REPORTS:

Monitoring the effects of the *Galerucella* beetle as a biocontrol agent of purple loosestrife (*Lythrum salicaria*) in Goodyear Swamp Sanctuary, summer 2002

Holly Meehan[1] and Matthew Albright

INTRODUCTION

Purple Loosestrife (*Lythrum salicaria*) is a perennial plant, native to Europe, which is extremely aggressive in disturbed conditions. Introduced to North America in the early 19th century, *L. salicaria* rapidly spread, infesting many wetlands across the continent (Stuckey, 1980). It forms dense, monotypic stands, choking out native endemic species in wetland and lakeshore habitats (Skinner, 1996). In its native habitat, a diverse arthropod community controls *L. salicaria* (Blossey, 1995). However, these herbivores were did not accompany *L. salicaria* when it was first introduced. In the absence of these natural predators, *L. salicaria* has quickly excluded native species, in part due to the ability of a single adult plant to produce in excess of 2 million seeds per year (Welling and Becker, 1990).

Previous attempts at controlling *L. salicaria* (cutting, herbicidal treatment, water level manipulation, and burning) have been unsuccessful (Malecki et al., 1993). Several species of insects have been evaluated regarding their ability to serve as effective biocontrol agents (Blossey et al., 1994). The agent had to be an isolated species meeting host-specificity requirements and having the ability to cause significant damage to *L. salicaria* (Skinner, 1996). From the results of that work, four species of insects were identified. Two of these species, *Galerucella calmariensis* and *G. pusilla,* leaf-eating beetles (Malecki et al., 1993), were introduced into Goodyear Swamp Sanctuary (N42°48.6'W74°53.9') in June 1997 (Austin, 1998). The release of the *Galerucella* spp. was performed in accordance with the protocols established by Blossey (1997). One hundred beetles were released at sites 1 and 2 (Figure 1) with the expectation that, following some increase in their population, they would damage the shoot meristematic regions and foliage of the plant, resulting in impaired growth, reduced seed production, and increased mortality (Blossey, 1995), allowing for the resurgence of native flora. Sites 3-5 were included in the study to evaluate the spread of *Galerucella* spp. over time. Since their introduction at Goodyear Swamp, *Galerucella* spp. have caused heavy damage to, and inhibited the flowering of, *L. salicaria* (Groff, 2001).

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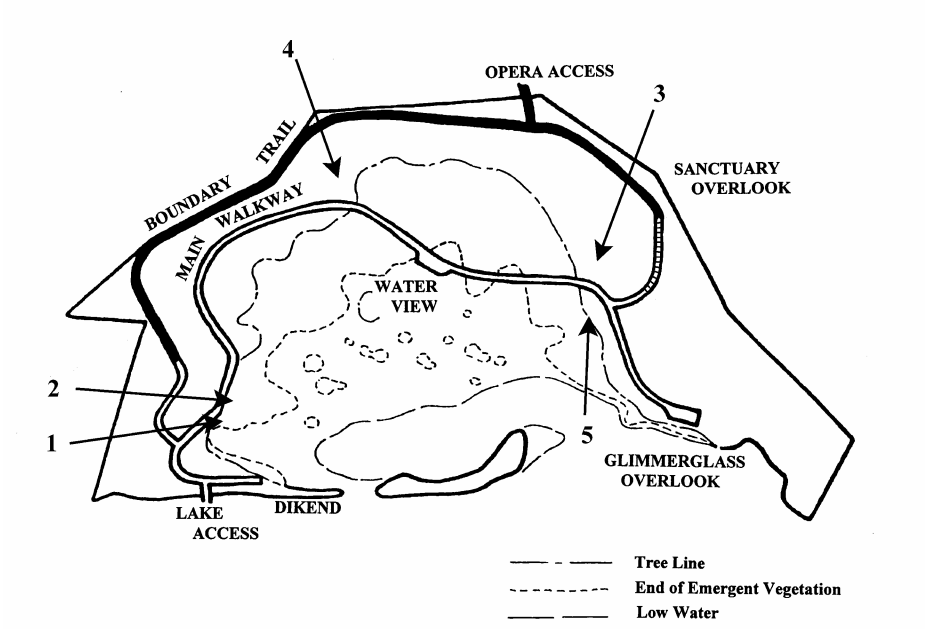


Figure 1. Map of Goodyear Swamp Sanctuary showing sampling sites. Sites 1 and 2 are where *Galerucella* spp. were stocked in 1997; sites 3-5 were used as controls and to evaluate the spread of *Galerucella* spp.

METHODS

One hundred adult leaf-beetles, *Galerucella calmariensis* and *G. pussila*, were introduced into two sites at Goodyear Swamp Sanctuary in June 1997 (Austin, 1998). Monitoring the increase in that population, as well as the resultant impacts on the flora, within the swamp has been done in accordance with Cornell's Monitoring protocol (Blossey, 1997). Five $1m^2$ quadrats were established in Goodyear Swamp Sanctuary (Figure 1) in which to assess the success of *Galerucella* spp. in controlling *L. salicaria* (Austin, 1998). Quadrats 1 and 2 were sites of the original release, where 50 beetles each were introduced. Quadrats 3, 4, and 5 were initially established in 1998 to serve as control sites and to provide insight into the movement of *Galerucella* spp. over time (Austin and Collins, 1999). Form 1 (Appendix 1) provides site information.

Spring monitoring (30 May 02) consisted of the assessment of populations of *Galerucella* spp., *L. salicaria*, and *Typha* spp (Form 1, Appendix 2). Within each quadrat, the number of *Galerucella* spp. eggs, larvae, and adults were estimated using abundance categories (Table 1). Observations of other insects present in the quadrats were also made. The number of stems of *L. salicaria* within each quadrat was counted and the five tallest measured. The percent cover of *L. salicaria* was estimated, as well as the percent damage attributable to *Galerucella* spp. *Typha* spp. was assessed by enumerating the number of stems, measuring the height of the 5 tallest stems, and estimating the percent cover. Fall monitoring (2 August 02), recorded on Form 2

Abundance Catagories		Frequency Catagories		
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 abundance and frequency.

(appendix 3), followed a similar protocol as spring monitoring, with additional measurements regarding *L. salicaria* inflorescences. The protocol involves counting the total number of inflorescences in the quadrat, measuring the lengths of the inflorescences of the 5 tallest stems, and from these, counting the flower buds per 5 centimeters of the inflorescence. However, the latter part of the protocol was not used as no inflorescences were present. Fall monitoring also included the identification and percent cover estimates of all plant species within the quadrats, a count of *Galerucella* spp., and a subjective estimate of the abundance of other insect species in the quadrats. Additional observations were also made on various dates throughout the summer with the intent being to gain more insight into the behavior and activities of *Galerucella* spp. at various stages of *L. Salicaria* damage and control. In addition to the monitoring outlined by Blossey's protocol (1997), nearby stands of *L. salicaria* were assessed for the presence of *Galerucella* spp. in order to evaluate the changing distribution of their population over time.

RESULTS AND DISCUSSION

Monitoring data are represented by abundance and frequency categories defined in Table 1. Note that due to the nature of these categories, changes between them can reflect a substantial change in abundance.

Spring sampling of the quadrats took place on 30 May, 2002 (Appendix 2). No eggs or larva were observed (Figures 2 and 3). Either eggs or larvae had been documented every spring since 1998. This situation is assumed due to the late frosts which occurred this spring, setting back the date of re-emergence by over-wintered adults, and in turn the timing of their mating. This situation was exaggerated because the survey occurred one week earlier than in most previous years. However, adult abundance in the quadrats was the highest yet recorded (Figure 4). Most adults were in copula. Of the 5 quadrats, 3 and 4 had the highest abundances of *Galerucella* spp. adults, indicating the beetles had moved from quadrats 1 and 2 to other areas of the swamp. Along with this increase in numbers of adult beetles, drastic increases in percent damage of *L. salicaria* were observed in quadrants 1-4 (Figure 5). Generally, what little *L. salicaria*

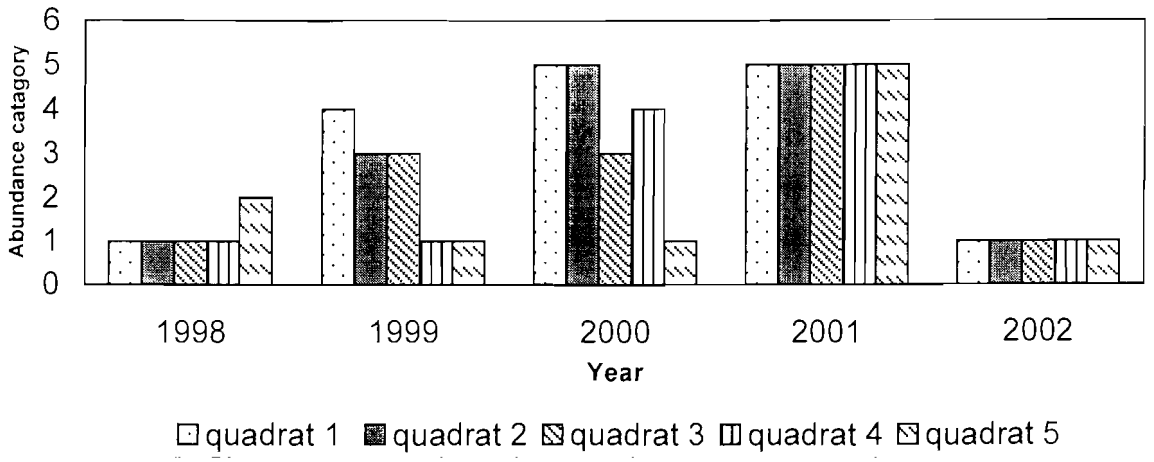


Figure 2. Comparison of *Galerucella* spp. egg abundance from yearly spring samplings. Abundance categories taken from Table 1.

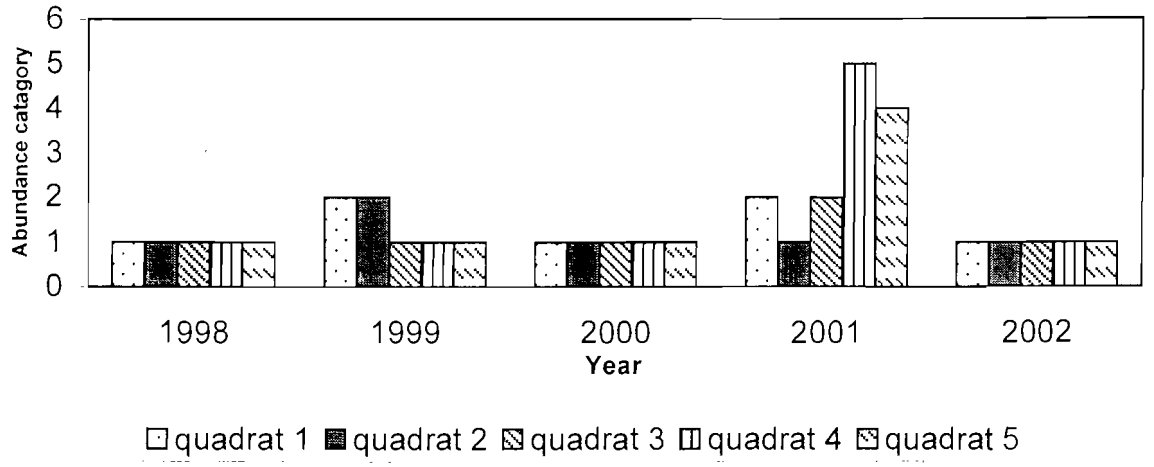


Figure 3. Comparison of *Galerucella* spp. larval abundance from yearly spring samplings. Abundance categories taken from Table 1.

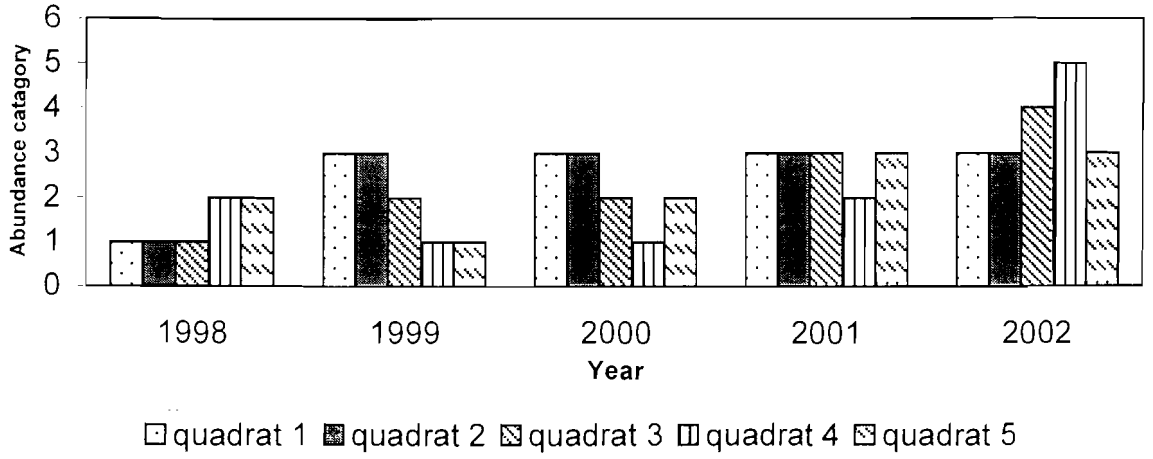


Figure 4. Comparison of *Galerucella* spp. adult abundance from yearly spring samplings. Abundance categories taken from Table 1.

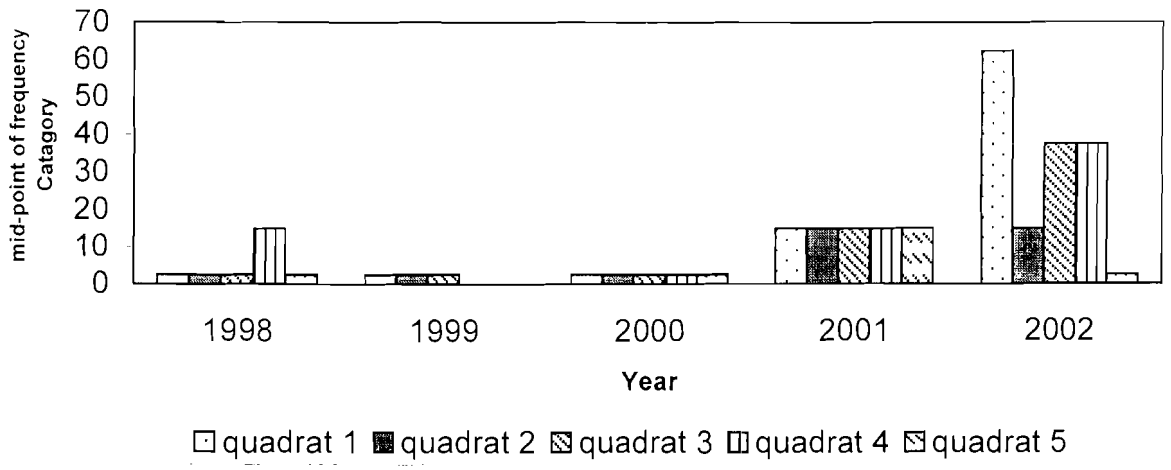


Figure 5. Comparison of percent damage estimations to purple loosestrife leaves from yearly spring samplings. Frequency mid-points taken from Table 1.

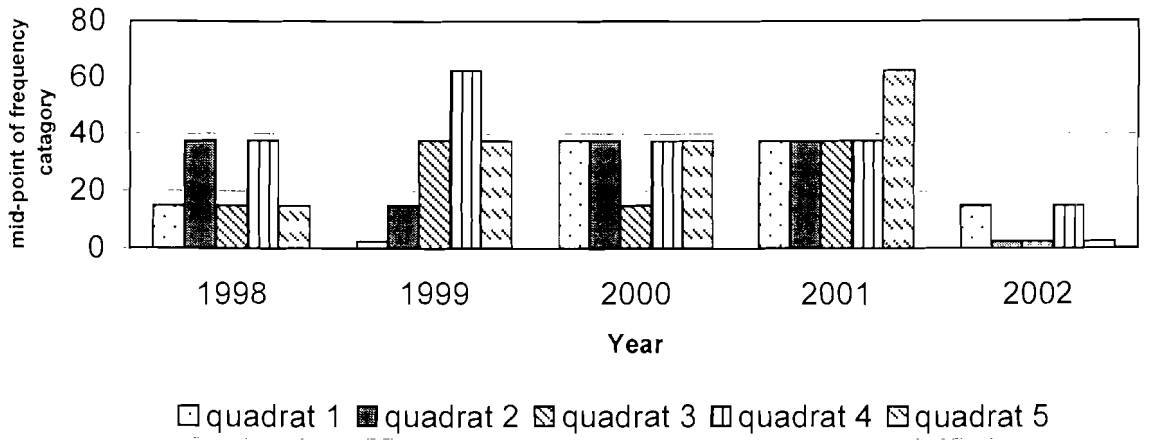


Figure 6. Comparison of percent cover estimations to purple loosestrife plants from yearly spring samplings. Frequency mid-points taken from Table 1.

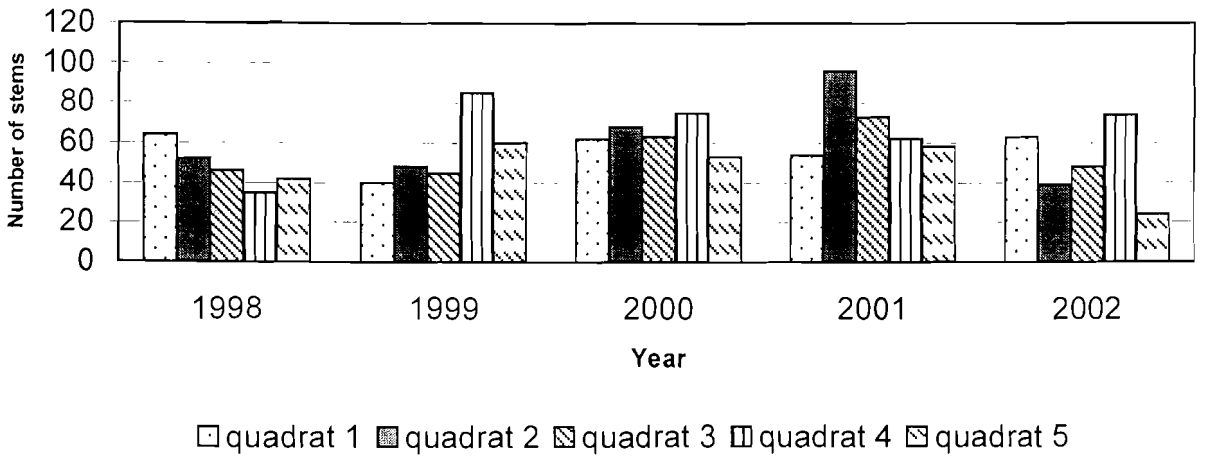


Figure 7. Comparison of the number of purple loosestrife stems from yearly spring sampling observations.

was observed was damaged and infested with *Galerucella* spp. Percent cover of *L. salicaria* in all quadrats decreased as the population of *Galerucella* spp. expanded (Figure 6).

The number of stems of *L. salicaria* per plot in the spring, on average, decreased slightly from previous years (Figure 7), creating the appearance of only a trivial change in the amount of *L. salicaria*. However, these numbers can be misleading due to the fact that stem number is not representative of biomass or health. Several stems of *L. salicaria* may dominate one quadrat, while dozens of stems in another quadrat may represent minimal percent cover. Percent cover, in conjunction with stem height, better describe the status of *L. salicaria.* Mean spring stem height was 175 cm in 1997 and had decreased to 23 cm by 2002.

Fall data were obtained on 13 August 2002 (Appendix 3). Percent cover and number of stems of *L. salicaria* in all quadrats were low (Figures 8 and 9), though it had been absent in fall 2001. This implies that *L. salicaria* had somewhat rebounded since the previous year; however, that is believed not to be the case. In both the summers of 2001 and 2002, above-ground portions of *L. salicaria* was virtually eliminated following the reproductive cycle of *Galerucella* spp. Following that, *Galerucella* spp. were not observed and new *L. salicaria* stems were able to emerge from the root crowns. *Lythrum salicaria* was absent at the fall 2001 monitoring, although its reappearance was noted by late August of that year (Albright, 2002). Because *Galerucella* spp. decimated the *L. salicaria* earlier in the season in 2002, its reappearance was underway prior to the fall monitoring. The average height of *L. salicaria* in the fall1 1997 survey was 175 cm, and had decreased to 24 cm in by 2002.

When the above-ground portions of *L. salicaria* are decimated by mid-summer, the root crown responds by generating many short stems. Because this is the second consecutive year in which this has occurred, these plants are assumed to be expending more energy in producing shoots than supplying carbohydrates to the roots via photosynthesis. This, as well as the complete lack of flower production over the last two years, would be expected to lessen the competitiveness of *L. salicaria*.

Concurrent with the decline of *L. salicaria*, species richness in the quadrats, and thoughout the Sanctuary, has increased. In August 2000, when *Galerucella* spp. were increasing but not to the point that they limited *L. salicaria,* a total of 14 taxa (usually to species level) were identified in the 5 quadrats, the average having 6.4 taxa. On average, species other than *L. salicaria* comprised 21 percent cover. By August 2002, 16 taxa were identified with each quadat having an average of 11.2 taxa. Species other than *L. salicaria* comprised an average of 78 percent cover.

Observations made throughout the summer have led to interesting findings regarding the life cycle of *Galerucella* spp. as well as the behavior and action of the beetles once *L. salicaria* had been removed (Table 2). While early reports suggested that *Galerucella* spp. is specific to *L. salicaria* (Blossey et al., 1994), recent research has documented some “spillover” (Blossey et al., 2001); that is, *Galerucella* spp. temporarily

moving to adjacent, non-target species. This situation is not believed to imply a lack of host-specificity by *Galerucella* spp., as they are not able to complete their life cycle without *L. salicaria*, but rather the need for *Galerucella* spp. to learn to recognize the appropriate host through rejection of suboptimal species (Blossey et al., 2001). Spillover has only been reported when *Galerucella* spp. populations were high and *L. salicaria* was limiting.

Research at Goodyear Swamp has been consistent with the above findings. Spillover was reported in 2001 (Groff, 2002), though for brief duration, when *Galerucella* spp. was feeding on red-osier dogwood (Conde, 2002). In 2002, spillover was more significant with *Galerucella* spp. utilizing more species for longer duration (Table 2). After *L. salicaria* was decimated, *Galerucella* spp. was noted on 9 non-target species and consumed four to varying degrees. Generally, the beetles were very active, moving among plants, presumably searching for *L. salicaria*. The most heavily damaged non-target species was speckled alder, though the damage was localized to a few portions of affected plants. Chemotactic tendencies, described elsewhere (Blossey et al., 2001), where *Galerucella* spp. congregate as a result of pheromone release, was likely the result of over 50 individuals being observed on a single leaf. Despite this herbivory, damage to non-target plants did not appear to be of sufficient intensity or duration to have any substantial impacts.

Preliminary searches for *Galerucella* spp. outside of Goodyear Swamp Sanctuary in 2001 revealed its presence on *L. salicaria* about 1 mi. (1.6 km) northeast of the Sancurary (Groff, 2002). In 2002, was observed in a *L. salicaria* stand at Brookwood Point on Otsego Lake, 9.0 km (5.6 mi) south of the release point. A search of another *L. salicaria* stand near the mouth of Leatherstocking Creek did not reveal *Galerucella* spp. That site is 0.6 km (0.4 mi) north of Brookwood point, meaning that if *Galerucella* spp. originated from Goodyear they bypassed the site at Leatherstocking Creek.

SUMMARY

Following the release of 100 *Galerucella* spp. in 1997, their populations steadily increased through spring 2000, though impacts to *L. salicaria* were limited to the sites of initial release. *Lythrum salicaria* was suffering damage, but not to the point of inhibiting its dominance nor its ability to produce seeds. However, by fall 2000 it seems that *Galerucella* spp. reached some critical population that allowed it to significantly control *L. salicaria*. That year, damage by the season's end limited the development of inflorescences. In 2001 and 2002, damage throughout the swamp was extensive, with virtually all above ground vegetation removed. Following the loss of *L. salicaria* in fall 2001, *Galerucella* spp. were not observed. The fact that *Galerucella* spp. was common in spring 2002 implies that either they returned in early spring 2002, which seems unlikely given their high population then (see Figure 4), or they remained on site in a dormant state beginning in mid-August. Aestivation, or a period of quiescence brought about by unfavorable environmental conditions, may be triggered in *Galerucella* spp. by food shortages. This seems a good adaptive strategy for an insect having such a strict

selectivity on a plant such as *L. salicaria* and a life history as *Galerucella* spp. has. *Galerucella* spp. populations peak in late summer, during which they are likely to exhaust their food supply. If they were to vacate the area in search of other *L. salicaria*, a risky endeavor itself, they would not be in a position to utilize new *L. salicaria* growth the following season. Given the ability of *L. salicaria* to store large energy reserves in its root crown, it is able to produce new shoots for long periods of time even after their being repeatedly decimated.

Species richness throughout the swamp has increased notably following the decline of *L. salicaria*. Areas that had been monotypic *L. salicaria* stands are now heavily occupied by cattails (*Typha* spp.) and swamp candles (*Lysimachia terrestris*).

The discovery of *Galerucella* spp. at a site 9 km away suggests mobility of a greater extent than generally cited in the literature, assuming they originated from Goodyear Swamp. Spillover, where *Galerucella* spp. were noted, and in some cases consuming, plants other than *L. salicaria*, was noted in 2001 and, to a greater extent, in 2002. Damage to non-target species was concentrated on localized area of the plants, and did not appear to be extensive enough or of great enough duration to have any substantial consequences.

REFERENCES

Albright, M.F. 2002. Personal communication. SUNY Oneonta Bio. Fld. Sta., SUNY Oneonta.

Austin, T. 1998. Biological control of purple loosestrife in Goodyear Swamp Sanctuary using *Galerucella* spp., summer 1997. *In* 30th Ann. Rept. (1997). SUNY Oneonta Bio. Fld. Sta., SUNY Oneonta.

Austin, T. and E. Collins. 1999. Biological control of purple loosestrife in Goodyear Swamp Sanctuary using *Galerucella* spp., summer 1998. *In* 31st Ann. Rept. (1998). SUNY Oneonta Bio. Fld. Sta., SUNY Oneonta.

Blossey, B. 1995. A comparison of various approaches for evaluating potential biological control agents using insects on *Lythrum salicaria*. Biol. Control 5:113-122.

Blossey, B. 1997. Purple loosestrif monitoring protocol, 2nd draft. Unpublished document. Dept. of Natural Resources, Cornell University.

Blossey, B., D. Schroeder, S.D. Hight and R.A. Malecki. 1994. Host specificity and environmental impact of two leaf beetles (*Galerucella calmariensis* and *G. pusilla*) for the biological control of purple loosestrife (*Lythrum salicaria*). Weed Science 42:134-140.

Blossey, B., R. Casagrande, L. Tewksbury, D.A. Landis, R.N. Wiedenmann and D.R. Ellis. 2001. Nontarget feeding of leaf-beetles introduced to control purple loosestrife (*Lythrum salicaria* L). Natural Areas Journal 21(4):368-377.

Conde, P. 2002. Personal communication. SUNY Oneonta Bio. Fld. Sta., SUNY Oneonta.

Groff, S. 2002. Biological control of purple loosestrife (*Lythrum salicaria)* in Goodyear Swamp Sanctuary using leaf-eating beetles (*Galerucella* spp.). *In* 34th Ann. Rept. (2001). SNY Oneonta Bio. Fld. Sta., SUNY Oneonta.

Malecki, R.A., B. Blossey, S.D. Hight, D. Schroeder, L.T. Kok and J.R. Coulson. 1993. Biological control of purple loosestrife. Bioscience 43:680-686.

Skinner, L. 1996. Biological control of purple loosestrife – a new control method for a tough wetland invader. Aquatic Nuisance Species Digest 1(4)43-45.

Stuckey, R.L. 1980. Distributional history of *Lythrum salicaria* (purple loosestrife) in North America. Bartonia 47:3-20.

Welling, C.H. and R.L. Becker. 1990. Seed bank dynamics of *Lythrum salicaria*: implications for control of this species in North America. Aquat. Bot. 38:303-309.

FORM 1: SITE LOCATION

Site Name: [illegible] Date: [illegible]

Town: [illegible] County: [illegible] State: [illegible]

Longitude: [illegible] Latitude: [illegible] GPS Derived? Y N

Elevation: [illegible] Range: _____ Twnship: [illegible] Sect: _____ QtrSect: _____

CONTACT PERSON:

Name: Dr. Willard Harman

Address: RD #2 Box 1066

City: Cooperstown

State: NY Zip: 13326

Phone: (607) 547-8778

LEGAL LANDOWNER:

Name: [illegible]

Address: [illegible]

City: [illegible]

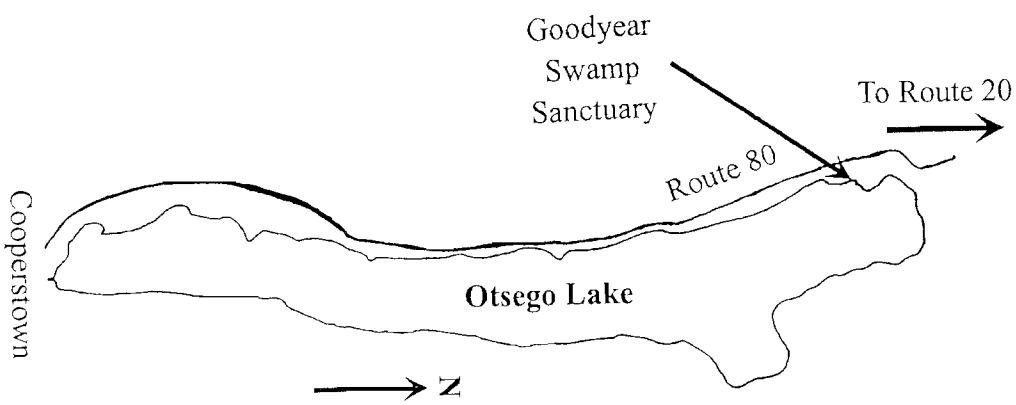
State: NY Zip: 13820

Phone: (607) 436-2513

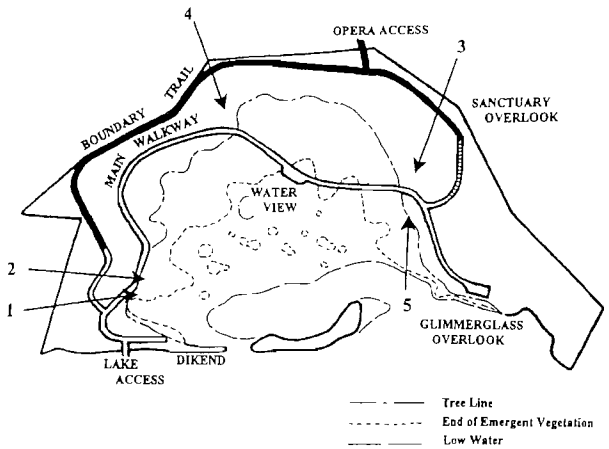
SITE CHARACTERISTICS:

Habitat Type: __River X Wetland __Lake __Meadow __Irrigation Ditch __Other

Road Map to Site



Site and Vegetation Map



INSECT RELEASE HISTORY:

Date (mm/dd/yy)	Species	Number and Stage (egg/larvae/adult)	Position of Release on Map (1,2,3,4...)
06/04/97	Galerucella		Sites 1 and 2
		> 100 Adults	
	G. Pusilla		

Appendix 1. Form 1 of Blossey's *Galerucella* spp. monotoring protocol covering general site information

FORM 2: SPRING QUADRAT SAMPLING:

Site Name: Goodyear Swamp Sanctuary Observer Name(s): Holly Meehan, Matt Albright

Date of Observations: 5/30/02 Time: 2:30 pm

Weather: Overcast, Calm Temperature: 70°F

2.1.

Quadrat #	Galerucella (use Chart A)			Hyl (use Chart A)	Nano (use chart A)	Purple Loosestrife rate% feeding damage and cover (Chart B) and count # of stems			Typha spp. rate % cover (Chart B) and count stems	
	E	L	A	A	A	%damage	%cover	#stems	%cover	#stems
1	1	1	3			E	C	63	A	0
2	1	1	3			C	B	39	A	0
3	1	1	4			D	C	48	A	0
4	1	1	5			D	B	74	A	0
5	1	1	3			B	B	24	A	0
6										
7										
8										
9										
10										
11										

Chart A. Abundance Catagories	
0	1
1-9	2
10-49	3
50-99	4
100-499	5
500-1000	6
>1000	7

Chart B. Frequency Catagories	
0	A
1-5%	B
5-25%	C
25-50%	D
50-75%	E
75-100%	F

2.2.

Quadrat	Purple Loosestrife Height (cm) of the 5 tallest plants					Typha spp. Height (cm) of the 5 tallest plants				
	1	2	3	4	5	1	2	3	4	5
1	40	38	35	29	35					
2	46	35	36	45	42					
3	39	35	35	42	38					
4	40	35	38	34	31					
5	25	23.7	19	23	21					
6										
7										
8										
9										
10										

2.3.

Insect species	Abundance (check one box)		
	Present	Abundant	Very Abundant

2.4. Other Observations:

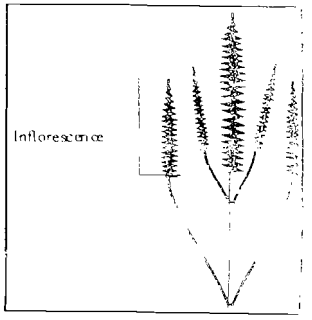
Appendix 2. Form 2 of Blossey's *Galerucella* spp. monitoring protocol covering spring sampling data.

Appendix 2. Form 2 of Blossey's *Galerucella* spp. monitoring protocol covering spring

Appendix 3. Form 2 of Blossey's *Galerucella* spp. monitoring protocol covering fall sampling data

FORM 2: FALL QUADRAT SAMPLING:

Site Name: Goodyear Swamp Sanctuary
Observer Name(s): Holly Meehan, Matt Albright, Jeane Bennett-O'Dea
Date of Observations: 8/13/02 Time: 2:15
Weather: Sunny, Hazy Temperature: 90°F



2.5.

Quad #	Purple Loosestrife rate % cover (Chart A) count number of stems		Typha spp. rate % cover (Chart A) and count stems		Typha spp. Height (cm) of the 5 tallest plants					Purple Loosestrife Height (cm) of the 5 tallest plants				
	%cover	#stems	%cover	#stems	1	2	3	4	5	1	2	3	4	5
1	C	60	B	2	34	20				33	28	26	23	23
2	B	6	A	0						25	29	16	20	19
3	B	36	A	0						31	27	24	29	28
4	B	39	A	0						26	23	27	27	25
5	B	15	B	1	43					23	22	22	23	23
6														
7														
8														
9														
10														
11														

Chart A. Frequency Catagories	
0	A
1-5%	B
5-25%	C
25-50%	D
50-75%	E
75-100%	F

2.6.

Quadrat	#inflorescences for 5 tallest plants					length of terminal inflor. for 5 tallest plants					#flower buds for 5cm of inflorescence					total #inflorescences per quadrat
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
1																0
2																5
3																
4																
5																
6																
7																
8																
9																
10																

2.7.

Plant species	Quadrats (estimate % cover using chart)									
	1	2	3	4	5	6	7	8	9	10
True Forget-Me-Not	C	C	C	C	B	15	15	15	15	15
Graminoid Sp.	B	B	E	D	E	2.5	2.5	6		6
Water Purslane	C	C	C	C	A	15	15	15		
Swamp Candles	B	B	C	A	A	2.5	2.5	15		
Marsh Bell-Flower	A	A	A	C	A					
Skull Cap	A	B	B	B	B		2.5	2.5		

2.7. Cont'd

Plant species	Quadrats (estimate % cover using chart)									
	1	2	3	4	5	6	7	8	9	10
Willow	A	C	A	B	A		15			
Jewel Weed	A	A	B	B	A					
Yellow Flag	A	A	B	B	A					
Fragrant Lily	A	A	A	C	B					
Burr Reed	A	A	A	B	B					
Lycops Mint	B	B	B	E	B					

FORM 3: LIST OF PLANT SPECIES:

Site Name:______________________ Observer Name(s):______________________

Date of Observations:______________ ______________________

Plant species	Quadrat (check box if species is present in quadrat) 1	2	3	4	5	6	7	8	9	10
[illegible]										
[illegible]										
[illegible]				✓						
Soft Stem Bulrush [illegible]				✓						
[illegible]	✓	✓			✓					
[illegible]	✓	✓		✓						
[illegible]	✓									
Gallium/Bedstraw	✓	✓		✓						
Water Cress	✓	✓		✓						
Duck weed	✓	✓	✓	✓	✓					
Veronica/Speedwell										
Button Bush										
Swamp Milkweed										
Turtle Head										
Water Plantain										
Royal Fern										
Horse tails										
Ditch Stone Crop										

Appendix 4. Form 3 of Blossey's *Gallerucella* spp. monitoring protocol covering native flora present in areas once dominated by *L. salicaria*. Note: not all plant species are found in quadrats.