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Purple Loosestrife: History, Management, and Biological Control in Iowa

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Purple loosestrife (*Lythrum salicaria*) is an invasive plant species infesting wetlands in North America. Biodiversity and wetland habitat quality are reduced following purple loosestrife establishment. Several management tactics, including cultural, mechanical, and chemical controls, have had limited success in reducing the spread of purple loosestrife. Beginning in the 1990s, a biological control program has introduced several species of natural enemies from Europe that feed on purple loosestrife. Since 1994, Iowa State University has reared and released two species of beetles that feed on purple loosestrife, *Galerucella calmariensis* and *G. pusilla.* Biological control is one component of an integrated purple loosestrife management and education program that is needed to reduce the spread and densities of purple loosestrife.

INDEX DESCRIPTORS: *Lythrum salicaria,* biological control, *Galerucella,* wetlands.

Wetlands are a highly complex and integral part of many ecological systems that are valuable for diversity, wildlife, and water integrity. Unfortunately, wetland abundance in the United States is decreasing. Twenty-two states have lost at least 50% of their original wetlands; Iowa has lost 99% of its wetlands (North Carolina State University 1998).

In the early 1800s, purple loosestrife (*Lythrum salicaria*) [Myrtiflorae: Lythraceae], an exotic wetland species originally from Europe, was accidentally introduced to the northeastern United States (Stuckey 1980). Since then, purple loosestrife has spread westward invading a variety of wetland systems (e.g., reservoirs, riverbanks, and marshes). In 1996, The Nature Conservancy considered purple loosestrife one of the most abundant weed species in natural areas (Randall 1996).

Cultural control measures such as burning, cutting, and flooding have not consistently reduced purple loosestrife densities (Malecki and Rawinski 1985). Herbicides have been used against purple loosestrife; however, most are nonspecific and may kill most plant species in a wetland (Skinner et al. 1994). Recently, biological control agents for purple loosestrife have been identified and imported from Europe. Since 1994, Iowa State University has reared and released two leaf-feeding beetle species: *Galerucella calmariensis* L. (Coleoptera: Chrysomelidae) and *Galerucella pusilla* Duftschmidt (Coleoptera: Chrysomelidae). Populations of these beetles have established at several sites in Iowa, and leaf damage has been observed.

This paper presents an overview of the biology of purple loosestrife and the control methods used against this weed species in North America. The last portion of this paper focuses on the purple loosestrife biological control program in Iowa.

BIOLOGY

Purple loosestrife (*Lythrum salicaria*), is a perennial exotic wetland plant species originating from Europe and Asian (Hultén 1971). It ranges in height from 0.5 to 2.5 m and may have between 30–50 stalks per plant (Skinner et al. 1994). Established plants are supported by a relatively large rootstock that stores nutrients. Purple loosestrife is recognized by its erect stalk of purple flowers, which bloom in late July to early August in Iowa. A mature plant is capable of producing an average of 2.5 million seeds annually (Thompson et al. 1989).

Because of the high reproductive capacity of purple loosestrife, this species can quickly colonize new areas. Seeds can be dispersed by wind, water, birds, or carried in mud on humans and animals. Once established in a region, purple loosestrife will invade wetlands, lakes, rivers, and streams in a watershed (Westbrooks 1998).

Purple loosestrife was first recorded in the United States in the early 1800s and was likely introduced into New York State via seed in ship ballast (Stuckey 1980). The close climatic match between Europe and the northern United States facilitated the plant's establishment. Increased disturbance and stress in wetlands due to canal construction facilitated expansion of purple loosestrife's range in the Northeast during the 1800s (Thompson et al. 1989).

Purple loosestrife owes much of its expansion into the Midwest and West to human intervention. Because of its bright purple flowers and herbal properties, early frontier families carried seed with them (Thompson et al. 1989). Medicinal powders were made from dried leaves and roots to treat diarrhea and dysentery (Stevens 1961). It is believed that seeds were also transported in mud attached to wagon wheels as they traveled across the United States (Stuckey 1980).

In the mid-20th century, purple loosestrife was acclaimed for the attractiveness of its flowers to honey bees (Grieve 1923). Pellet (1956) gave instructions for "naturalizing" purple loosestrife. In Iowa, the natural spread of loosestrife down the Raccoon River from Storm Lake was noted by Pellet (1977).

Since 1940, purple loosestrife has spread at an annual mean rate of 645 km^2 and has had a severe effect on native wetland fauna (Emery and Perry 1995). In some wetlands >50% of the original plant biomass has been replaced by purple loosestrife (Balogh and Bookhout 1989). Loosestrife continues to colonize new areas through waterways, horticulture escapes, migratory birds, and intentional plantings.

WHY IS IT A PROBLEM?

Once purple loosestrife enters a wetland community, it out-competes native vegetation and forms a monoculture, reducing biodiversity (Weiher et al. 1996, Mal et al. 1997). The introduction of purple loosestrife can have detrimental effects on habitat quality for wildlife. Many wetland conservation areas are designed as waterfowl habitat, and purple loosestrife does not meet the needs of migratory waterfowl that rely on wetlands for resting, nesting, breeding, or feeding (North Carolina State University 1998).

In many areas where purple loosestrife is increasing, wildlife species are decreasing (North Carolina State University 1998), and, therefore, the expansion of purple loosestrife is an important factor influencing the vulnerability of threatened wetland plants and wildlife. Although wetlands represent a small percentage of the total landmass in the United States, more than one-third of threatened and endangered species live in wetlands (North Carolina State University 1998). An additional 20% of U. S. endangered or threatened species use or inhabit wetlands at some point in their life cycle (North Carolina State University 1998).

In addition to habitat for wildlife, wetlands are important for agriculture, water quality, flood control, and recreational activities such as hunting, fishing, and bird watching. Purple loosestrife can disrupt the functional and economic value of a wetland. Water flow and irrigation systems can be impeded by purple loosestrife (Malecki et al. 1993). Habitat alterations may have negative effects on fish and spawning grounds, thus decreasing fish populations (Lindgren 1996). Wetland restoration projects could be jeopardized due to the invasion of purple loosestrife (Lindgren 1996).

ATTEMPTS TO CONTROL PURPLE LOOSESTRIFE

Land managers and conservationists have viewed purple loosestrife as a problem for a number of years. In January 2000, the U.S. Fish and Wildlife Service declared purple loosestrife "Public Enemy #1 on Federal Lands" (Stein 2000). Purple loosestrife also ranked #2 on The Nature Conservancy weed survey of most troublesome weeds in wildlands (Randall 1996). Even though a number of control measures have been used against this plant species, purple loosestrife persists as a major weed in wetlands.

Mechanical Control

While probably the most accurate control method, mechanical control of purple loosestrife by hand pulling is very labor intensive. It involves the physical removal of all stems, branches, and perennial rootstock (Mal et al. 1992). Young plants (1–2 years old) with smaller rootstocks are relatively easy to remove; older plants with larger root masses are much more difficult to remove. Because of the physical energy and time requirements needed for this method of removal, it is not practical for large stands of purple loosestrife. Hand pulling is an effective method, however, for small stands or isolated plants.

A second mechanical control method involves cutting purple loosestrife stems. Cutting of young plants before rootstock expansion effectively reduced current year biomass of purple loosestrife (Gabor and Murkin 1990). Cutting was not a sustainable method of control, however, because roots and seeds could establish the next year or even later in the same year (Malecki and Rawinski 1985). Effective control by cutting requires annual repetition. Comparisons of mean seed mass of cut and uncut loosestrife plants showed that plants cut during pre-flower stages produced a greater amount of seed than uncut plants (Venecz and Aarssen 1998). In addition, cut stems may result in vegetative regeneration and clonal spread (Malecki and Rawinski 1985). Another concern is that native vegetation in the area may be disturbed by cutting, creating opportunity for establishment of new loosestrife seedlings. Thus, stem cutting may actually increase density of loosestrife plants in a wetland.

Cultural Control

Cultural controls for purple loosestrife include water manipulation, fire, and plant replacement methods. Each of these methods attempts to alter environmental conditions to interfere with the growth and reproductive cycle of purple loosestrife.

Large-scale water manipulations of water levels in an ecosystem to reduce purple loosestrife densities have not been a reliable control measure. The age of the plant and the frequency and duration of flooding can influence results of water inundation. Balogh (1986) obtained 100% seedling mortality following 8 wks of flooding with a range of water levels. Maintaining the greatest water depth during loosestrife's most active growing period has been shown to result in death of loosestrife plants (Rawinski 1982). Malecki and Rawinski (1985), however, noted that reproductive output of surviving plants was unaltered and observed regrowth from roots and seeds in years following flooding.

Purple loosestrife often occurs around lakes, streams, and reservoirs where it may be difficult or impossible to flood (Malecki and Rawinski 1985). Also, flooding may increase seed dispersal to new areas. There are also concerns that ecosystem manipulations of this magnitude may change community composition and threaten desired vegetation and wildlife (Malecki and Rawinski 1985).

Purple loosestrife is tolerant of control measures based upon the use of fire. The overwintering rootstock is below the soil surface, where it is insulated from the heat of a surface fire. A surface fire tends to consume dried purple loosestrife stems but does not generate sufficient heat to destroy the rootstock; therefore the plant will regenerate. Also, the soil in rhe wetland habitats are generally moist, and, therefore, it is difficult to sustain a managed fire.

Growth of purple loosestrife may be reduced by planting more competitive, but less detrimental, plants (Mal et al. 1992). The use of replacement vegetation in native wetland communities has limited value, because the treatment (introducing new plant species to the environment) is potentially just as harmful to the community as purple loosestrife. Mal et al. (1992) described the successful control of a purple loosestrife infestation at Great Meadows National Wildlife Refuge near Concord, Massachusetts after repeated mowing and plowing, and planting of reed canary grass. Rawinski (1982) tested seven plant species as potential replacements for purple loosestrife in the greenhouse and concluded that Japanese millet to be the most promising competitor. The millet plants seemed to be more tolerant of flooding than purple loosestrife, and out-competed loosestrife seedlings. In addition, mallards and black ducks fed on millet seeds.

Chemical Control

Two herbicides have been widely used for purple loosestrife control: Rodeo® (active ingredient: glyphosate [N-(phosphonomethyl) glycine], Monsanto Agricultural Company, St. Louis, MO) and Garlon® 3A (active ingredient: triclopyr ([(3,5,6 trichloro-2-pyridinyl)oxy]acetic acid), DowElanco, Indianapolis, IN) (Gardner and Grue 1996). Glyphosate, a nonselective herbicide that kills broadleaf plants and grasses, is effective at relatively low concentrations and has a low potential for bioaccumulation (Mullin 1998). At the Montezuma Natural Wildlife Refuge in New York, no significant effects of application rates were observed on purple loosestrife mortality, but timing of application was a significant factor (Rawinski 1982, Malecki and Rawinski 1985). An application timed with flowering caused 100% flower-spike reduction (Rawinski 1982, Malecki and Rawinski 1985). In the following growing season, purple loosestrife seedling establishment was also affected by the timing of the application the previous year—plots sprayed in June became reinfested; however, plots sprayed in July and August did not produce purple loosestrife seedlings the following year.

Triclopyr spot spraying is used for purple loosestrife because it selectively kills woody and broadleaf plants (Mullin 1998). Triclopyr is not labeled for aquatic sites, but is used in road ditches for loosestrife control (Mullin 1998). Triclopyr treatments reduce purple loosestrife biomass, but purple loosestrife seedlings were observed in all treated plots later that season (Nelson et al. 1996). Triclopyr is most efficient when applications are made close to the root masses of purple loosestrife plants (Katovich et al. 1996).

The use of chemical controls on natural habitats is criticized because of potential nontarget effects on wildlife and the plant community. Both herbicides used in the control of purple loosestrife are broad spectrum compounds (Skinner et al. 1994). Direct application of the herbicide on a cut purple loosestrife stem would reduce nontarget effects and increase the amount of chemical that reaches the rootstock (Wahlers et al. 1997).

Noxious Weed Status for Purple Loosestrife

Many states regulate the commercial production, sale, and/or use of purple loosestrife. Declaring purple loosestrife a noxious weed is an effective means to limit introduction and spread within a state. California, Idaho, Minnesota, Illinois, and Ohio have already declared loosestrife a first-order noxious weed (Thompson et al. 1989). This year, Iowa outlawed the sale of all purple loosestrife cultivars (Iowa Legislature 2001). This is an important step in limiting the spread of purple loosestrife because these supposedly sterile cultivars may cross with wild purple loosestrife plants (Anderson and Ascher 1993, Ottenbreit and Staniforth 1994).

Biological Control

The goal of biological control is not complete elimination of a weed, but a reduction to acceptable levels, brought about by an increase in the stress on the weed population. Biological control programs do not produce immediate results; ≥10 years may be needed before reductions in weed densities are observed (Harley and Forno 1992).

Several characteristics of purple loosestrife make it a suitable candidate for biological control. It is an introduced perennial species that is not closely related to economically valuable plants. It has potential for doing serious damage over large areas, but is restricted to a relatively specific and stable habitat. The more or less continuous distribution of purple loosestrife creates pathways for dispersal of the introduced natural enemies. Alternative means of control have been tried, but found to be inadequate and infeasible. Purple loosestrife has not been attacked to any noticeable degree by native North American phytophagous insects or plant pathogens (Hight 1990, Blossey and Schroeder 1995). In Europe, natural enemies maintain purple loosestrife densities at low levels.

More than 100 insect species are associated with purple loosestrife in Europe (Batra et al. 1986); 14 species were determined to be host specific to *Lythrum* (Blossey 1995). Detailed ecological and host-specificity studies were recommended for 6 of the 14 species: a cecidomyiid fly (*Dasineura salicariae*), a gall producer that reduces purple loosestrife foliage by 75% and seed production by 80%; a stem-and-root boring weevil (*Hylobius transversovittatus*); two chrysomelids (*Galerucella calmariensis* and *G. pusilla*) that can cause nearly 50% defoliation; and two weevils (*Nanophyes marmoratus* and *N. brevis*) that feed on the ovaries and seeds.

Demographic parameters such as life history, habitat preferences, impact, distribution, and abundance were quantified to determine the most promising biological control agents (Blossey 1995). Each species was given a score based upon laboratory studies and life history characteristics and assigned a relative ranking. *Galerucella calmariensis* and *G. pusilla* ranked first with high fecundity, widespread distribution and high abundance (Blossey et al. 1994, Blossey 1995). *Galerucella calmariensis* shows a high level of host specificity, but some transient feeding on nontarget plant species by newly eclosed adults has been observed (Kaufman and Landis 2000).

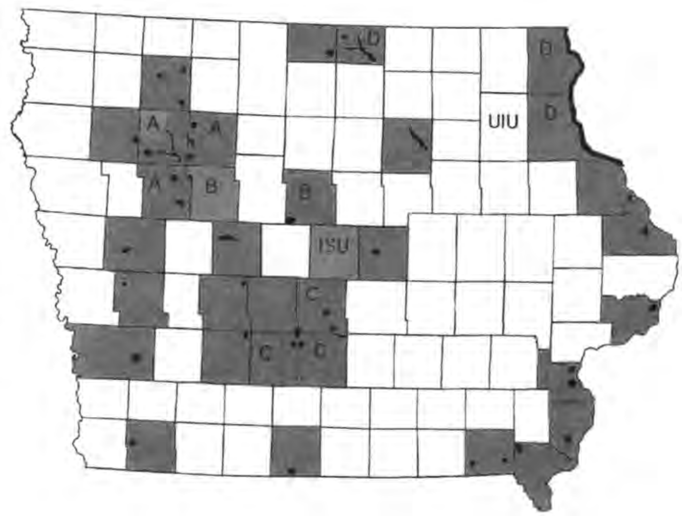

Fig. 1. Counties in Iowa with documented purple loosestrife infestations are shaded. Capital letters denote the counties where *Galerucella* species have been released beginning in the following years A) 1994 B) 1995 C) 1996 and D) 1997.

Releases of *Galerucella* beetles began in 1992 in New York, Pennsylvania, Maryland, Virginia, Minnesota, Oregon, and Washington, as well as releases in Canada. (North Carolina State University 1998) Colonization and establishment of these two species has been successful in most areas (Hight et al. 1995). In Minnesota, feeding by the two *Galerucella* species reduced purple loosestrife survival in the field by 33–66% (Katovich et al. 1999).

Both *Galerucella* species appear in early spring (April or May) on young plants; adults emerging from overwintering sites feed on meristematic tissues of leaf tips before they unfold. In mid-May, females begin to lay eggs (Blossey et al. 1994) Oviposition peaks mid-June, but continues at a reduced rate through July. The eggs are circular, opaque in color, covered with a line of frass, and laid in batches on stems and leaves. Young larvae are bright yellow-orange and feed in buds and on developing leaves. Later instars eat both leaves and stems. Pupation occurs in soil or liter beneath purple loosestrife plants.

Galerucella calmariensis and *G. pusilla* disperse following spring emergence and have good host-searching capacity (White 1996). Adults feed on plants until a high level of damage occurs, then they leave damaged plants in search of unattacked plants (White 1996) Defoliated plants are less healthy and produce less flowers (Cortilet 1998).

IOWA

In the mid-1940s, purple loosestrife was planted near Storm Lake, IA and several nearby streams to establish a new plant for honey bees (Stuckey 1980). Today, this area is heavily infested with purple loosestrife. Loosestrife seed is easily dispersed, and new infestations of purple loosestrife have been observed along the Raccoon River and its tributatries (Pellet 1977). Wetlands in 33 Iowa counties are infested with purple loosestrife (Cortilet 1998, Fig. 1), and infestations of purple loosestrife continue to increase throughout the state.

In 1994, a biological control project was initiated in Iowa to reduce purple loosestrife. Previous attempts by state and county

Table 1. Mean height, stem density, and percentage cover (means + SE) of *Lythrum salicaria* at three IDNR wetlands in 1994, 1995, and 1999.

Site	Year	Stem Density (stems/m^2)	Mean Height (meters)	Biomass Cover (%)
Little Storm Lake	1994	27.3 ± 5.2a	2.0 ± 0.8a	67.0 ± 2.3a
	1995	29.0 ± 5.5a	2.0 ± 0.1a	66.0 ± 3.4a
	1999	14.8 ± 5.0b	1.7 ± 0.4a	70.7 ± 2.7a
Black Hawk Marsh	1994	31.5 ± 3.0a	1.4 ± 0.2a	60.0 ± 3.1a
	1995	33.2 ± 3.7a	1.5 ± 0.4a	69.0 ± 7.1a
	1999	7.0 ± 2.4b	1.2 ± 0.4a	32.1 ± 2.9b
Sunken Grove Marsh	1994	37.1 ± 5.1a	2.5 ± 0.5a	70.0 ± 5.7a
	1995	36.1 ± 7.3a	2.0 ± 0.5a	73.0 ± 4.6a
	1999	14.7 ± 2.2b	1.6 ± 0.3a	87.8 ± 6.0a

Means based on 8 sampling dates in 1994 (n = 40), 10 sampling dates in 1995 (n = 50) and 3 sampling dates in 1999 (n = 30)

agencies to manage these infestations had not been successful. The Biological Control Laboratory at Iowa State University developed a mass rearing program of *G. pusilla* and *G. calmariensis.* Releases of *Galerucella* species have been concentrated in northwest Iowa where the purple loosestrife problem is most severe. Beginning in 1998, releases were also made in central Iowa where purple loosestrife is increasingly becoming a problem.

Since 1994, over 800,000 beetles have been released in Iowa wetlands (Cortilet 1998, Wiebe et al. 2001). Both *Galerucella* species have successfully overwintered and become established in Iowa (Wiebe et al. 2001). Stem density and plant biomass have been recorded at three release sites in Iowa for three years (Table 1). We observed an inverse relationship between beetle density and purple loosestrife stem density at the three release sites. There has, however, been no observed reduction in plant biomass. Natural enemies in Iowa wetlands may be limiting beetle densities, and biotic interference is currently being investigated.

CONCLUSION

Successful management of purple loosestrife requires an integrated approach that includes public education of the problems caused by purple loosestrife. An integrated management program for purple loosestrife could include hand pulling small patches and using biological control to limit the growth of large stands.

Iowa State University, the Illinois Natural History Survey, Michigan State University and the Minnesota Department of Natural Resources have promoted purple loosestrife awareness through outreach education. Purple loosestrife education materials have been developed for grades K–12. Community groups have joined in the rearing and releasing of *Galerucella* beetles. Increased enthusiasm and awareness will enhance public support of the management of this invasive wetland weed species.

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