the Gardens' Bulletin

Royal
Botanical
Gardens

Hamilton, Ontario
Canada.

from *PAPPUS* Vol. 12, No. 2, Spring, 1993
ISSN 0710-0469

EFFICACY OF TRICLOPYR AMINE IN CONTROLLING *Lythrum salicaria L.* (PURPLE LOOSESTRIFE).

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In 1978 the International Joint Commission compiled the Great Lakes Water Quality Agreement which outlined specific requirements for the development of Remedial Action Plans for areas of concern in the Great Lakes Watershed. Hamilton Harbour, including Cootes Paradise, was identified as an area of particular significance. The Remedial Action Plan for Hamilton Harbour and surrounding area includes the Fish and Wildlife Habitat Restoration Plan of which the project for the restoration of Cootes Paradise and Grindstone Marshes is a significant part. This project is expected to be underway in the near future. A priority of this project is to provide suitable habitat for the re-establishment of native submergent and emergent vegetation throughout much of Cootes Paradise and Grindstone Creek marshes. Two of the most significant reasons for the lack of vegetation in these marshes is the activities of Carp (*Cyprinus carpio*) and water movement (waves and current). Once these stresses are removed conditions for plant growth are expected to improve. The presence of lush plant growth is essential for the improvement of water quality as well as providing suitable habitat for fish and wildlife.

Purple loosestrife is an invasive weed that is quickly spreading to and taking over North American wetlands. Because of its invasive nature and competitive ability it is anticipated that purple loosestrife will also take advantage of the new habitat created by the restoration project. This could become a threat to the establishment of indigenous species. Purple loosestrife seeds are already in the seed bed throughout Cootes Paradise and Grindstone Creek, and existing stands of purple loosestrife are located adjacent to the areas most favourable for the development of new plant habitat. The control of purple loosestrife is therefore essential to the success of the marsh restoration project.

Triclopyr amine (3,5,6-trichloro-2-pyridinyloxyacetic acid as triethylamine salt) is a broad-leaf weed herbicide that is currently being tested to gain registration in Canada for use over water. Research conducted thus far indicates that it is an effective and safe product and would be useful as part of an integrated management program to keep purple loosestrife in check. A field study was conducted in Mercer's Glen, an isolated pond owned by the Royal Botanical Gardens in Burlington. Four treatments and a control were incorporated into the trials. Results showed that Triclopyr amine at moderate concentrations is effective against purple loosestrife, and may become an important component of an integrated pest management program at RBG.

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[1] *Funded through a grant received from Ontario Pesticides Advisory Committee (OPAC).*

Purple loosestrife is native to Europe and parts of Asia (Shamsi and Whitehead, 1974). In Europe it reaches a northern distribution near the 65th parallel (in Russia) and southern limit along the coast of Algeria. It occurs throughout central Europe, as far east as the western border of China. It is not found in central or western China but is found in eastern China, Manchuria, Japan, southeast Asia and Northern India. It has since spread to eastern Africa, Australia, Tasmania, New Zealand, and North America (Thompson et al, 1987). The spread of purple loosestrife corresponds roughly with the discovery and exploration of these areas by Europeans.

The introduction of exotic species has often led to serious economic and environmental problems. In many cases the introduced species quickly reach undesirable concentrations and have detrimental effects on indigenous species. A species is considered pre-adapted if the habitat that it invades is very similar to that which it colonizes in its area of origin (climatic and bio-geophysical similarities). This means that once it is introduced to the new habitat it is at least as well off as any indigenous species. Competitive ability is perhaps best described as the success of a species in terms of its spread and establishment in a given set of environmental circumstances. It is possible that an exotic species can colonize an area more quickly and fare better in the presence of its new competitors than its competitors can fare in the presence of the exotic species. When species are introduced to a new region it is often without associated predators or pathogens which keep its population in check in their native region. The absence of disease and predators gives the introduced species a large advantage. The pre-adaptation of a species to its new environment, higher competitive ability, and the lack of predator species are three major factors that contribute to the success of an exotic species.

Purple loosestrife (*Lythrum salicaria L.)* is an erect herbaceous perennial that is taking over wetlands in North America. It out-competes the native North American flora and forms dense mono-specific stands. Purple loosestrife provides little food, shelter or nesting areas for indigenous wildlife. It also has the potential of seriously affecting the populations of muskrat (*Ondatra zibethica*), mink (*Mustela vison*), waterbirds and plants.

L. salicaria occupies the same habitat as *Typha latifolia* (cattail), which is the principal food source of muskrats. It has been noted that when feeding in purple loosestrife infested areas muskrats forage on cattail but do not generally damage adjacent purple loosestrife plants. This helps the spread and establishment of this exotic species by removing the competition (Thompson et al, 1987). Once established purple loosestrife eventually excludes cattail and thus less food is available for muskrats.

The impact of purple loosestrife on already declining species will undoubtedly be greater. Species such as the Black Tern (*Chlidonias niger*), and Canvasback Duck (*Aythya valisineria*) which rely on open nesting sites supplied by muskrat houses, will find it increasingly difficult to find appropriate nesting sites. Purple loosestrife infested areas will support fewer muskrats (and therefore fewer muskrat houses), and muskrat houses provide an ideal substrate for purple loosestrife to grow on. A decline in rodent and bird species associated with marsh ecosystems is expected with the formation of mono-specific loosestrife stands. These are the primary food sources for mink and the decrease in a food supply for mink will undoubtedly be reflected by fewer mink. There have been several reports that purple loosestrife infestation has resulted in the decline of endemic plant species which were already rare or threatened (Thompson et al, 1987).

The introduction of *Lythrum salicaria* to North America most likely occurred in the early 1800's via seeds contained in the ballast of ships (Stuckey, 1980). In the 1800's wet sand was frequently used as ballast. This sand was taken from the harbour shores of Europe, a habitat where loosestrife grows. Upon arrival in North America the ballast was often dumped overboard. It comes as no surprise then that the earliest records of purple loosestrife in North America occur in these coastal areas (Thompson et al, 1987). Introduction of purple loosestrife also occurred via the importation of seeds and rootstocks by horticulturists (Thompson et al, 1987). There are several records of the escape of purple loosestrife near gardens or cultivated areas, suggesting that this was also an important source of colonization. The recent development of cultivars has also contributed to the spread of purple Loosestrife.

Several cultivars which were thought to be sterile have been shown to be merely self-incompatible. That is, the plants cannot produce viable seed when crossed with themselves. However, Anderson and Ascher (1990), have reported that these cultivars are highly fertile when crossed with wild *Lythrum salicaria* (Appendix 1). Purple loosestrife was also deliberately seeded for use as a honey plant by bee keepers (Pellet, 1977, Balogh, 1985).

Mature *L. salicaria* can be very large. Plants will often become 2 m in height and 1.5 m wide. The perennial rootstock which may reach 50 cm in diameter can give rise to as many as 50 stems annually (Thompson et al, 1987). It has been estimated that a mature purple loosestrife plant can produce up to 2.7 million seeds annually (Thompson et al, 1987), and a plant can produce up to 100,000 seeds in its first season (Nelson, 1987). Thompson et al (1987) reported that seeds are still viable after three years of refrigeration. The primary method of seed dispersal is through water, although seeds may also be spread by waterfowl and other birds. There have been reports of seeds being in the mud on the feet, beaks, and feathers of ducks (Anatidae), (Thompson et al, 1987). Most seeds that fall in the water sink to the bottom and start to float after they germinate (Ridley, 1930).

The spread of purple loosestrife across North America was facilitated by the development of the extensive canal system in the Northeastern United States (Stuckey, 1980). Purple loosestrife can now be found in all of the ten Canadian provinces and 36 of the 48 contiguous states of the U.S. (Fig. 1). Although not presently a problem in all regions, purple loosestrife is a threat in all areas.

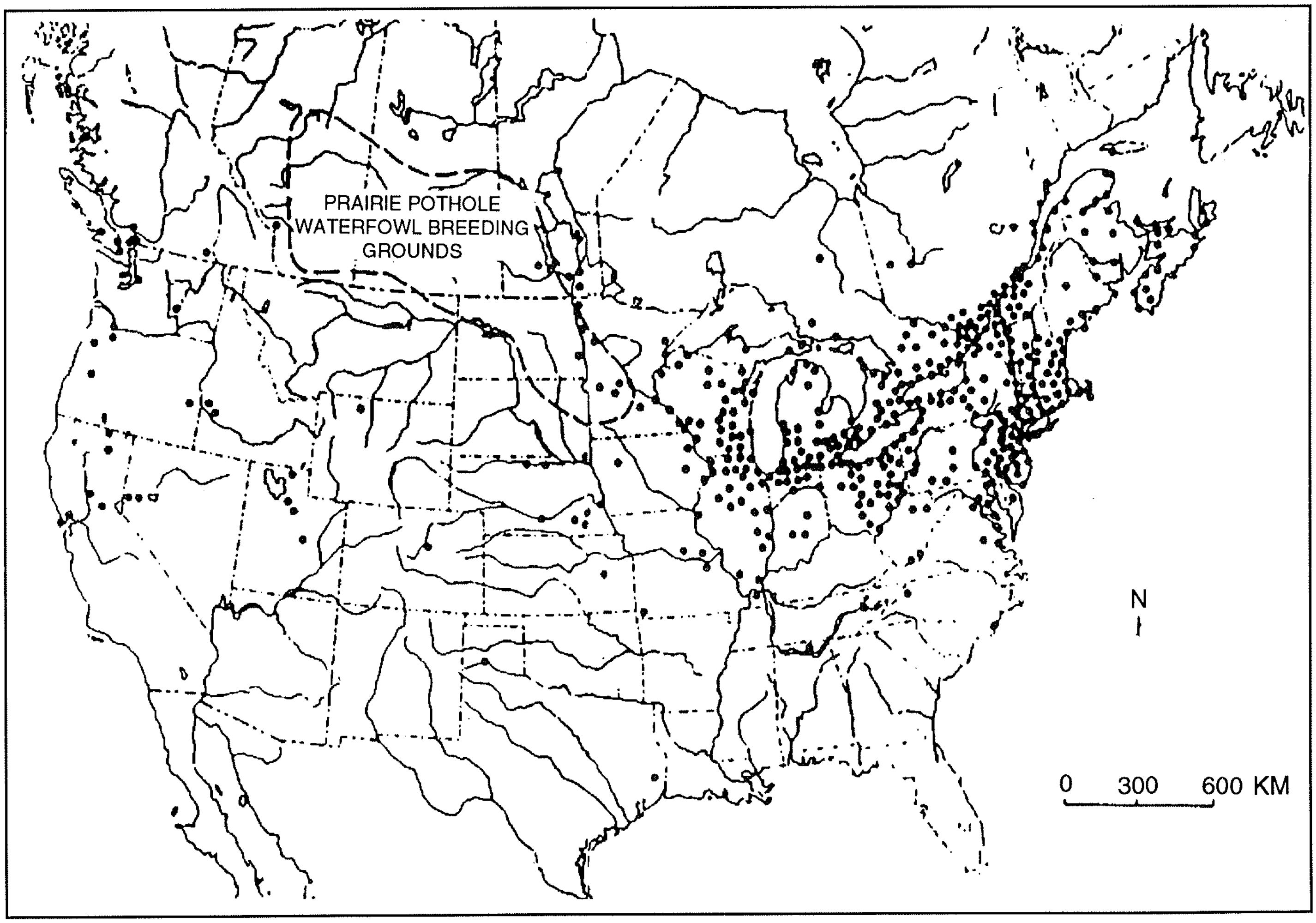

Figure 1. Distribution of purple loosestrife *(Lythrum salicaria L.)* in North America as of 1985 (From Thompson et al. 1987).

Early botanical surveys by A. Tamsalu in 1953, documented *Lythrum salicaria* on Royal Botanical Gardens property but it was not listed by Judd in 1949. Surveys conducted in 1992 (Fig. 2), show that it now occurs on all RBG properties with the exception of Rock Chapel. In Hendrie Valley and Grindstone Creek purple loosestrife occurs in roughly 50 percent of the area, and in Cootes Paradise it occurs along 40 percent of the shoreline. There are also some isolated patches in the Berry Tract as well as large populations in Middle Pond and Mercer's Glen, and it occurs throughout the Rock Garden water system.

The rate of spread along with its tendency to exclude all native plants has led many jurisdictions in North America to declare purple loosestrife a noxious weed. In Canada, the provinces of Alberta, Manitoba, and Prince Edward Island have included purple loosestrife on their noxious weed lists. Under the Weed Control Act, the Ontario Government has approved by-laws naming purple loosestrife a local noxious weed in approximately 70 municipalities (DeClerck-Floate, 1992). The reluctance of the province to list purple loosestrife as a noxious weed province-wide stems from the lack of a control strategy against it. Even if it was designated as a noxious weed, the act does not contain clauses preventing the sale of the plant by nurseries. However, due to the negative publicity surrounding the issue, most nurseries have voluntarily stopped selling the plant (DeClerck-Floate, 1992).

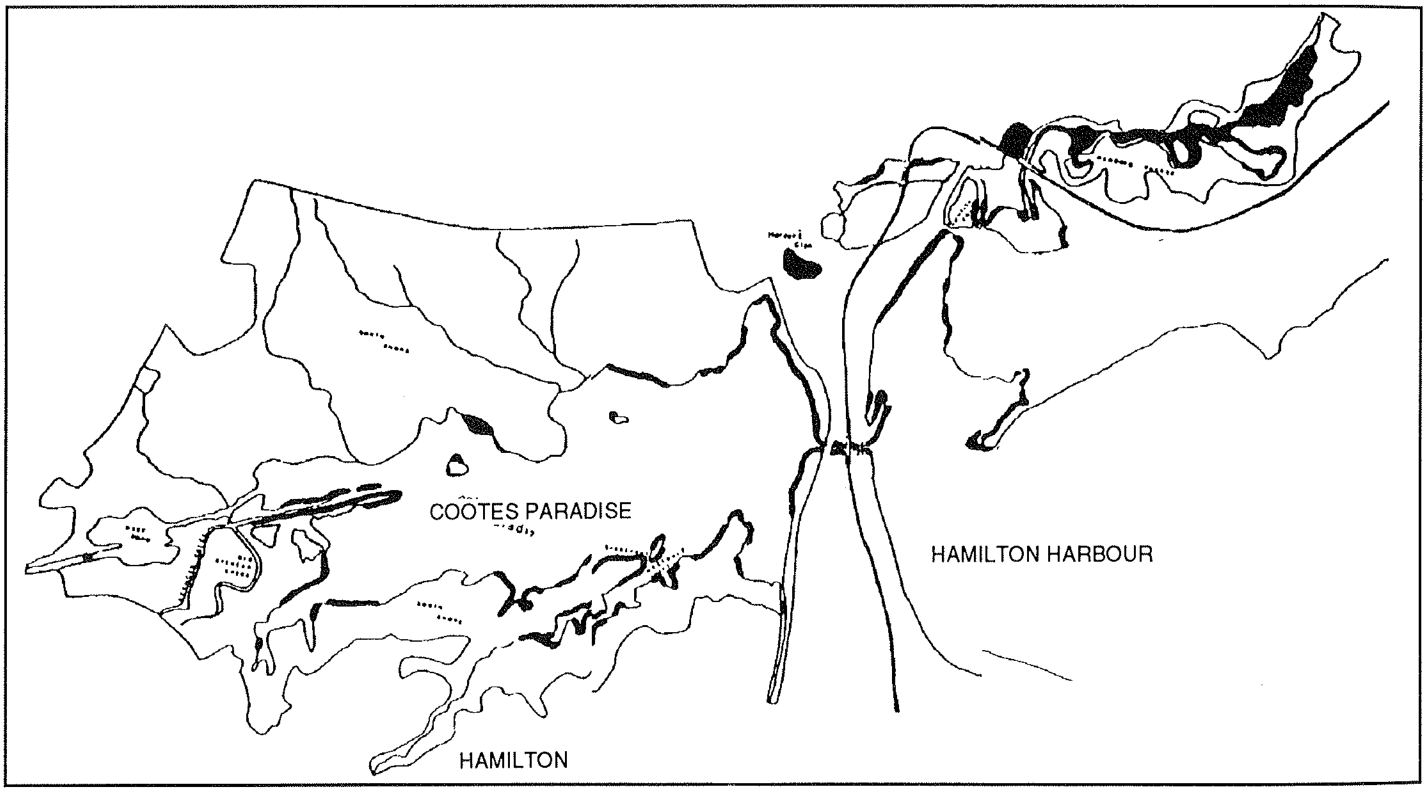

Figure 2. Occurence of purple loosestrife (Lythrum salicaria L.) in Cootes Paradise, Hendrie Valley and Grindstone Creek, and Carroll's Bay as of 1992.

PURPLE LOOSESTRIFE CONTROL WITH HERBICIDES

In the past several herbicides have been used to try and control purple loosestrife. Louis-Marie (1944), established 32 plots in which he tested several control methods including chemical control. None of these treatments provided good control. McKeon (1959), tested six different chemicals (Weedazol, 2,4-D, 2,4,5-T, Karmex 40, 2,4-Dow, and Kuron), and found that although several provided good top kill all were unsatisfactory in providing long term effective management. Rawinski (1982), Malecki and Rawinski (1985), and Balogh (1986), tested the efficacy of Glyphosate formulations (Roundup and Rodeo). Results were encouraging, however Rawinski

(1982), warned against the widespread use of Glyphosate in a marsh ecosystem. Balogh (1986) also tested Casoron as a possible control agent but found it to be unsatisfactory. At present in Canada there are no herbicides licensed for use in aquatic habitats (DeClerck-Floate, 1992).

GARLON 3A FIELD TRIALS AT RBG

DowElanco Inc. and Ducks Unlimited are two agencies also concerned with the rapid spread of this noxious weed. These two agencies are collaborating with RBG, (funding provided by OPAC), in conducting field trials to test the efficacy of a herbicide in controlling purple loosestrife. The herbicide being tested is Garlon 3A.[2] Garlon 3A is a broad-leaf weed herbicide that has been registered for use in the United States since the 1970's. If Garlon proves to be an effective means of controlling purple loosestrife then further steps will be taken to obtain its registration for use over water in Canada. Garlon 3A (Triclopyr as Triethylamine salt, 44 percent active ingredient), is a systemic, auxin-like herbicide which is readily absorbed by green bark, leaves, and roots. It is rapidly translocated through the entire vascular system of the plant. Auxin type herbicides are synthetic plant growth regulators that cause the growth system to malfunction (CPPA, 1986).

Garlon 3A is environmentally safe and has been used in the United States for fifteen years producing no ill effects (CPPA, 1986). In soil it has an average half-life of 30 days. It is rapidly broken down by microorganisms and interacts with soil particles so leaching is minimized. In water it is rapidly broken down by sunlight with photolysis occurring in less than twelve hours (Green et al, 1989). Testing has also shown that Triclopyr amine has very low toxicity to aquatic biota, birds, and mammals (Green et al, 1989). Garlon 3A does not bio-accumulate and is very safe to handle and spray.

The field trial that RBG is involved in is taking place in an isolated shallow pond known as Mercer's Glen. Mercer's Glen is located on the north side of Old Guelph Rd. east of the Hwy. #403 overpass. The topography and vegetation has changed

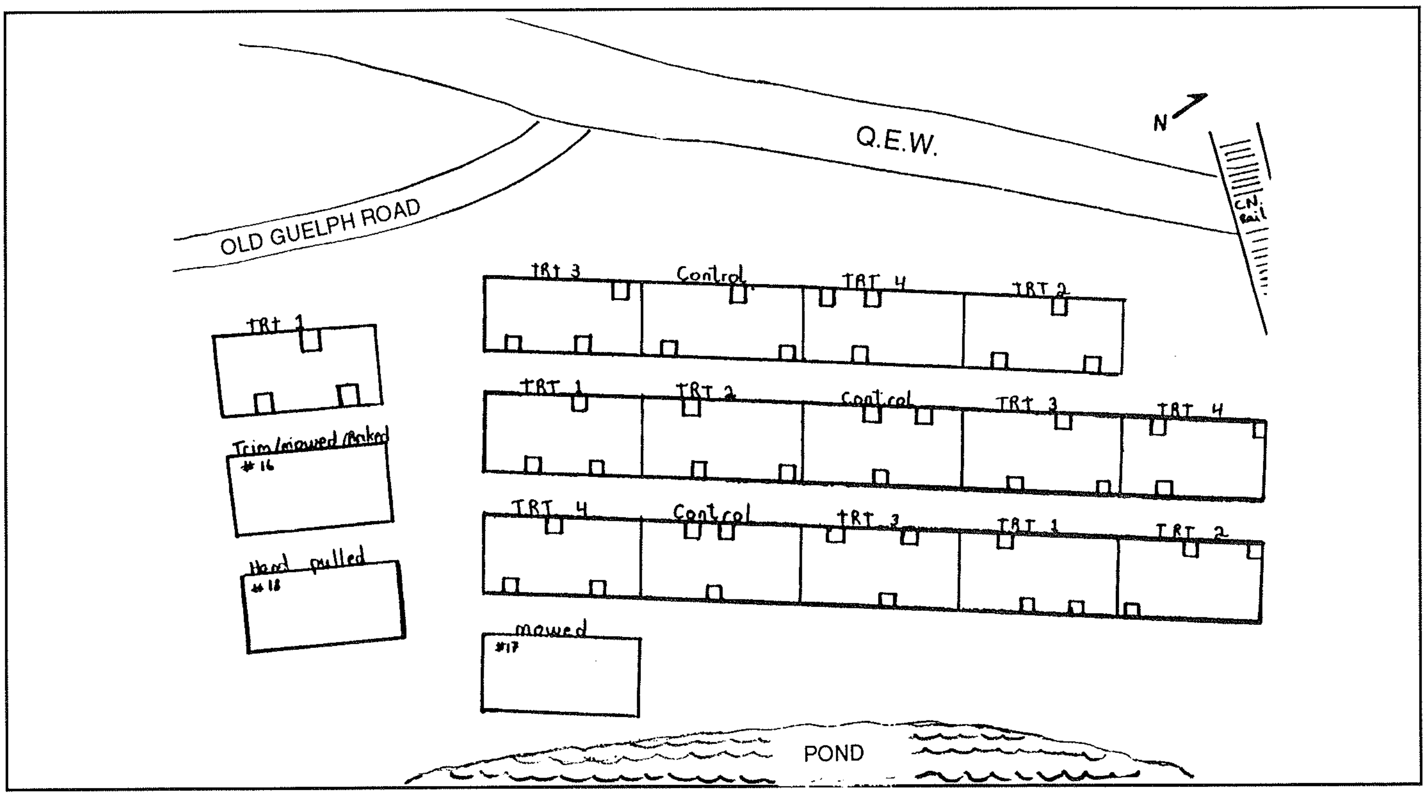

Figure 3. Mercer's Glen Research Plots

[2] *Registed Trademark of DowElanco Canada Inc.*

considerably in Mercer's Glen over the last century due to the growth and expansion of the transportation system in this area. Originally Mercer's Glen was part of a deep valley connecting Cootes Paradise to Hamilton Bay. In the fall of 1989 Mercer's Glen was drained to eliminate carp. As a result the water level remains very low and the area which the research plots are located on dries out entirely by mid spring.

In the Fall of 1991 the entire area was mowed to make the area accessible to work crews, enabling them to set up the plots. In the spring of 1992, a randomized complete block design, (replicated three times), was established on the site (Fig. 3). Four treatments and a control were incorporated into the trial (Table 1). Each plot measures 10 m x 3 m. All four corners were marked with a (2" x 2" x 8') stake painted orange. Five plots were placed end to end with a two metre buffer strip between each block of five plots. Metal T-bars were used to demarcate the outside corners of the blocks. These were driven into the ground so that only the tips were visible and they would be difficult to pull out. This was done so that the plot locations could still be determined if the wood stakes were pulled out. A metal tag indicating the treatment and replication number was stapled to the southeast corner of each plot.

Within each plot three (1 m x 1 m) quadrats were placed at random. The corners of each quadrat were marked with a (2" x 2" x 4') stake painted orange. In each of the treatment plots twenty purple loosestrife stems were marked with flagging tape. Ten of these were within the three 1 m^2 quadrats and ten were located outside of the quadrats. Two pieces of flagging tape were secured to each of these twenty plants. One piece was attached at mid-height for easy identification and one at the base for permanency so that the fate of each stem could be followed into the next growing season.

On July 7,1992 the plots were treated with triclopyr as Garlon 3A triethylamine salt formulation (360 g/L AE). The sprayer used was a R & D Backpack sprayer with a two metre boom and four Teejet flat fan 8020 nozzles. The boom height was approximately 1.5 metres and the spray tank was operated at a pressure of 276 Kpa (40 psi.). The application rates used are outlined in table one. Spraying was done between 3:45 and 6:00 pm. by the DowElanco representative. Cloud cover was 30 percent, temperature 29º C, and wind with gust up to 15 km/hr. The spraying was accomplished by walking down each side of the plot for fifteen seconds at a constant speed. The spray boom was held at arms length about one metre above the plants so that half of the plot was sprayed with each pass.

Table 1: Treatment rates used in Garlon 3A field trial

Treatment #	Treatment	Application Rate (L/ha)	% v/v
1	XRM-3724 [3]	7.0	0.7
2	XRM-3724	9.7	1.0
3	XRM-3724	12.5	1.25
4	XRM-3724 AGRAL 90 [4]	9.7 —	1.0 0.5
5	CONTROL	—	—

Each marked plant was examined and categorized at two, four, six, eight, and ten weeks post-treatment. There were four categories, these being: 100% Alive, > 50% Alive, < 50% Alive, and 100% Dead. These categories were assigned numbers 1 – 4 respectively. Stems were only considered 100% alive if there was no apparent damage to any leaves or flowers. Stems were considered 100 percent dead if no green tissue was visible. The density of purple loosestrife stems within each of the one metre quadrats was determined before treatment, ten weeks post-treatment, and will be determined again one year post-treatment.

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[3] *DowElanco code name for Garlon 3A*
[4] *Registered Trademark of Imperial Chemical Industries*

RESULTS AND DISCUSSION

The data acquired from categorizing the marked stems at two week intervals was analyzed using the PROC ANOVA procedure (SAS users Guide, 1982). The Proc Anova procedure detected a difference between the treatments listed in Table 1, and between the blocks. Tukey's, Duncan's, and T-Tests (LSD), were run simultaneously to determine where the difference(s) existed. Values were considered significant at the 0.05 level of significance. All three tests detected nearly identical differences within the data set. The PROC ANOVA procedure was also used to detect a difference between treatments when the variable being measured was the stem density changes of purple loosestrife from pre-treatment to ten weeks post-treatment.

STEM DENSITY

The change in stem density is important to monitor due to the possible occurrence of resurgent stems. It is possible to achieve 100 percent top kill of all stems and yet have no significant decrease in overall stem density due to resurgent stems. There may also be new plants due to the germination of seeds already in the soil. In all of the treatments there was at least one resurgent arising from an otherwise completely dead-looking plant. This signifies that 100 percent root kill was not achieved. Analysis of the data showed that there was a significant difference in the change of stem density between treatments 4 and the control. Differences between other treatments were not considered significantly different. Table 2 shows the change in stem density in terms of percentage decrease or increase.

Table 2: Percent change in stem density for each treatment ten weeks post-treatment.

	TRT 1	TRT 2	TRT 3	TRT 4	Control
pre-treatment	398	516	405	439	565
ten weeks post-treatment	338	418	245	52	735
percent change	- 15.07	- 19.00	- 39.50	- 88.15	+ 30.08

Treatment four reduced purple loosestrife stem densities the most at an 88 percent decrease. An increase in stem density between ten weeks post-treatment and one year post-treatment is expected to occur due to seed germination and resurgent growth.

BLOCK EFFECT

There was a significant difference between at least one of the blocks and two other blocks in all but the last observation period (ten weeks post-treatment). However there does not seem to be an explanation for these discrepancies besides possible human error. In the first observation period there was no difference between blocks one and two but block three recorded a significantly higher effect. In the second observation period it was block two which had a significantly higher value while blocks one and three were considered similar. In observation periods four and five block, one had a significantly lower value than two and three, which were considered similar.

There was a slight slope and therefore a water gradient on the research site. Block three was located close to a standing pond while block one was furthest away and uphill from the water. As a result the purple loosestrife plants within block three were much larger and denser. The results did not show this gradient to have an effect. Balogh (1985), also noted that there was no correlation between a water gradient and plant susceptibility.

In all observation periods block one recorded the lowest value. This is most likely due to the subjective nature of the data. The information was gathered by two different people. Each observation period the same person would start gathering data in block one and the other in block three. It is likely the discrepancy occurred

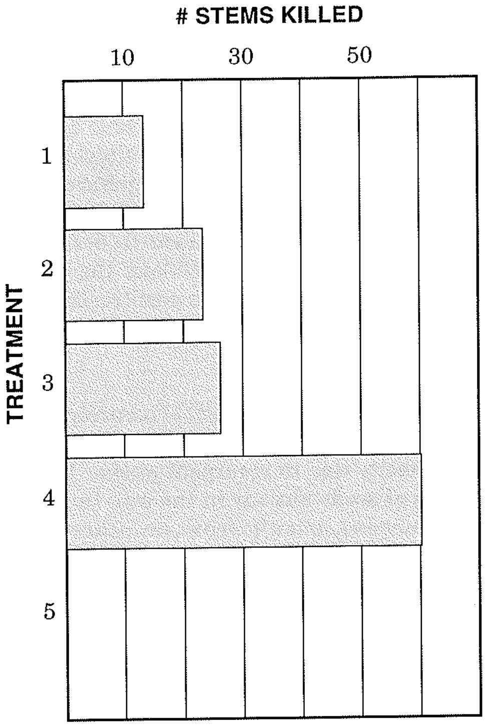


Figure 4. Number of stems categorized as 100 percent dead in each treatment ten weeks post-treatment.

when each person was deciding whether a plant was more or less than fifty percent dead. In observation period one, block three was significantly higher than blocks two and one. In the second observation period the value of block three is lower than in the first observation. This can only mean that there was human error. In all other observation periods block two recorded a higher value than blocks one or three.

Block one was the only block with a significant number of non-target species. For this reason no statistical analysis of the effect of Garlon 3A on non-target species was possible. The fate of these non-target plants was monitored subjectively and the findings are discussed in Appendix 3.

TREATMENT EFFECT

In the first observation period there was no significant difference between treatments one, two, three, and five (control group), but treatment four recorded significantly higher values than all other treatments. In all other observation periods treatments two and three were not considered significantly different from one another, but both were significantly higher than treatment one, and five. Treatment four recorded the highest effect on plant life in all observation periods. In treatment four 88 percent of the tagged stems were killed. Treatment three was the next most effective treatment at 42%, treatment two was lower than treatment three but was not considered significantly different (37%). Treatment one was the least effective treatment at 20% (Fig 4.). Treatment four caused a significant decrease in plant life due to the use of surfactant. A surfactant decreases the surface tension of the fluid and therefore more leaf surface area comes into contact with the spray. This increases absorption of the product by the plant.

In almost all observation periods there was an increase in the number of stems falling into category four (100% dead). The only exception to this was in treatment three between the second and third observation period. In the second observation period there were fourteen dead stems and in the third there were eleven. This discrepancy is not due to the appearance of new shoots from the rootstock. Only individual stems were marked and observed, other stems arising from the same rootstock were not considered. The only possible explanation is human error. Since plants were only considered completely dead when no green tissue was visible this would seem impossible to mistake. However, due to the density of the plots and slight subjectivity, different observers may end up with slightly different results.

Although the overall trend on the efficacy of the treatments was expected, there were some difficulties in achieving a uniform herbicide coverage which may have influenced the magnitude of effect exhibited by the treatments. In all of the plots sprayed there were some plants, or at least some stems, that did not receive direct exposure to the product. This was primarily due to the plants being too tall and spray boom too narrow to give adequate coverage. In several plots there was a 15 to 25 cm strip down the centre of the plot which remained un-sprayed. In some cases these untreated areas extended over the subplots or contained one of the stems being used for observing the effect of the herbicide. This will lend some inaccuracy as to the effect exhibited by the treatment in the estimation of densities within these plots one year post-treatment. Treatment at an earlier date when loosestrife plants are not as tall would alleviate this problem.

In each of the treatments at least one rootstock had some resurgence occurring by the fourth observation period. New shoots were arising from rootstocks whose shoots had been killed by the application of the herbicide. This indicates that triclopyr did not translocate to the rootstock in sufficient amounts to cause death. The stem densities one year post-treatment will give a better indication as to the extent of root kill achieved. The low number of resurgent stems in treatment four indicates that a sufficient amount of herbicide was translocated to the roots in this treatment.

A similar trial using the same product was conducted by Ducks Unlimited near Smith Falls, Ontario. The most significant differences between the two trials is that the site in Smith Falls was located in a permanently flooded location and a different application method was used. At Smith Falls plants were sprayed with a known product concentration until they were completely wet. The disadvantage of this method is that much more product is used. This creates higher costs and can increase the amount of product that enters the water system. However it allows for thorough coverage and better control of densely planted areas. The preliminary results show that this method does indeed provide better control (100%).

CONCLUSION

The results obtained show that Triclopyr amine can be effective in controlling purple loosestrife. In all the treatments flowering was reduced (and thus seed production), by nearly 100 percent. Low dose applications could be used in controlling the spread of purple loosestrife. The preliminary results show that the use of a surfactant greatly increased the effectiveness of the product. The 88 percent kill achieved with treatment four indicates that the use of Triclopyr Amine with a surfactant will be a useful tool in reducing purple loosestrife populations to acceptable levels. Stem densities one year post-treatment will give an indication as to the root control achieved.

ALTERNATE METHODS OF PURPLE LOOSESTRIFE CONTROL

The search for one or several reliable, environmentally safe, and effective methods which land managers can use to control purple loosestrife has extended beyond the use of herbicides. Such methods as hand-pulling, cutting, burning, flooding, and biological control have also been investigated.

Hand-pulling can be effective but is a labour-intensive method of controlling purple loosestrife. Mature plants that are over two years of age have a large rootstock which is heavy. The best results are obtained if pulling is done in the spring because the ground tends to be softer and fewer roots are broken off. Any root segments which are left behind have the potential of producing new plants which may flower that same year (Balogh, 1985). If pulling is done later in the season there is also much more above ground growth to deal with. Any stems which may be accidentally broken off and left behind also have the potential for producing new plants. Hand pulling in the spring also avoids seed dispersal. Perhaps the most significant drawback is that this method creates habitat disturbance making it easier for purple loosestrife seeds to germinate and recolonize the area. Hand pulling would be impractical to use on a large scale.

Cutting or mowing can be used to reduce stem density and seed production. Plants should be mowed late in the season but before flowering occurs to ensure that the plants do not have sufficient time to regrow and bloom in the late fall (Rawinski, 1982). As mentioned earlier, stem segments which may be left behind can produce new plants, therefore care must be taken to ensure that all mowed or cut material is removed. Rawinski (1982) reported mowing to be an impractical and ineffective control method. In 1987 near Smith Falls, Ontario, researchers attempted to control purple loosestrife by cutting stems below the water surface. This did not seem to have any greater effect. The purple loosestrife had recovered completely within two years (Hanna, 1989).

Hand-pulling, mowing and cutting were tried at Mercer's Glen on 30 m^2 plots. All of the above problems were encountered. In the plot that was hand-pulled there was a large flush of seedlings within a few weeks. Although a few native species also germinated these were relatively sparse. Mowing and cutting trials did not reduce the density of purple loosestrife because the large rootstock is unaffected by mowing. We also found it difficult to ensure that all stem fragments were removed.

Burning has also been tried and has proven to be unsatisfactory (Louis-Marie, 1944, McKeon, 1959). Burning, as with mowing, only affects the above ground portions of the plant. The rootstock is not destroyed and re-sprouting will occur. Burning is most easily used very late in the season when the plants have dried out. This limits its effectiveness in controlling seed production but does provide a means of removing debris so that thorough herbicide coverage can be obtained the following year.

Flooding has been used in some areas to drown *Lythrum salicaria* colonies. Rawinski (1982) noted that when water levels were maintained at 40 cm for three years purple loosestrife densities decreased sharply. R.H. Smith (1964) however, found that mature plants could survive many years when submerged to a depth of two to three feet. Flooding is most effective in controlling purple loosestrife seedlings. Balogh (1985), found that significant seedling mortality was achieved by flooding seedlings to a depth of 30 to 40 cm for six to eight weeks. However this method is not selective as all littoral zone seedlings are affected.

BIOLOGICAL CONTROL

Perhaps the most desirable form of management is the use of classical biological control. Ideally classical biological control is the use of host specific predators to reduce the target species to below pest status without continued management. That is to say that the predator and prey populations regulate each other without interference and the predator species effects no species other than the target species. The populations will tend to oscillate but stay within acceptable densities. This makes the method environmentally friendly and cost effective.

Three insects have been found that are excellent candidates for use as biological control agents of *Lythrum salicaria* (Blossey & Schroeder, 1988 & 1989). Research thus far has indicated that these insects will be able to significantly reduce purple loosestrife populations (Blossey, 1992a, 1992b). Researcher Dr. John Laing at the University of Guelph is currently involved with rearing colonies of these different insects which are known to feed almost exclusively on *L. salicaria*. All three insects are endemic to Europe and do not currently occur in North America. Two of the insects are leaf eating beetles, (*Galerucella calmariensis* L. and *G. pusilla* Duft.), the third is the root-feeding weevil, (*Hylobius transversovittatus* Goeze), (Appendix 2). In the United States these insects were released in the summer of 1992 and they have now been approved for release in Canada. Dr. Laing fully expects to begin a release program in the spring of 1993.

The establishment of newly introduced biological control agents takes many years. However, in the future biological control will undoubtedly become a significant part of integrated pest management at RBG. Dr. Laing was contacted and we expressed our interest in having one or all of these insects released on RBG property. Dr Laing has agreed to co-operate with RBG since the extensive purple loosestrife populations occurring here would facilitate the establishment of these insect populations.

ACKNOWLEDGEMENTS

We would like to thank the Ontario Pesticides Advisory Committee for providing the funds needed to conduct the field trials, DowElanco and Ducks Unlimited for their technical assistance, and Sharon McConnell for her help with the analysis of results.

APPENDIX 1 LYTHRUM CULTIVARS

Plants of the genus *Lythrum* have been used extensively for horticultural purposes. As a result many cultivars have been developed. Current research suggests that cultivars of *L. salicaria* and *L. virgatum*, and the native North American loosestrife species *L.alatum* may all be lending to the current problem of *L. salicaria* taking over North American wetlands.

Lythrum virgatum is a plant closely related to purple loosestrife (*Lythrum salicaria* L.), that has also been introduced from Europe, very likely by the same means and in the same time period. *L. virgatum* looks similar to *L. salicaria*, and was at one time considered to be a variety of the latter (Thompson et al, 1987). Although the species *L. virgatum* has not become a problem in North America, both the species and cultivars that have been developed from it can hybridize with *L. salicaria* (Anderson and Ascher, 1991). Some of the cultivars which were thought to be sterile are only self-incompatible, that is, they do not produce seed when crossed with themselves. However, recent studies have shown that they can cross pollinate with wild *Lythrum salicaria*. These hybrids are often very fertile and in the case of

Morden Pink x wild *L. salicaria*, the hybrid offspring produce more viable seed than either parent plant (Anderson and Ascher, 1991).

There are also many cultivars of *Lythrum salicaria* available. The same potential exists as with *L. virgatum* cultivars.

Anderson and Ascher (1991), have also reported that many traits never before reported on *Lythrum salicaria* plants, but typical of *Lythrum alatum* Pursh, a loosestrife species that is native to North America, are now seen quite regularly. This suggests that *L. alatum* will hybridize with *L. salicaria*. Tests done by these researchers show that this is indeed the case. Hybrids of these two plants may be more competitive than either parent plant and thus be more likely to cause a problem.

Although there are currently no answers to these problems, in light of the findings of Anderson and Ascher (1991), the Royal Botanical Gardens has taken upon itself to discontinue the cultivation of all cultivars and species of *Lythrum* (Graham, 1992).

It should be noted however that it is still legal to propagate, grow and sell all cultivars and species of Loosestrife in Ontario (DeClerck-Floate, 1992).

APPENDIX 2 CLASSICAL BIOLOGICAL CONTROL

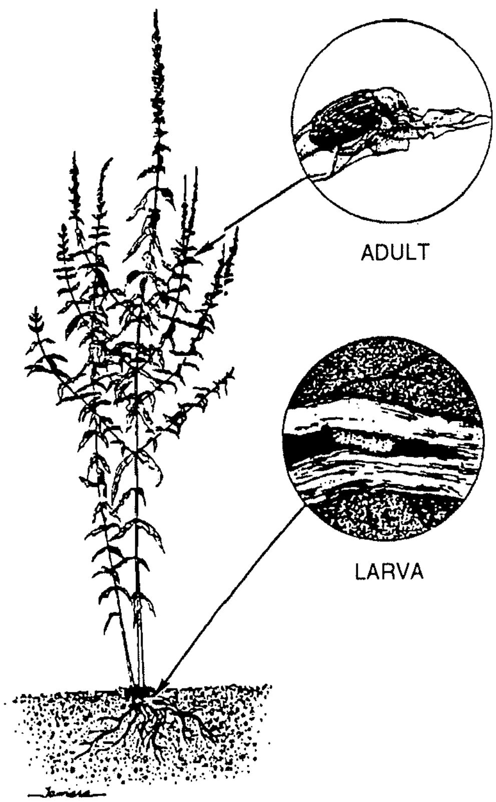
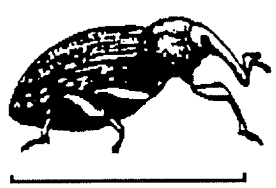


Figure 1. (From Malecki, 1990)



Hylobius transversovittatus
(root-mining weevil)

A plant species that invades a new region usually does so without the accompaniment of all the insects and pathogens that affect its success in its area of origin. A lack of natural enemies is perhaps the most significant cause of introduced species becoming pests.

Classical biological control is the concept of introducing one or more of these natural enemies to naturally reduce the host species to a non-pest status (Hight and Drea, 1991). This differs from other methods of biological control such as the mass production and release of natural enemies. A successful classical biological control program reduces the population density of the pest species to an environmentally and economically acceptable level. This is accomplished without eradicating the target plant (Hight and Drea, 1991).

The use of natural enemies to manage pest populations has been applied since 1863 (Rosenthal et al, 1984). Biological control was used successfully for the first time in North America in the 1940's (Huffaker and Kennet, 1959). Since that time many insects have been released for the control of weeds, but in no instance has an insect introduced for the control of a foreign weed in North America ever itself become a pest (Harris, 1988).

In North America surveys were conducted by several different agencies (Insect Biocontrol Laboratory, U.S. Dept. of Agriculture, Agriculture Research Service), to identify natural enemies of *L. salicaria* indigenous to this continent (Hight, 1990). Sixty species of phytophagous insects were found. However, none of the insects collected reduced populations of *L. salicaria* or caused significant damage to the plant.

Results from surveys done to identify any pathogens associated with *L. salicaria*, both in North America and throughout Europe, revealed that no pathogens were damaging to the plant (Schroeder and Mendl, 1984). In Europe there have been no recorded epidemics of closely associated pathogens of purple loosestrife in the past sixty years (Schroeder and Mendl, 1984).

Surveys for insects damaging to *L. salicaria* conducted in Europe revealed several insects as candidates for biological control (Hight and Drea, 1991). After extensive research the three insects which caused the most damage to purple loosestrife, and were most host specific, were found to be *Hylobius transversovittatus* (Goeze), *Galerucella calmariensis* (L.) and *Galerucella pusilla* (Duftsmidt) (Blossey and Schroeder, 1988, 1989).

HYLOBIUS TRANSVERSOVITTATUS

Hylobius transversovittatus is a rare but widely distributed root-feeding weevil in Europe. It is found on *L. salicaria* in all habitat types with the exception of marshes with open standing water year round. The weevil's ability to locate *L. salicaria* plants is reflected by the fact that the relative frequency of attack was similar in all sites regardless of loosestrife patch size. The weevil was found on two thirds of field sites ranging from Finland, southern Sweden, Denmark, Germany, Austria, Switzerland, and France (Blossey, 1992a). Its wide range in Europe signifies that it will likely be able to adapt to the climate in North America.

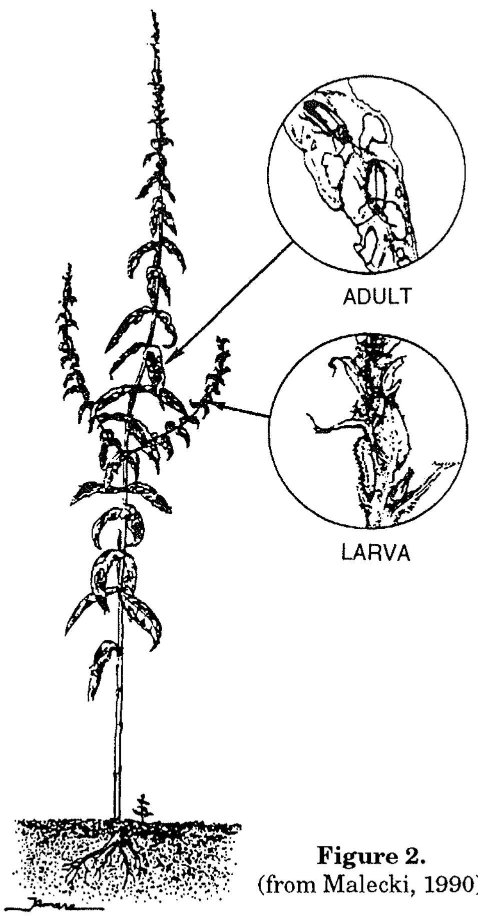


Figure 2.
(from Malecki, 1990)

LIFE HISTORY

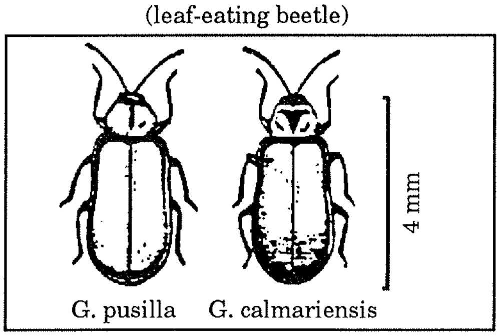
This root weevil is relatively long lived and can hibernate for two winters as a larvae and two to three winters as an adult (Blossey, 1992a). Adults emerge in April and oviposition begins three weeks later. Oviposition continues to approximately the middle of September. Eggs are laid in the soil or on purple loosestrife stems near the soil. Upon hatching larvae feed on root hairs (if hatched in soil), or bore into the stem (if hatched on the stem), before moving into the rootstock. Development to adulthood may take one or two years. Pupation will occur in the upper portion of the rootstock from July into early October. Adults which emerge early in the season may start to oviposit that year (Blossey, 1992a).

Hylobius transversovittatus is a nocturnal species. Adults will feed on the leaves after nightfall if temperatures remain high enough. It is the larvae however that inflict most of the damage on *L. salicaria* populations by eating the roots (Fig. 1). As stated previously the larvae enter the rootstock shortly after hatching. Once they have entered the root system they feed on the vascular and storage tissue (Blossey, 1992a).

GALERUCELLA CALMARIENSIS AND *G. PUSILLA*

Both of these leaf eating beetles are very similar in the niches they occupy and their life histories. The adults can be distinguished without difficulty but as yet there are no reliable characters found to separate the larvae and eggs (Blossey, 1992b). As with the root weevil these species are broadly distributed in Europe but are considerably more common than *H. transversovittatus*.

Galerucella spp.
(leaf-eating beetle)



LIFE HISTORY

These two species are short lived and can reach maturity within 35 days (Blossey, 1992b). Adult beetles will emerge in mid April and can be found on the sprouting plants. They preferentially eat the young buds and leaves on shoot tips (Fig. 2). Newly hatched larvae first feed on developing leaves in the shoot buds and later will skeletonize the expanded (mature) leaves (Blossey, 1992b). Females lay approximately 500 eggs in their one year life span between May and July (Hight, 1992). Eggs are laid on the stem surface, in the leaf axil and on leaf surfaces. There are three larval instar and pupation occurs in the soil. The parent population dies in mid summer. If conditions are favourable a new generation of adults will start emerging in July (35 days after hatching). If the temperature remains high these adults may copulate in their first summer. However most egg laying occurs in the following summer (Hight, 1992). Due to high summer temperatures in some regions of North America two generations per year may be possible.

Field surveys conducted in Europe show that these two beetles can significantly reduce the growth and fecundity of *L. salicaria*. The rate of attack by *Galerucella calmariensis* and *G. pusilla* in Europe was variable. However attack rates as high as 400 larvae per stem were found (Blossey, 1992b). Typically enough eggs are laid to achieve complete defoliation of plants (DeClerck-Floate, 1992). In some instances seed production is reduced to less than one percent (Blossey, 1992b).

The herbivory of roots by *Hylobius transversovittatus* and above ground by *Galerucella calmariensis* and *G. pusilla* will undoubtedly have a significant effect on North American populations of purple loosestrife. All three have shown to have a very narrow host range. Tests conducted in Europe found that *H. transversovittatus* would feed on only three plants (not including *L. salicaria*), but showed a high degree of preference for *L. salicaria*. The two leaf-eating beetles also showed a narrow host range. Although they were not as host specific as the root weevil it was found that *Galerucella calmariensis* and *G. pusilla* larvae could only complete development on four of forty two plants tested (DeClerck-Floate, 1992). All tests conducted thus far indicate that none of these three insects have the potential of becoming pests themselves once introduced to North America.

As mentioned earlier the release of these insects has already occurred in the United States. In the summer of 1992 a release program was initiated in the state of New York. Plans for release in Canada are underway and will undoubtedly begin in 1993. In the first several years the survival and dispersal of these insects will be of primary concern. The release of these insects will undoubtedly play a significant role in the control of purple loosestrife during the Marsh Restoration Project in Cootes Paradise. It is expected that areas which are manipulated to provide more suitable habitat for macrophyte growth will be colonized by purple loosestrife. Other control methods create habitat disturbance which is detrimental to the establishment of less competitive endemic species. Biological control has the potential of providing an effective and labour free control of purple loosestrife.

APPENDIX 3 SUBJECTIVE MONITORING OF NON-TARGET SPECIES

There were eight non-target species present within block one which were monitored. The species are listed in table 1. Representative plants were tagged with flagging tape to facilitate monitoring of the plants. Photographs were taken of non-target plants at each observation period. Brief notes were taken to accompany the photographs.

Table 1. Non-target species present in block one of the Mercer's Glen Triclopyr amine trials.

LATIN NAME	COMMON NAME
Solidago sp.	Goldenrod
Dipsacus sylvestris	Teasel
Impatiens capensis	Jewel weed
Geum aleppicum	Yellow avens
Geum laciniatum	Rough avens
Arctium minus	Common burdock
Polygonum convolvulus	Black bindweed
Senecio aureus	Golden ragwort

The above list is in order of abundance. Not all of the species occurred within each of the treatment plots. Treatment one did not contain any non-target species. All of the species were initially affected by the treatments. This was reflected in the twisting of stems, browning of shoot tips, dying of leaves, and stunted growth. In treatment two and three all species present exhibited all of the above symptoms and in some cases plants were killed. Goldenrod, Teasel, Jewel weed, and Yellow avens were the predominant species in treatments two and three. Yellow avens was already setting seed when the spraying occurred. Twisting of the stems was noted but seed set did not seem to be interrupted, although seed viability was not determined. Goldenrod plants were severely stunted and the shoot tips were killed. Some plants were killed but most remained alive. Teasel and Jewel weed were the least affected. Both species showed stress but many plants recuperated and eventually flowered. In treatment four Golden ragwort and Teasel seedlings, and mature Black bindweed plants remained alive. All the plants were smaller than those in other plots but were still green in the fifth observation period.

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