Purple Loosestrife (*Lythrum Salicaria*): The threat posed to UNDERC and a management plan to minimize the probability of invasion

BIOS 569: Practicum in Field Environmental Sciences

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Abstract

Invasion of non-indigenous plants threatens the integrity and function of ecosystems. Purple loosestrife (*Lythrum salicaria*) is an invasive perennial herb of Eurasian origin that is highly detrimental to North American wetlands. A colony of purple loosestrife recently found in Tenderfoot Lake threatens the habitat integrity and the research value of UNDERC. This four-fold study of purple loosestrife consisted of 1. assessing the population size, 2. studying growth rates and herbivory for purple loosestrife and three competing species, 3. studying morphological variation among and within individual plants, and 4. experimentally determining the most effective means of removal. Results were as follows: 1. The population on the island consisted of over 500 plants and had spread to the middle of Tenderfoot Lake. 2. The population has much morphological variation, both among and within plants. 3. Purple loosestrife had the highest growth rate of all plants tested, yet was greatly impacted by herbivory. Swamp loosestrife, likely an important competitor, was not observed to be herbivorized. 4. Plants with their roots removed did not regrow, while the majority of those that had their stems removed but roots left intact grew new shoots in two weeks. After the completion of this study, all purple loosestrife plants were removed including the roots. This will need to be repeated for a number of years due to the long-lived seed bank. Through this study I have created an ecologically based management plan consisting of both biological and physical control that can be used in the future to minimize the chance of purple loosestrife's invasion of UNDERC.

Introduction

The invasion of non-indigenous plants is considered one of the primary threats to the integrity and function of ecosystems as well as to rare and endangered species (Blossey et al. 2001). Purple loosestrife (*Lythrum salicaria*) is a perennial native to Europe which is a serious threat to North American wetlands. Purple loosestrife disrupts ecosystems in many ways. Its invasion of North American wetlands has eliminated plants that provide important habitat and food for wildlife (Nelson et al. 1996, Mullin 1998, Blossey et al. 2001), disrupted nutrient cycling (Blossey et al. 2001), and reduced wetland biodiversity. Purple loosestrife often creates monospecific stands with thick spreading roots that can choke waterways (Mullin 1998).

Purple loosestrife infestations are typically associated with wetland disturbance, however, once established, it is a superb competitor (Weihe & Neely 1997, Rachlich & Reader 1999). This species' height, prolific seed production (over 2 million seeds are produced annually by each mature plant), high percentage of seed germination, and fast germination (Blossey et al. 2001) allow it to effectively out-compete and eliminate native plants over time, such as cattails (*Typha;* Mal et al. 1997). Purple loosestrife is spreading through the contiguous US except Florida at a rate of 190,000 ha per year (Mal et al.1997). Purple loosestrife's establishment in US wetlands is aided by the low rates of herbivory seen in the region (Rachich and Reader 1999).

Although a perennial, purple loosestrife is capable of producing seeds during its first growing season (Munger 2002). Its seeds are spread primarily by water, but wind, birds, other wildlife and humans (by way of muddy shoes, vehicle wheels, and motorboats) can also disperse seeds. Purple loosestrife also spreads vegetatively by

resprouting from stems, and possibly from rootstocks, though this point is disputed. For management purposes, removal of roots is advised in most literature (Nelson et al. 1996, Mullin 1998, Munger 2002, MN Seagrant 2004), yet reported to be unnecessary in another study (Stevens et al. 1997).

This exotic species is found in a variety of freshwater habitats in North America, including streambanks, lakeshores, floodplains, bogs, and vernal ponds (Munger 2002), all of which are found in abundance at UNDERC. During summer 2003, a small patch of purple loosestrife was discovered on a large island in the southeastern end of Tenderfoot Lake (Reuben Keller, personal communication), which henceforth in this paper shall be referred to as "the island" (Figure 1). From the island, I believe that purple loosestrife could easily move north and invade the varied wetland areas found throughout the UNDERC property. Such an invasion poses a large threat to the ecosystem integrity and the research value of UNDERC.

My study consisted of four parts, the first of which was to assess the population on the island. Secondly, I looked at two mechanisms of competition, growth rate and herbivory, and how these may be affecting invasion rates. Thirdly, I studied morphological variation among and within individual plants, with the goal of aiding others identify this exotic. Lastly, I completed an experiment to determine the most effective means of removal of purple loosestrife. The end result of my study is an ecologically based management plan that can be used in the future to reduce the risk of purple loosestrife's invasion of UNDERC.

Methods and Materials

Population Assessments

The main part of this study was conducted during June and July 2004 on the island in Tenderfoot Lake, Vilas County, WI. The island is 86 meters in diameter across its widest point and within a half a mile of UNDERC property. It is privately owned; the caretaker granted me permission to use the island for scientific research. I surveyed the entire island for purple loosestrife. I noted the population size and estimated its age based on the presence of dead stalks (last year's growth). I also gathered information about where the population occurred. To this end I looked at soil characteristics, distance to water, and the other plant species present at the major sites of infestation.

Growth Measurements & Herbivory

In order to determine the growth rate of purple loosestrife compared to associate species, I began by choosing ten purple loosestrife clumps on the island. Each clump contained dead flower stalks from last year's growing season, which signified that these plants were at least in their second growing season. Two haphazardly chosen stems from each clump were marked and their height was measured six times over the span of 35 days (June 6 – July 10). Markers were made by writing identification numbers on flagging tape with permanent marker and loosely tying the tape low around the stem. Height was measured from the base of the visible stem to the highest point of the top leaf. Ten clumps of each of the three most prominent competing species, grass, sweet gale (*Myrica gale*), and swamp loosestrife (*Decodon verticillatus*), were chosen based on their proximity to the purple loosestrife clumps. Two stems from each of these clumps were marked and measured in the same manner. Swamp loosestrife was not measured until

late June. Prior to this time, it was too small and not abundant enough to identify as an important competitor to purple loosestrife.

Morphological Variation

In order to study the variation of purple loosestrife plants, I recorded three characteristics of each of the stems marked for measuring: leaf arrangement, number of sides of the stem, and leaf shape. I then haphazardly chose two additional stems from each clump and noted the same characteristics, in order to better quantify the variation within each clump. Number of sides of the dead flower stalks was also noted for each clump. The notes on the living stems were taken twice, on June 5 and June 17.

Removal experiment

In order to determine the most effective means of removal of purple loosestrife, I established an experiment on the island on June 28 and 29. A total of 60 purple loosestrife plants were used: 30 clumps and 30 smaller plants consisting of only a single stem. For this experiment, I defined a clump as an autonomous plant consisting of more than ten stems and often including dead stalks of last years growth. The clumps received the following treatments: Ten were dug out with a spade, removing as much of the root system as possible. Ten had their stems cut below the first leaf node, as close to ground level as possible, using gardening shearers. For this second treatment, all dead stalks of last year's growth were removed from the clumps in the same manner, any tiny sprouts present were removed, and the roots were left intact. The remaining ten clumps were left as a control group and received no treatment. All treatments were randomly assigned to the clumps by means of a random number table. The experiment was replicated on 30

single stem plants. Ten were pulled out by the roots, ten were cut below the first node, leaving the roots intact, and ten remained as controls.

During the experiment, care was taken to minimally disturb the area and to remove all plant pieces that had been scattered on the ground. All removed plants and stems were sealed in double or triple layered black trash bags and thrown away, as recommended by the DNR and Stevens et al. (1997). I returned to the island 12 and 17 days after the experiment was begun to count the number of new stems each treated plant had regrown, measure their average height, and note the health of the control plants. After the experiment was completed on July 15, all purple loosestrife clumps and single stems on the island were removed using the best means as determined by the experiment: digging out the roots (see below). The remains were carefully bagged and disposed of as described above. Purple loosestrife was also removed from the reedy island in the middle of Tenderfoot Lake.

Results

Population Assessments

Population size of the purple loosestrife colonies was determined by the number of plants that were removed on July 15. Population on the island was 110 clumps and 464 single stems. Purple loosestrife has spread to the low reedy island in the middle of Tenderfoot Lake as well. There we removed 13 clumps and 18 single stems. In both locations, everything we could find was removed.

The southern edge of the island has the gentlest gradient and receives the most direct sunlight, as there are few emergent plants and trees. The purple loosestrife on the

island was concentrated in this area. While the majority of purple loosestrife plants on the island were on the wet and sunny southern side, I found one clump on the eastern side growing among dense grass and one on the northeastern edge growing in a shady, rocky area. All plants were found growing 0 – 3 m away from water. Early in the season, when water levels were high, many purple loosestrife plants grew directly in standing water, at depths up to 15 cm. Purple loosestrife on the island was associated with thick, rich, silty substrate full of detritus and open patches of soil between native plants. Its associate species on the island were sweet gale, swamp loosestrife, winged loosestrife (*Lythrum* alatum), swamp milkweed *(Asclepias incarnata)* and varied types of grasses and sedges. Purple loosestrife was also found on the low island full of reeds halfway between the island and Kilarney Point in Tenderfoot Lake. Here the major associate species were *Typha*, bulrushes, swamp milkweed, and horsetails.

Growth Measurements & Herbivory

Over the 35 days I took growth measurements, purple loosestrife grew very quickly, especially during the first few weeks. From June 5 – June 10, its growth rate was 1.98 cm/day; from June 10-18, 2.24 cm/day (Figure 2). From June 18 through July, many of the stems experienced herbivory. This herbivory was characteristic of white-tailed deer—entire tops of the stems were bitten off, high above the ground, and the cuts were jagged, not the precise cut characteristic of hares and rabbits. Based on these observations and deer tracks on the island, I am confident that deer were the cause of the herbivory. This herbivory greatly affected the purple loosestrife. Herbivorized stems had much lower growth rates and, most importantly, failed to produce buds in the time I observed them, while non-herbivorized stems did produce buds.

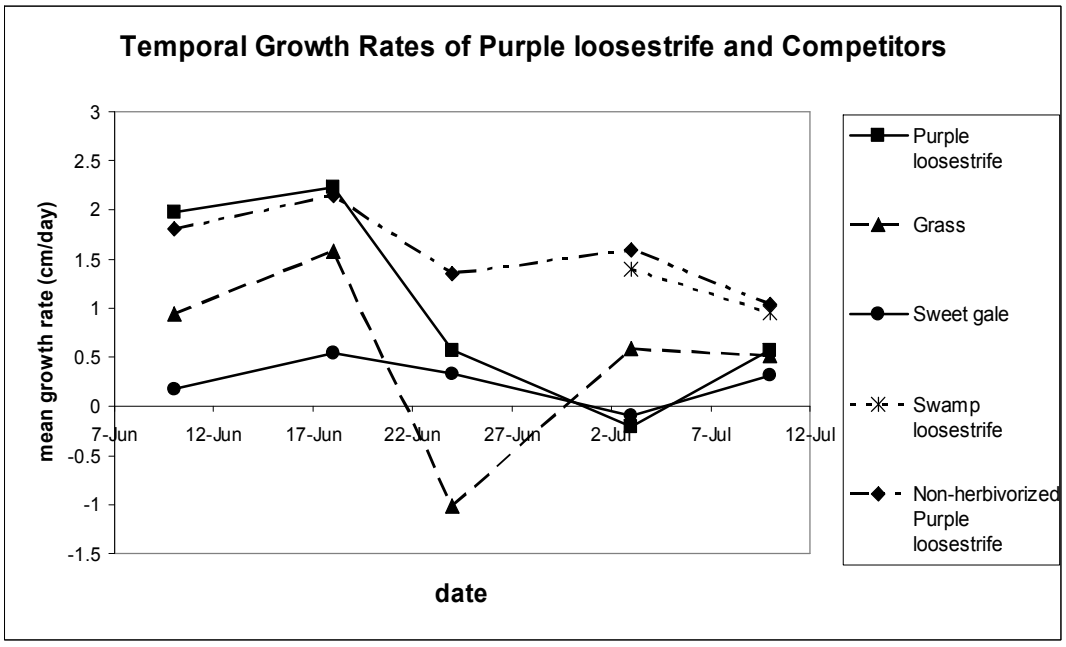

Figure 2: Growth rates of purple loosestrife (n=20), grass (n=20), sweet gale (n=20), swamp loosestrife (n=20), and non-herbivorized purple loosestrife (n=6). Non-herbivorized PL is a subset of the total PL group and represents only those stems not herbivorized by deer over the 35 day span. Measurements taken June 5 – July 10, 2004 on Tenderfoot Island in Vilas County, WI.

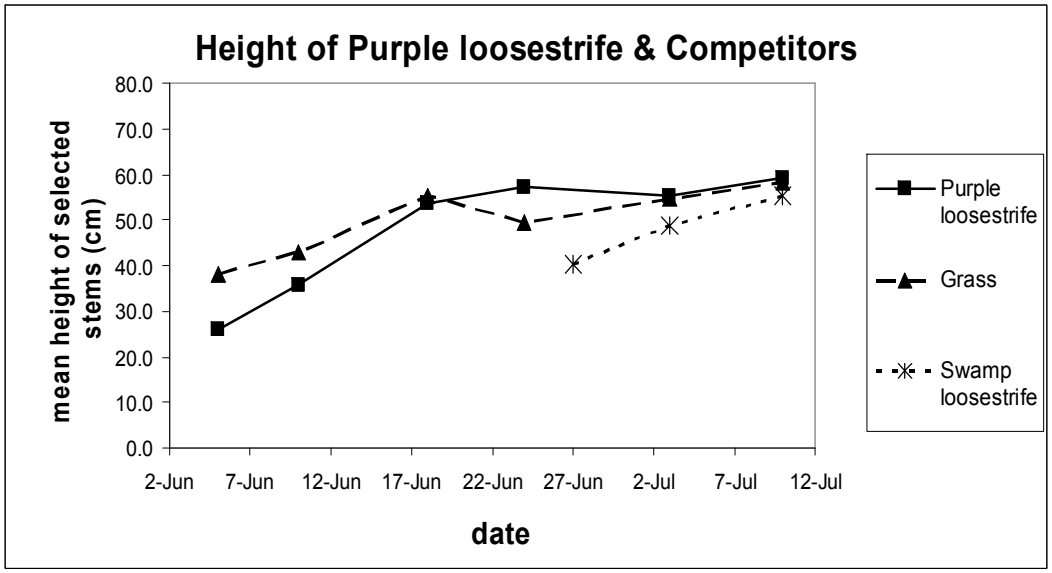

Figure 3: Mean height of purple loosestrife stems (n=20), grass stems (n=20), and swamp loosestrife stems (n=20). Sweet gale not included due to its more horizontal growth. Measurements taken June 5 – July 10, 2004 on Tenderfoot Island in Vilas County, WI.

It appears that deer preferentially grazed on purple loosestrife. Fourteen out of the 20 purple loosestrife stems in this study experienced herbivory, while only six of the grass stems and none of the swamp loosestrife or sweet gale were eaten. Data was analyzed using ANOVA and Bonferroni tests. All reported data are from the Bonferroni unless otherwise stated. The first test took deer browsing into account (ANOVA, $p<.001$). Non-herbivorized purple loosestrife ($n=6$) had a significantly higher growth rate than herbivorized purple loosestrife ($p<.001$), both non-herbivorized and herbivorized grass ($p<.05$ & $p<.001$), and sweet gale ($p<.001$). When not taking herbivory into account (ANOVA, $p<.001$), the combined purple loosestrife group ($n=20$) only had a significantly higher growth rate than sweet gale ($p<.05$). Swamp loosestrife and purple loosestrife did not have significantly different growth rates in either case ($p>.05$).

Herbivorized plants included, purple loosestrife remained taller than swamp loosestrife throughout the summer (Figure 3). In early June grass was the tallest plant; however, purple loosestrife overtook it by the end of the month. At the end of the 35 day measurement period, purple loosestrife and grass averaged about the same height.

Morphological Variation

The population of purple loosestrife I studied exhibited a large amount of morphological variation. Leaf arrangements noted in the population on the island were: opposite, alternate, spiral, and whorls of three. Of these, opposite was the most common (29 out of 40 stems). There also was a strong correlation between number of sides on stem and leaf arrangement. Ninety-five percent of all 4-sided stems had opposite leaves, 92% of all 5-sided stems had leaves in a spiral arrangement, and 89% of all 6-sided stems had leaves in whorls of three. Besides variation among plants, much variation was found

within individual clumps of purple loosestrife (Table 1, see esp. Clumps 8-10) and even on individual stems. Several of the stems that were studied on both dates either completely changed leaf arrangements (i.e. from alternate to spiral) or added an additional type of leaf arrangement above the original arrangement (See Table 1, Clumps 2, 5, 6 and 9). Leaves also varied among plants. Young stems tended to have broader leaves. As stems matured, their new leaves became increasingly linear as the stems grew upward. Even this mature leaf shape was subject to variation. Leaves on the 20 stems studied (two from each of the ten clumps) varied in shape from slender to more broad, from distinctly lanceolate to more linear. Leaf tips ranged from pointed to more rounded; bases varied from slightly chordate to rounded. Most dead stalks were 4-sided, a few were 5-sided.

Removal experiment

The results of the removal experiment were clear. Twelve days subsequent to their removal, 0% of the clumps and 0% of the single stems receiving Treatment 1 (roots removed) had regrown, while 90% of the clumps and 60% of the single stems receiving Treatment 2 (stems cut, roots left intact) had grown new shoots. Five days later, the results were the same. After 17 days, the clumps with regrowth had produced an average of 33 new shoots (mean height 12 cm) with a minimum of 11 and a maximum of 91. The single stems with regrowth had produced an average of 3.33 new shoots (mean height 2.83 cm) with a minimum of one and a maximum of five. The new shoots generally grew directly off the base of the cut stems. The control clumps and single stems remained healthy and many stems on the control clumps produced buds. In several of the large holes produced by digging out the clumps, many tiny seedlings sprouted. These

Morphological Variation of Purple Loosestrife

June 5			June 17		
Clump #	**# sides on stem**	**leaf arrangement**	**Clump #**	**# sides on stem**	**leaf arrangement**
1	4	opposite	1	4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
2	4	opposite	2	4	alternate, opposite
	5	spiral		5	Spiral
	4	spiral		5	Spiral
	4	spiral		5	Spiral
3	4	opposite	3	4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
4	4	opposite	4	4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
	4	2 alt, rest opposite		4	Opposite
5	4	opposite	5	4	alternate, opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
6	5	alternate	6	5	Spiral
	5	alternate, then spiral		5	Spiral
	4	opposite		5	Spiral
	6	whorls of 3		5	Spiral
7	4	opposite	7	4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
	4	opposite		4	Opposite
8	5	spiral	8	5	Spiral
	4	opposite		4	Opposite
	4	opposite		4	Opposite
	4	1 opposite, rest spiral		4	alternate, opposite
9	4	opposite	9	4	Opposite
	4	opposite		4	alternate, opposite
	4	opposite		4	Opposite
	6	2 opposite,rest whorls of 3		6	whorls of 3
10	6	whorls of 3	10	6	whorls of 3
	6	whorls of 3		6	whorls of 3
	6	whorls of 3		5	Spiral
	6	spiral		4	Opposite

Table 1: Morphological characteristics (# of sides on stem and leaf arrangement) of ten purple loosestrife clumps on Tenderfoot island, Vilas County, WI. The same two stems from each clump (the shaded rows) were studied on two different dates. In addition, two haphazardly chosen stems from each clump (white rows) were also studied at each date, to further show variability among and within clumps.

seedlings resembled the tiny purple loosestrife sprouts I had removed from the Treatment 2 clumps; however, they were too small to identify positively as purple loosestrife.

Discussion

Removal Experiment

My results indicate that purple loosestrife can rapidly resprout in response to intense aboveground damage. This is consistent with the USDA Forest Service's report (Munger 2002). Crossle´ and Brock (2002) found that cutting shoots 1-2 inches above the soil twice during the growing season increased biomass and seed production. While my results clearly indicate that stem cutting does not cause morality, Katovich et al. (1999) found clipping shoots at 4-week intervals throughout the growing season to provide the degree of stress necessary for mortality. Perhaps if I was able to repeat the cutting treatment, I would see morality. However, given the incredibly rapid and prolific regrowth on the cut stems, I find this unlikely.

There is some disagreement among scientists over the importance of removing purple loosestrife's roots. Some say purple loosestrife can spread vegetatively from both stems and rootstocks (Nelson et al. 1996, Mullin 1998) and broken roots may sprout new plants (MN Seagrant 2004); therefore roots must be removed. The USDA Forest Service and Minnesota Seagrant both recommend removing the roots. One study however, says purple loosestrife can only resprout from stems, making removal of roots unnecessary (Stevens et al. 1997). I observed many instances of regrowth on damaged stems, both the bits of stems that remained from the cutting experiment and pieces of stems that I found on the island that had been naturally damaged or broken completely off the root crown.

Since purple loosestrife stem bases reach deep into the root crown, it seems the only way to remove all of the stems is to remove the entire rootstock. Further study is needed to determine if roots themselves, with no stem bases attached, can generate regrowth.

Growth Measurements & Herbivory

Purple loosestrife achieves a competitive advantage from its height and high growth rate. By quickly becoming the tallest plant in its habitat, purple loosestrife has exclusive access to sunlight and can shade out competing plants. Swamp loosestrife, likely its most important competitor on the island, has its own competitive advantage: avoiding deer herbivory. While grazing resulted in a meaningful reduction of buds produced by purple loosestrife, the damage sustained was not great enough to kill the plants. Rachich and Reader (1999) found that herbivores inhibited purple loosestrife's sexual reproduction by eating the tips of shoots, thereby preventing the formation of its terminal inflorescence. Grazed plants generally produced one or more replacement shoots near the stem base, but none of these shoots budded (Rachich and Reader 1999). More research is needed to determine if deer herbivory results in a significant reduction of sexual reproduction of purple loosestrife in this area.

Morphological Variation

My results are consistent with *Through the Looking Glass: A Field Guide to Aquatic Plants* (Borman et al. 1997)'s descriptions of purple loosestrife's leaf arrangement and stem variation. Borman et al. also report that all three stem types can be found on a single plant. This field guide is also the most helpful when identifying young purple loosestrife plants. Crow and Hellquist (2000) and Voss (1985) only use flowers for identification and do not mention leaf arrangement or the plant's most distinguishing

feature, its angular stem. Needless to say, if it were not for *Through the Looking Glass*, it would have been nearly impossible for me to positively identify purple loosestrife without blooms. From a management perspective, this is a grave inadequacy, given that it is important to remove these exotic plants before they become established if flowering and seed-set is to be prevented.

Two native wetland plants, swamp loosestrife and winged loosestrife, look very similar to purple loosestrife when they are young (Figure 4). Winged loosestrife has toothed leaves and a smooth stem; purple loosestrife can be differentiated from this species by its angular (4-, 5-, or 6-sided) stem and smooth-edged leaves. Swamp loosestrife has an angular stem and smooth-edged leaves as well; therefore, to differentiate purple loosestrife from this species, one must look at how the leaves attach to the main stem. Swamp loosestrife leaves have a leaf stem, while purple loosestrife leaves lack a leaf stem and attach directly to the main stem.

Population Assessments

The locations in Tenderfoot Lake where I found purple loosestrife are consistent with Borman et al.'s (1997) report that purple loosestrife can be found in a wide variety of sites from moist soil to shallow water. The DNR reports that purple loosestrife has been found in Palmer Lake. The purple loosestrife on the Tenderfoot Lake island is likely to have emigrated by seed from there, through the Ontonagon River either by simple water flow or by boaters that travel from Palmer to Tenderfoot. The population on the island was much larger than expected, and presence of large clumps and many dead flower stalks from last year's growing season indicate that this is an established population.

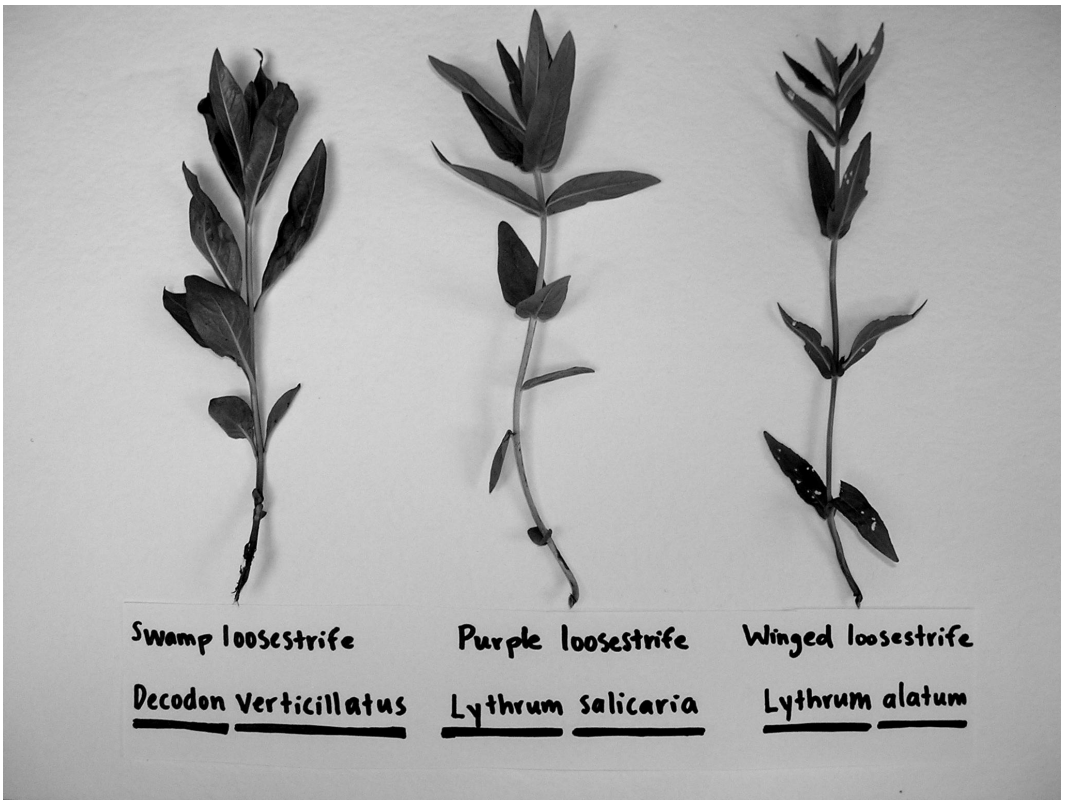

Figure 4: Comparison of a small purple loosestrife plant and its two most visually similar species. All plants taken from Tenderfoot Island in Vilas County, WI in July 2004. Purple loosestrife can be differentiated from winged loosestrife by its angular (4-, 5-, or 6-sided) stem and from swamp loosestrife by its lack of leaf stems.

The fact that purple loosestrife has spread north from the island to the low reed island in the middle of Tenderfoot Lake is a concern. Unfortunately, the plants had just begun to bloom by the time this paper was due, so I was not able to extensively survey the entire Tenderfoot Lake area. This is something that should be done later this summer and in future years. Other low-lying reedy areas close to the island or the reed island in the middle of the lake should be checked for infestation, as well as Kilarney Point, where there is much disturbed ground. Disturbed sites allow purple loosestrife seeds to germinate and colonies to expand (Borman et al. 1997). From Kilarney Point, purple loosestrife could easily spread to Tenderfoot Creek. If it becomes established there, it could spread to the rest of UNDERC.

Management Plan

This study comprises the first year of management of purple loosestrife at UNDERC. Complete removal will take many years of active management. The extensive seedbank will not be depleted for many years as the seeds remain viable for at least 3 years (Munger 2002). Next summer, both the main island and the low reed island should be surveyed to see if any dead flower stalks are present. If not, then it can be said that the digging out we completed this summer was successful at preventing sexual reproduction and subsequent enlargement of the seedbank.

Using the information and pictures I have provided and *Through the Looking Glass* (Borman et al. 1997), young purple loosestrife plants should be identified early in the summer and pulled out by the roots, being careful to remove all pieces of stem and root stock. By removing plants when they are small, disturbance, and thereby the amount of open soil available for seedlings to colonize, is minimized. Early removal also reduces

the chance of seed production that growing season, as plants can flower only eight weeks after they have germinated (Borman et al. 1997). The plants should be removed and bagged as described in this paper. This procedure must be repeated every year until the population on the island, as well as every site of infestation in the whole of Tenderfoot Lake, is eliminated.

To help control the amount of new plants that will regrow this summer and in following years, we will release *Galerucella* spp. beetles on the island this August. The DNR advocates *Galerucella* spp. beetles as means of biologically controlling purple loosestrife populations. The beetles have been proven to effectively control large purple loosestrife populations (Cathy Cleland, DNR exotics specialist, personal communication). *Galerucella* spp. reduce purple loosestrife's aboveground biomass, height, and seed production, thus reducing its competitive advantage over native wetland plants and limiting its spread (Katovich et al. 1999). Studies have shown that these insects have a high host specificity—they feed nearly exclusively on purple loosestrife and do not damage native plant species (INHS 2004). Biocontrol is an important way to reduce the spread of purple loosestrife; however, it has not been shown to be effective at eliminating populations. For this reason, I recommend continuing to physically remove purple loosestrife plants from the Tenderfoot Lake area. In order to gauge the beetle's effectiveness, all purple loosestrife plants that are removed in the following years should be examined for beetle herbivory and the beetles themselves.

To prevent reimmigration of purple loosestrife into Tenderfoot Lake, the populations in Palmer Lake and the Ontonagon River should also be targeted in the following years. Managing these source populations will further reduce the risk of

invasion to UNDERC property. The size of these populations must be determined and the proper management method(s) chosen. Since biocontrol is the best option for controlling large, established populations of purple loosestrife, perhaps beetles should also be released in these areas. Beetles can be obtained from the DNR office in Rhinelander, WI.

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