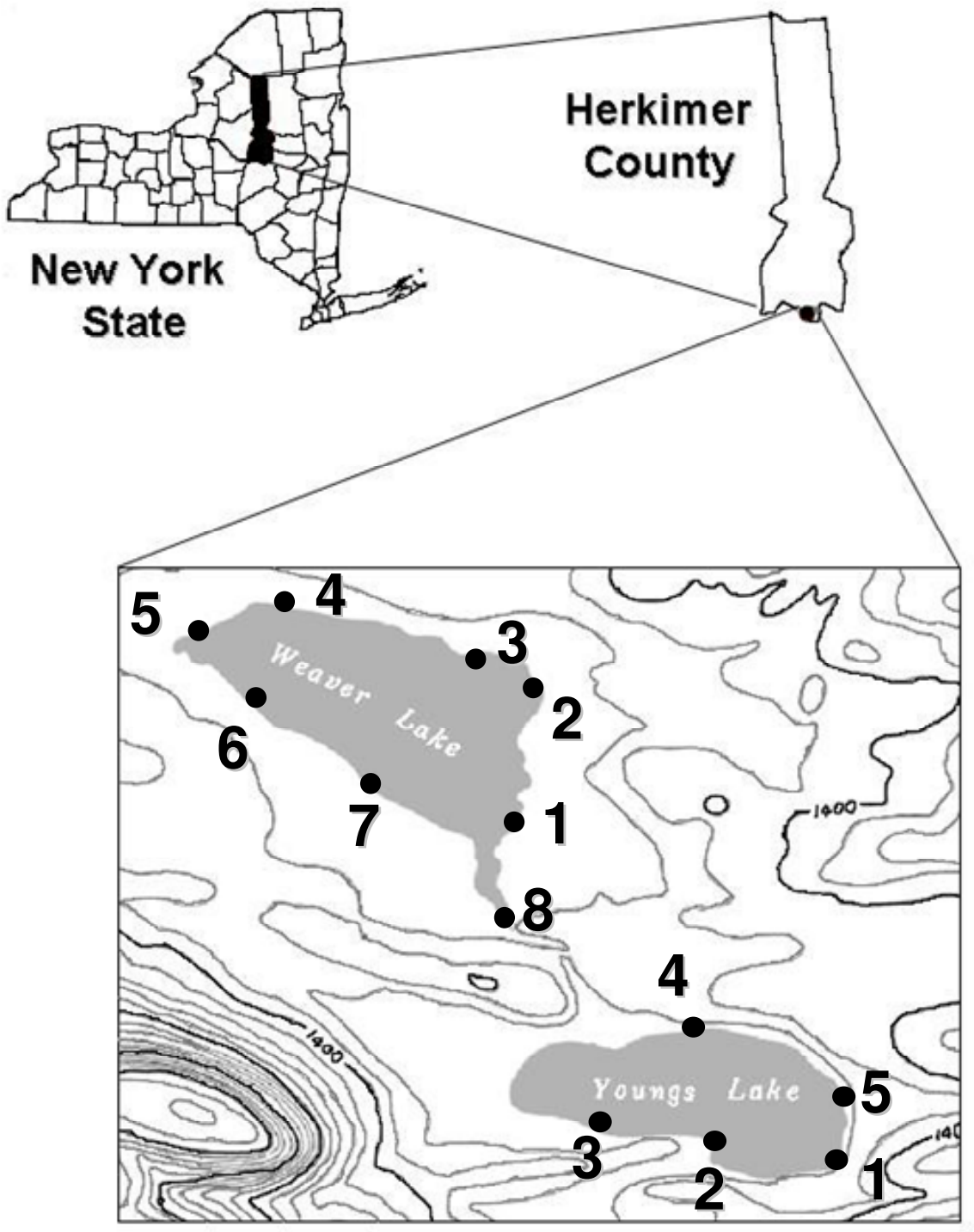

Figure 3. Sample sites of Weaver and Youngs Lakes visited to evaluate loosestrife damage, its vigor and evidence of *Gallerucella* spp. on 3 and 9 August 2007, respectively.

RESULTS & DISCUSSION

All monitoring data are represented by abundance and frequency categories defined in Table 1. Changes between these frequency categories can represent a substantial change in abundance (Albright 2004).

Goodyear Swamp Sanctuary

Spring Monitoring (29 May 2007)

Egg and larva abundance of the *Galerucella* beetle was slightly increased relative to the spring of 2006 (Figure 4 & 5) (Snyder 2006). No larvae were found because spring sampling generally takes place prior to the hatching of the eggs. Adult abundances decreased overall about the quadrats since 2006 (Snyder 2006) (Figure 6). An obvious correlation exists between the percent damage and frequency of stems of *L. salicaria* with the relative abundance of *Galerucella* spp. in the quadrats. Percent damage of loosestrife has decreased (Figure 7) along with overall species abundance of the *Galerucella* beetles. Consequently, the number of loosestrife stems has increased (Figure 8). These data may account to the delay in hatch of the *Galerucella* beetles this year. Although the number of stems of loosestrife has increased, percent cover has remained the same as compared to 2005 and 2006.

Purple loosestrife serves as the only source of food for beetles; therefore *Galerucella* spp. populations are directly dependent upon loosestrife densities within the swamp. This demonstrates the population dynamics of host-specific organisms and their dependency upon host populations (Fagan et al. 2002). Even though the quantity of *L. salicaria* stems this spring has increased, previous years of diminished growth would demote an increase or even stability in beetle foraging success, reproduction vigor, and ultimately this year's population size. Percent cover remains consistent with past years, staying well under a frequency midpoint of 20 percent annually since 2002.

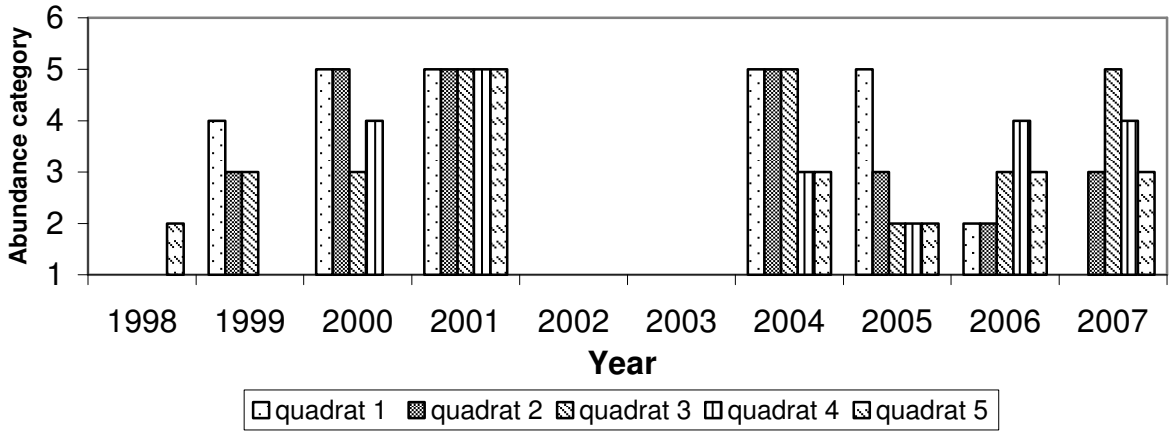

Figure 4. Comparison of *Galerucella* spp. egg abundance from yearly spring samplings. Abundance categories taken from Table 1.

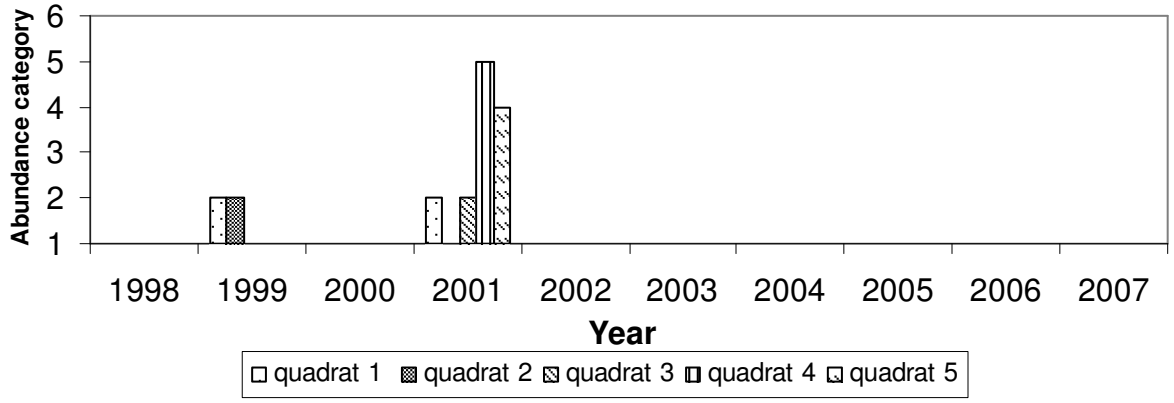

Figure 5. Comparison of *Galerucella* spp. larval abundance from yearly spring samplings. Abundance categories taken from Table 1.

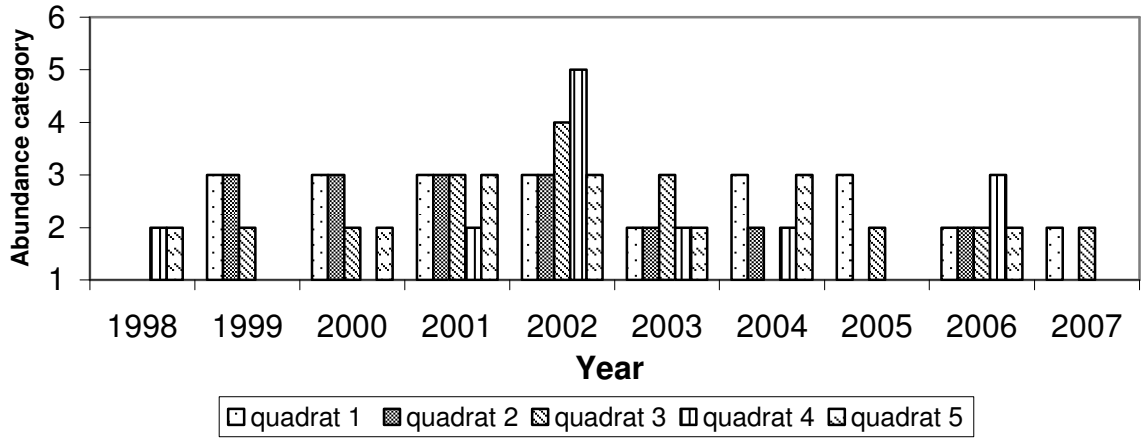

Figure 6. Comparison of *Galerucella* spp. adult abundance from yearly spring samplings. Abundance categories taken from Table 1.

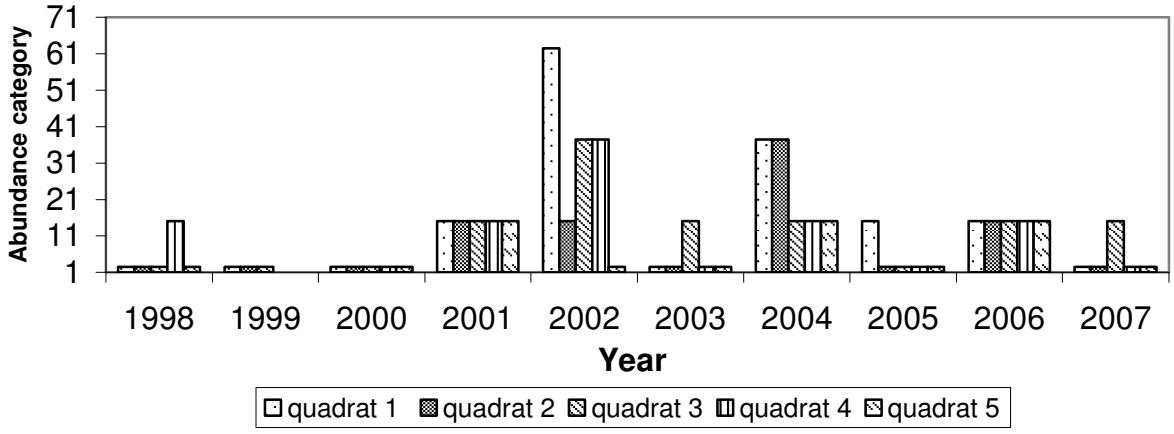

Figure 7. Comparison of percent damage estimates to purple loosestrife leaves from yearly spring samplings. Frequency mid points taken from Table 1.

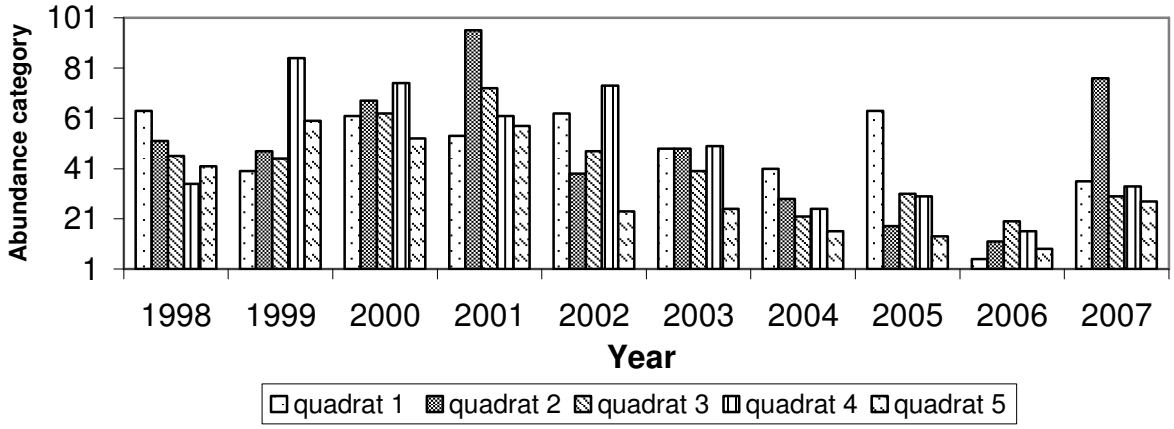

Figure 8. Comparison of the number of purple loosestrife stems from yearly spring sampling observations.

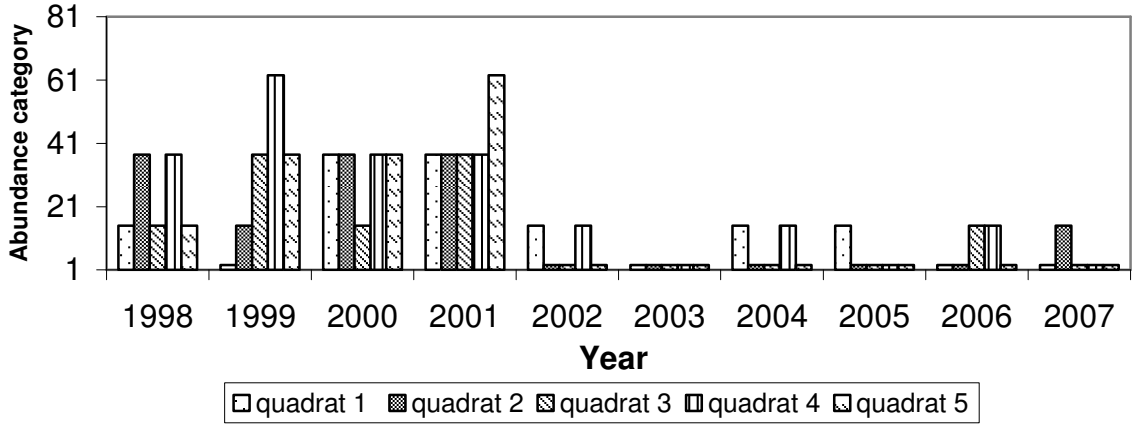

Figure 9. Comparison of percent cover estimates by purple loosestrife from yearly spring samplings. Frequency mid-points taken from Table 1.

Fall Monitoring (9 August 2006)

Although the quantity of loosestrife stems per quadrat has decreased since 2006, the plants observed were generally taller and had more flowering bodies. Percent cover has remained about the same relative to the fall of 2006. The number of stems and percent cover of *L. salicaria* per quadrat in the fall from 1997-2006, where available, are give in Figures 10 and 11 respectively. Purple loosestrife inflorescences were recorded in the study only in 1997, 2005, 2006, and this year (Snyder 2006). However, no inflorescences were observed in any quadrat in the fall monitoring period of 2006 (though several plants in the sanctuary, outside the quadrats, had flowered by 10 August).

Figure 12 summarizes mean stem height, mean inflorescences per plant and total inflorescences per qudrat in 1997 (prior to the establishment of Gallerucella spp.), in 2005 (Meehan 2006), 2006 (Snyder 2006), and 2007. Declines in these categories imply a substantial decline in the vigor of purple loosestrife over time. However in 2007 slight increases in the categories correlate with data collected from the spring. Overall, fewer beetles from any life stages were observed this year, resulting in the increase of *L. salicaria.*

Overall there are fewer loosestrife stems than last fall, however they are healthier plants according to height, percent cover, and inflorescences. This trend, along with *Galerucella* abundance from the spring data may indicate that the beetles are ineffective at eradicating loosestrife but are useful in the management of the invasive plant.

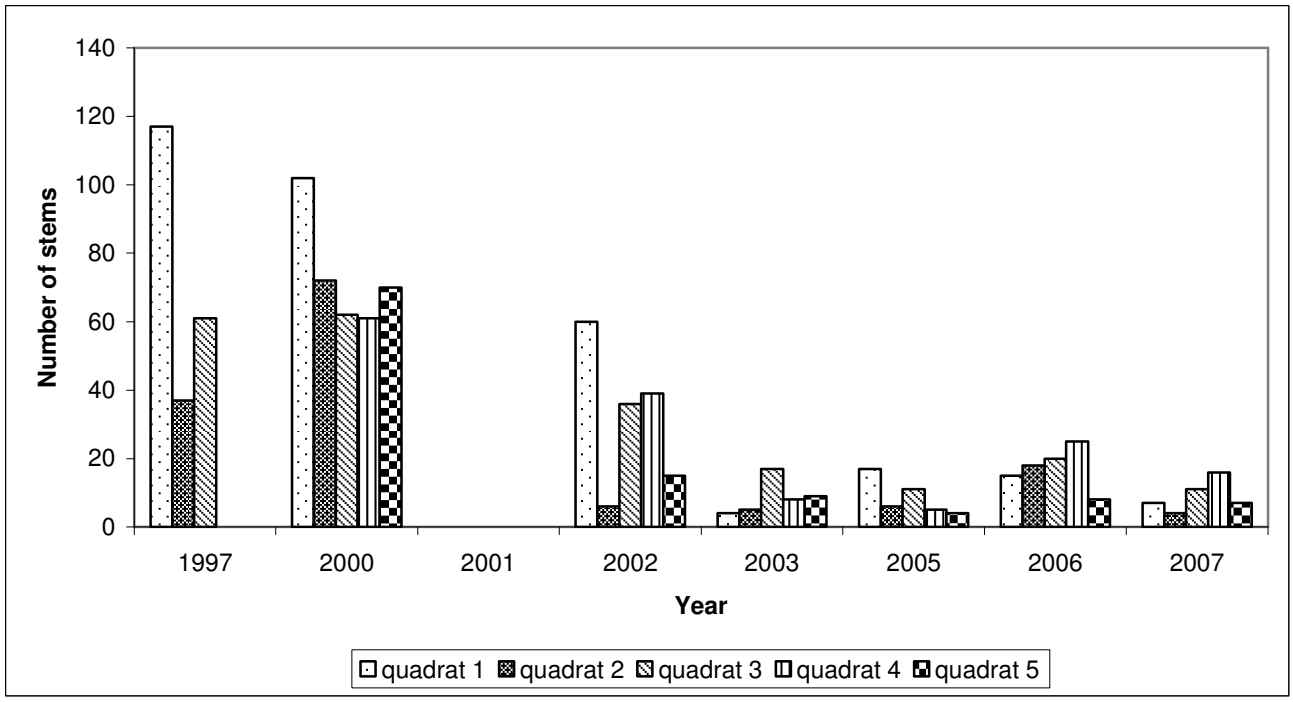

Figure 10. Number of purple loosestrife stems per quadrat during fall monitoring, 1997, 2000-2007.

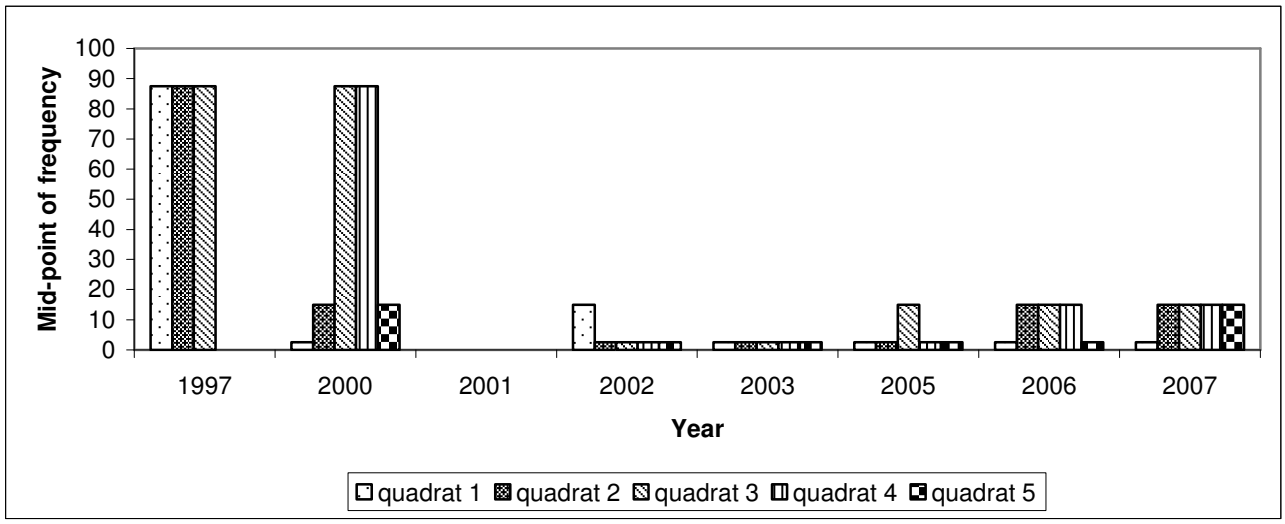

Figure 11. Mean estimated percent cover by purple loosestrife during fall monitoring, 1997, 2000-2007.

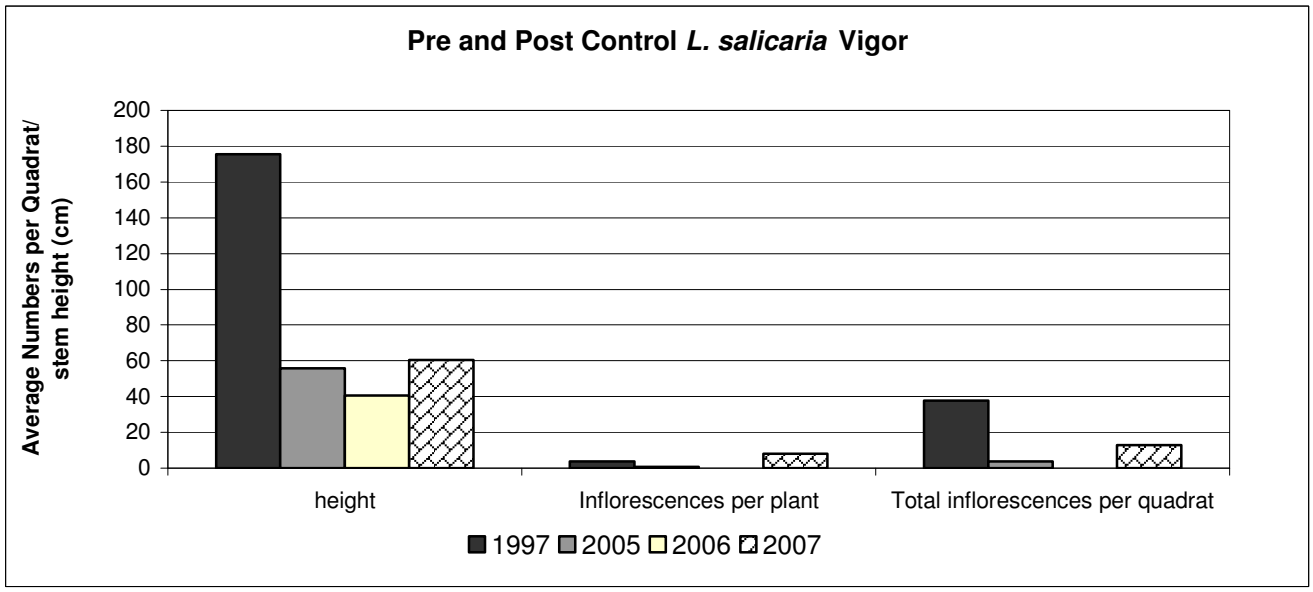

Figure 12. Data related to purple loosestrife vigor; average stem heights; total inflorescences per plant, and total inflorescences per quadrat under pre control (1997) and post control (2005, 2006, & 2007).

Otsego Lake Shoreline Assessment (26 and 27 July 2007)

Due to the steep topography of Otsego Lake's perimeter, transition to upland generally occurs within a few meters of the shoreline. As a result, the ideal wetland habitats for purple loosestrife around the lake are sparse (Meehan 2006). However, small dense stands of loosestrife were found in several locations that had open, non-forested shorelines such that of golf courses, shoreline lawns, and stream mouths. In forested portions, more scattered and less dense stands were observed. *Galerucella* spp. populations were present at each site, in low to moderate numbers.

A correlation was observed between *L. salicaria* frequency and *Galerucella* spp. abundance. Thicker stands of loosestrife (higher frequency) had relatively lower populations of *Galerucella* beetles than sparse stands of loosestrife. Few beetles were observed presumably due to the timing during the life cycle. The abundance of beetles had a direct impact on the percent damage in the area. Higher numbers of beetles were observed at sites with high amounts of loosestrife decimation. Herbivory indicates that *Galerucella* spp. continues to disperse around Otsego Lake where purple loosestrife is present. Another trend exhibited by the data in Table 5 is the percent damage of loosestrife compared to the height of the plants. Overall, smaller plants were more readily decimated by the beetles.

Within *L. salicaria* stands, many individual plants were undamaged, while other individuals appeared to be decimated from *Galerucella* spp. herbivory. This variation was present at most purple loosestrife sites, thus making it difficult to estimate percent damage of the entire stand. Inconsistent herbivory may be attributed to anomalies between meristematic tissue growth between individual plants, differences in habitat, and presence of other arthropods.

Table 5. Results of Otsego Lake shoreline assessment 26 and 27 July. Frequency, % damage and abundance categories taken from Table 1.

Date		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
27 July	Habitat	Narrow, steep, & rocky beach	Narrow, steep, & rocky beach	Golf course	Open, sandy banks	Rocky & sandy gradual beach	Open, rocky delta
	L. salicaria Frequency	B	C	C	C	E	F
	% Damage	B	F	D	C	B	C
	Flowering	Yes	No	Yes	Yes	Yes	Yes
	Height (cm)	75-150	25-100	50-150	25-150	25-200	75-200
	Galerucella spp. abundance	3	5	4	3	2	3

Weaver Lake Shoreline Assessment (3 August 2007)

Due to the ambiguous nature of the perimeter of Weaver Lake, site descriptions were not recorded and sample sites were selected relatively equidistant from each other. The entire shoreline of Weaver Lake provides ideal habitat for *L. salicaria,* resulting in widespread succession and monotypical stands of the aggressive plant. The gradual boundaries of Weaver exhibited flora associated with wetlands, such as dogwood (*Cornus* spp.), spiraea (*Spiraea* spp.), jewelweed (*Impatiens capensis*), red maple (*Acer rubrum*), cattail (*Typha* spp.), arrowleaf (*Sagittaria* spp.), reed canary grass (*Phalaris arundinacea*), sensitive fern (*Onoclea sensibilis*), bayberry (*Myrica pensylvanica*), and *L. salicaria*.

Galerucella spp. appeared to be ubiquitous in dispersal along the shoreline of Weaver Lake. No beetles were at site 3, however damage was observed indicating recent or unseen presence (Table 6). There appears to be a positive correlation with beetle presence and percent damage to the loosestrife. Adult and larval populations were observed.

Table 6. Results of Weaver Lake shoreline assessment 3 August 2007. Frequency, % damage and abundance categories taken from Table 1.

Date		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
3 Aug	*L. salicaria* Frequency	C	D	C	B	B	C	C	D
	% Damage	B	C	B	E	E	D	D	D
	Flowering	Yes	Yes	Yes	Yes	Yes	Yes	No	No
	Height (cm)	75-150	25-100	75-150	50-125	50-125	75-125	50-125	50-150
	Galerucella spp. abundance	2	3	1	3	3	2	2	3

Youngs Lake Shoreline Assessment (9 August 2007)

L. salicaria occurs along the whole shoreline of Youngs Lake. Youngs Lake is relatively shallow with a wide eulittoral zone and broad wetland type habitat around most of its perimeter. The plant life of the shoreline is dominated primarily by sedges (*Carex* spp.), rushes (*Juncus* spp.), cattail, arrowleaf, dogwood, bayberry, buttonbush (*Cephalanthus occidentalis*), along with loosestrife.

Only five sampling sites were established at Youngs Lake due to the difficulty in access. A terrestrial approach of the shoreline resulted in navigation through extremely dense underbrush. An aquatic approach proved to be prohibitive in most areas due to thick detritus. It is recommended for future purposes to assess the sample sites by canoe or other lightweight vessel.

Galerucella spp. were located at every area where loosestrife occurred. Each sample site exhibited relatively prominent damage and presence of *Galerucella* beetles. At sample site 4, the extensity of damage correlated with low height and lack of flowering bodies of *L. salicaria* (Table 7). As opposed to Weaver Lake, only adult populations were observed. A metamorphosis of *Galerucella* beetles may have occurred during the week interim between the sampling of Youngs Lake and Weaver Lake.

Table 7. Results of Youngs Lake shoreline assessment 9 August 2007. Frequency, % damage and abundance categories taken from Table 1.

Date		Site 1	Site 2	Site 3	Site 4	Site 5
9 Aug	*L. salicaria* Frequency	E	C	C	B	D
	% Damage	C	C	C	E	B
	Flowering	Yes	Yes	Yes	No	Yes
	Height (cm)	50-125	50-125	50-150	25-75	50-150
	Galerucella spp. abundance	2	2	2	2	2

CONCLUSIONS

The dispersal of *Galerucella* spp. is expanding from the original site release at Goodyear Swamp and has indicated its potential effectiveness as a biological agent against the invasive *L. salicaria.* Research and monitoring of *Galerucella* spp. and *L. salicaria* populations and dynamics should be continued in the future in order to understand the proceedings of such a control measure. Knowledge of the dynamics of this system would be valuable to land and resource managers who are working on control measures for unmanaged invasive species.

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