Purple Loosestrife

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Pest Status of Weed

Purple loosestrife, *Lythrum salicaria* L., (Fig. 1) is a weed of natural areas and its spread across North America has degraded many prime wetlands resulting in large, monotypic stands that lack native plant species (Thompson *et al*., 1987; Malecki *et al*., 1993). Established *L. salicaria* populations persist for decades, are difficult to control using conventional techniques (chemical, physical, and mechanical), and continue to spread into adjacent areas (Thompson *et al*., 1987). Purple loosestrife has been declared a noxious weed in at least 19 states.

Figure 1. Purple loosestrife stand. (Photo by B. Blossey.)

Nature of Damage

Economic damage. With the exception of reduced palatability of hay containing purple loosestrife and reduction of water flow in irrigation systems in the West, purple loosestrife does not cause direct economic losses. Indirect losses accrue due to reductions in waterfowl viewing and hunting opportunities.

Figure 2. Wetland dominated by purple loosestrife. (Photo by B. Blossey.)

Ecological damage. The invasion of *L. salicaria* alters biogeochemical and hydrological processes in wetlands. Areas dominated by purple loosestrife (Fig. 2) show significantly lower porewater pools of phosphate in the summer compared to areas dominated by *Typha latifolia* L. (Templer *et al*., 1998). Purple loosestrife leaves decompose quickly in the fall resulting in a nutrient flush, whereas leaves of native species decompose in the spring (Barlocher and Biddiscombe, 1996; Emery and Perry, 1996; Grout *et al*., 1997). This change in timing of nutrient release at a time of little primary production results in significant alterations of wetland function and could jeopardize detritivore consumer communities adapted to decomposition of plant tissues in spring (Grout *et al*., 1997).

Specialized marsh birds such as the Virginia rail (*Rallus limicola* Vieillot), sora (*Porzana carolina* L.), least bittern (*Ixobrychus exilis* Gmelin), and American bittern (*Botaurus lentiginosus* Rackett), many of which are declining in the northeastern United States (Schneider and Pence, 1992), avoid nesting and foraging in purple loosestrife (Blossey *et al*., 2001a). Black terns (*Clidonias niger* L.), once a common breeding species at the Montezuma National Wildlife Refuge in upstate New York, declined and became locally extinct by 1987. The local extinction coincided with a population explosion of purple loosestrife from few individuals in 1956 to a coverage of more than 19% of the total area (600 ha), representing 40% of the emergent marsh habitat in 1983 (T. Gingrich, pers. comm.). Another wetland specialist, the marsh wren (*Cistothorus palustris* Wilson), was conspicuously absent in purple loosestrife-dominated wetlands but used adjacent cattail marshes (Rawinski and Malecki, 1984; Whitt *et al*., 1999). The federally endangered bog turtle (*Clemmys muhlenbergi* Schoepff) loses basking and breeding sites to encroachment of purple loosestrife (Malecki *et al*., 1993).

Purple loosestrife is competitively superior over native wetland plant species (Gaudet and Keddy, 1988; Weiher *et al*., 1996; Mal *et al*., 1997). The species is dominating seedbanks, particularly in areas with established purple loosestrife populations (Welling and Becker, 1990; 1993).The fact that expanding purple loosestrife populations cause local reductions in native plant species richness has been demonstrated by the temporary return of native species following the suppression of *L. salicaria* through use of herbicide (Gabor *et al*., 1996). However, without the continued use of herbicides, purple loosestrife re-invades and re-establishes dominance within a few years (Gabor *et al*., 1996). In areas where the distributions of *L. salicaria* and of the native winged loosestrife, *Lythrum alatum* Pursh., overlap, the taller, more conspicuous purple loosestrife reduces pollinator visitation to *L. alatum* resulting in significantly reduced seed set of *L. alatum*. (Brown, 1999).

Extent of losses. Direct losses are difficult to quantify due to lack of long-term monitoring programs and data.

Geographical Distribution

Lythrum salicaria now occurs in all states of the United States, except Florida, Alaska, and Hawaii, and in nine Canadian provinces. The abundance of *L. salicaria* varies throughout this range with populations in all but the eastern United States (the oldest infested area) still expanding, In the Northeast and Midwest, a significant portion of the potentially available habitat has been invaded.

Background Information On The Pest Plant

Taxonomy

Purple loosestrife is a member of the Lythraceae (the Loosestrife family), with highly variable growth form and morphology. Main leaves are 3 to 10 cm long and can be arranged opposite or alternate along the squared stem and are either glabrous or pubescent. The inflorescence is a spike of clusters of reddish-purple petals (10 to 15 mm in length). Flowers are tri-morphic with short, medium, and long petals and stamens. Many ornamental varieties have been developed, some through introgression with the native *L. alatum* (Ottenbreit and Staniforth, 1994). Until recently, *Lythrum virgatum* L. was treated as a separate species also introduced from Europe but the species is now considered a synonym of *L. salicaria* (Ottenbreit and Staniforth, 1994). Further details can be found in Mal *et al*., (1992).

Biology

Purple loosestrife needs temperatures above 20°C and moist open soils for successful germination. Seedlings grow rapidly (>1 cm/day) and plants can flower in their first growing season. Established plants can tolerate very different growing conditions, including permanent flooding, low water and nutrient levels, and low pH. Plants can grow in rock crevasses, on gravel, sand, clay and organic soils. Plants develop a large, laterally branching rootstock with starch as the main form of nutrient storage (Stamm-Katovitch *et al*., 1998). Mature plants can develop rootstocks of heavier than 1 kg and can produce more than 30 annual shoots reaching a maximum height of more than 2 m. Plants are long lived and mature plants may produce more than 2.5 million seeds annually, which remain viable for many years. Spread to new areas occurs exclusively by seed, which is transported mainly by water but also adheres to boots, waterfowl and other wetland fauna.

Analysis of Related Native Plants in the Eastern United States

The Lythracea belong to the order Myrtales of which four families (Lythraceae, Thymelaceae, Onagraceae, and Melastomataceae) are native to much of North America. Within the Lythraceae, 12 species (excluding *L. salicaria*) belonging to the genera *Ammannia, Cuphea, Decodon, Lagerstroemia, Lythrum, Rotala,* and *Didiplis* (*Peplis*) occur in the northeastern Unites States (Gleason and Cronquist, 1991). With the exception of *Didiplis diandra* (Nutt.), water purslane, all species of the Lythraceae covered by Gleason and Cronquist (1991) were used in the host specificity testing (Blossey *et al*., 1994a, b; Blossey and Schroeder, 1995).

History of Biological Control Efforts in the Eastern United States

Area of Origin of Weed

Lythrum salicaria has distribution centers in Europe and Asia. The European distribution extends from Great Britain across western Europe into central Russia with the 65th parallel as the northern distribution limit (Tutin *et al*., 1968). Purple loosestrife is common throughout central and southern Europe and along the coastal fringe of the Mediterranean basin. In Asia, the main islands of Japan are the core of the species native range, with outlying populations extending from the Amur River south across the lowlands of Manchuria and other parts of China to Southeast Asia and India (Hultén and Fries, 1986). *Lythrum salicaria* was introduced to North America in the early 1800s in ship ballast, wool, and most likely also as an ornamental or medicinal herb (Thompson *et al*., 1987).

Areas Surveyed for Natural Enemies

Research in Europe began in 1986 with field surveys for potential control agents. By 1992, field surveys for natural enemies were conducted in Finland, Sweden, Norway, Denmark, Germany, Switzerland, Austria, and France, extending earlier observations (Batra *et al*., 1986). These surveys covered 140 different sites and an area from the northernmost distribution in central Finland to the Mediterranean basin (Blossey, 1995b). Additional surveys were conducted in North America from Maryland to Nebraska (Hight, 1990).

Natural Enemies Found

No native or accidentally introduced herbivores with the potential for control of *L. salicaria* were found in North America (Hight, 1990). More recently, several native pathogens have been evaluated for their potential as biological control agents (Nyvall, 1995; Nyvall and Hu, 1997). Surveys in Europe identified more than 100 different insect species most commonly associated with purple loosestrife (Batra *et al*., 1986), but only nine species were evaluated in more detail (Blossey, 1995b).

Host Range Tests and Results

Of the nine potential control agents identified in Europe, six species were tested for their host specificity, against 48 test plant species in 32 genera (for a complete list of test plants taxonomically associated, associated wetland plants, and important agricultural plants see Blossey *et al*., 1994b). This selection was based on literature reports of their specificity, their distribution and availability in the field, and initial observations of their impact on purple loosestrife performance. The selected species were the root-mining weevil, *Hylobius transversovittatus* Goeze; two leaf beetles, *Galerucella calmariensis* L. and *Galerucella pusilla* Duftschmidt; a flower-feeding weevil, *Nanophyes marmoratus* Goeze; a seed-feeding weevil, *Nanophyes brevis* Boheman; and a gall midge, *Bayeriola salicariae* Gagné.

Host specificity tests identified two native North American plant species, *Decodon verticillatus* (L.) Ell. (swamp loosestrife) and *L. alatum* as potential hosts for the *Galerucella* leaf beetles (Blossey *et al*., 1994b) and with less probability for *H. transversovittatus*. (Blossey *et al*., 1994a). Both plant species are members of the family Lythraceae and therefore closely related to *L. salicaria*. The flower and seed feeding weevils *N. marmoratus* and *N. brevis* were entirely restricted to *L. salicaria* (Blossey and Schroeder, 1995). The gall midge *B. salicariae* attacked and successfully completed larval development on *L. alatum, Lythrum californicum* Torr. and Gray and *Lythrum hyssopifolia* L. although attack rates were much lower than on *L. salicaria* (Blossey and Schroeder, 1995).

Releases Made

Based on results indicating a potential wider host range, the gall midge *B. salicariae* was not proposed for introduction (Blossey and Schroeder, 1995). After review by the Technical Advisory Group, it was determined that further invasion by *L. salicaria* is considered a greater threat to the native *L. alatum* and *D. verticillatus* than potential attack by the leaf beetles or the root feeder, and releases were approved. Initial introductions in eastern North America occurred in Virginia, Maryland, Pennsylvania, New York, Minnesota, and southern Ontario in August, 1992 (Hight *et al*., 1995). Predictions that at high population densities beetles might nibble at other species (Blossey *et al*., 1994a, b; Blossey and Schroeder, 1995) were confirmed (Corrigan, 1998; Blossey *et al*., 2001b), but attack was transient and restricted to newly emerging beetles.

Approval to introduce the flower-feeding weevil *N. marmoratus* was granted followed by introductions in New York and Minnesota in 1994. Additional releases occurred in New Jersey in 1996. The seed-feeding weevil *N. brevis*, while approved for introduction, was not released into North America, due to the presence of a nematode infection. This infection appeared benign for *N. brevis*, however, due to the potential for non-target effects of the nematode after introduction into North America, only disease free specimens should be introduced, which, at present, effectively precludes the introduction of *N. brevis*.

Biology and Ecology of Key Natural Enemies

Galerucella **calmariensis and** ***G. pusilla*** **(Coleoptera: Chrysomelidae)**

Galerucella calmariensis (Fig. 3) and *G. pusilla* are two sympatric species that occur throughout the European range of purple loosestrife (Palmén, 1945; Silfverberg, 1974) and share the same niche on their host plant (Blossey, 1995a). With some experience adults can be identified to species; however, eggs and larvae are indistinguishable. The two introduced species easily can be confused with other North American *Galerucella* species (see Manguin *et al*., 1993 for descriptions of all five species in the genus *Galerucella* known from North America).

Figure 3. Mating pair of *Galerucella calmariensis*. (Photo by B. Blossey.)

Adults overwinter in the leaf litter and emerge in early spring synchronized with host plant phenology. Adults feed on young plant tissue causing a characteristic “shothole” defoliation pattern. Females lay eggs in batches of two to 10 on leaves and stems from May to July. First instar larvae feed concealed within leaf or flower buds; later instars feed openly on all aboveground plant parts. Larval feeding strips the photosynthetic tissue off individual leaves creating a “window-pane” effect by leaving the upper epidermis intact. Mature larvae pupate in the litter beneath the host plant. At high densities (>2 to 3 larvae/cm shoot), entire purple loosestrife populations can be defoliated (Fig. 4). At lower densities, plants retain leaf tissue but show reduced shoot growth, reduced root growth, and fail to produce seeds (Blossey 1995a, b; Blossey and Schat, 1997). Both species are usually univoltine, although a second generation may occur in some parts of North America. Adults are mobile and possess good host finding abilities. Peak dispersal of overwintered beetles is during the first few weeks of spring. New generation beetles have dispersal flights shortly after emergence and are able to locate patches of host plants as far away as 1 km (Grevstad and Herzig, 1997).

Figure 4. Defoliated purple loosestrife plants. (Photo by B. Blossey.)

Hylobius transversovittatus **(Coleoptera: Curculionidae)**

In the spring, overwintered *H. transversovittatus* adults (Fig. 5) appear shortly after *L. salicaria* shoots begin to grown. The largely nocturnal adults (10 to 14 mm) consume foliage and stem tissue; oviposition begins approximately two weeks after adults emerge from overwintering and lasts into September (Blossey, 1993). Females lay white, oval-shaped eggs in plant stems or in the soil close to the host plant. First instar larvae mine the root cortex and older larvae subsequently enter the central part of the rootstock where they feed for one to two years. Development time from egg to adult is dependent upon environmental conditions (temperature, moisture) and time of oviposition (Blossey, 1993). Pupation chambers are found in the upper part of the root and adults emerge between June and October and can be long-lived (several years).

Figure 5. *Hylobius transversovittatus* adult. (Photo by B. Blossey.)

Figure 6. Destroyed rootstock (due to *Hylobius transversovittatus* larval feeding). (Photo by B. Blossey.)

Adult feeding is of little consequence; however, larval feeding can be very destructive (Fig. 6) (Nötzold *et al*., 1998). With increasing attack rates, larval feeding reduces shoot growth, seed output, and shoot and root biomass, and can ultimately result in plant mortality (Nötzold *et al*., 1998). Attack rates vary widely with rootstock age and size (up to 1 larva/10 g of fresh root weight) and up to 40 larvae have been found per rootstock (Blossey, 1993). Large rootstocks can withstand substantial feeding pressure and several larval generations will be necessary before significant impacts can be expected. In Europe, the weevil occurs in all purple loosestrife habitats, except permanently flooded sites (Blossey, 1993), from southern Finland to the Mediterranean and from western Europe through Asia. Experiments have shown that adults and larvae can survive extended submergence. However, excessive flooding prevents access to plants by adults and will eventually kill developing larvae. Aside from this restriction, the species appears quite tolerant of a wide range of environmental conditions. Information on movements of *H. transversovittatus* is sparse because of its nocturnal nature and secretive habits during daylight hours. The most likely time to find adults is at night using a flashlight or on overcast days with light rain. Adults move primarily by walking, but dispersal flights of newly emerged adults have been reported (Palmén, 1940).

Nanophyes marmoratus (Coleoptera: Curculionidae)

Overwintered adults of *N. marmoratus* (1.4 to 2.1 mm) (Fig. 7) appear on purple loosestrife in mid to late May in upstate New York. The beetles start feeding on the youngest leaves. As soon as flower buds develop, beetles move to upper parts of flower spikes where they mate and feed on receptacles and ovaries. Oviposition starts soon thereafter and continues into August. Eggs are laid singly into the tips of flower buds before petals are fully developed. Larvae first consume stamens and, in most cases, petals, followed by the ovary. Mature larvae use frass to form pupation chambers at the bottom of the bud. Attacked buds remain closed and are later aborted. The new generation beetles appear mainly in August and feed on the remaining green leaves of purple loosestrife before overwintering in the leaf litter. Complete development from egg to adult takes about 1 month. There is one generation a year. Adult and larval feeding causes flower-bud abortion, thus reducing the seed output of *L. salicaria*. Attack rates can reach more than 70%.

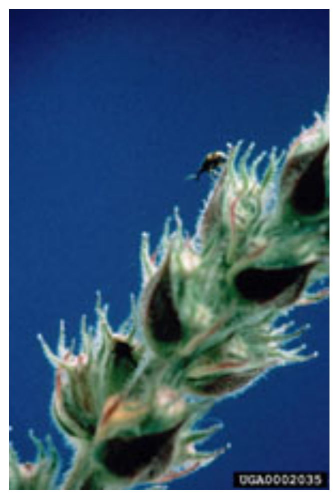

Figure 7. *Nanophyes marmoratus* adult. (Photo by B. Blossey.)

Evaluation of Project Outcomes

Establishment and Spread of Agents

All four introduced species have successfully established in North America. The two *Galerucella* species are established in Maine, Massachusetts, Connecticut, Rhode Island, Vermont, New Jersey, New York, New Hampshire, Maryland, Delaware, Virginia, West Virginia, Pennsylvania, Ohio, Indiana, Tennessee, Michigan, Illinois, Wisconsin, Minnesota, Kansas, and Iowa. The species have spread up to 5 km from the original release sites and *G. calmariensis* appears to be more successful than *G. pusilla*. The secretive nature of *H. transversovittatus* makes assessments of its status difficult. Releases have occurred throughout the United States but establishment (attacked roots) is confirmed only for Colorado, Maryland, Pennsylvania, New York, Indiana, Minnesota, New Jersey, Michigan, and Virginia. The flower-feeding weevil now occurs in New York, New Jersey, Colorado, and Minnesota, and populations are expanding.

Suppression of Target Weed

At several release sites complete defoliation of large purple loosestrife stands (many hectares) has been reported with local reductions of more than 95% of the biomass (Fig. 8). Such outcomes are currently restricted to some of the earlier release sites but similar observations have been made in Rhode Island, Connecticut, New York, Indiana, Michigan, Illinois, Minnesota, and Canada.

Figure 8a. Purple loosestrife before suppression. (Photo by B. Blossey.)

Figure 8b. Purple loosestrife after suppression. (Photo by B. Blossey.)

Recovery of Native Plant Communities

A standardized long-term monitoring program has been developed to follow the development of wetland plant populations. Presently, it is too early to assess results, other than limited observations at the most advanced release sites. For example, at a release site in Illinois, several native plant species were re-discovered after suppression of purple loosestrife. Similar results and a resurgence of cattails and other wetland plants have been observed at several release sites in New York. Further long-term data are needed to evaluate changes in plant communities.

Economic Benefits

The successful control and further implementation of biological control has resulted in reductions of herbicide purchases.

Recommendations for Future Work

At present, the focus in the purple loosestrife biocontrol program is on evaluation of releases using the standardized monitoring protocol. A second focus is the continued mass production of beetles to make control agents available to interested agencies or private citizens. The development of an artificial diet for the root-feeding weevil *H. transversovittatus* is anticipated to accelerate the release program and increase establishment rates. Later plans include redistribution of the flower-feeding weevil *N. marmoratus*.

Ongoing research and monitoring programs are testing the assumption of cumulative effects of herbivores. Agent combinations are anticipated to be more destructive to plants than a single species alone (Malecki *et al*., 1993). However, agent combinations also may impede some species, as even spatially separated herbivores can compete via their common host plant (Masters *et al*., 1993; Denno *et al*., 1995). Whether these interactions have any influence on control of *L. salicaria* where both *Galerucella* and *H. transversovittatus* were introduced requires further study.

Results from early release sites indicate that successful suppression of purple loosestrife can be achieved. However, it is not yet clear what type of replacement communities will develop. At many sites, a diverse wetland plant community replaces the once monotypic stands of *L. salicaria*. At several sites, other invasive species such as *Phragmites australis* (Cav.) Trin. ex Steudel (common reed) or *Phalaris arundinacea* L. (reed canary grass) may expand as purple loosestrife is controlled – clearly not a desired result. At yet other sites, dense purple loosestrife litter limits growth of native species. In cooperation with land managers, we are currently investigating means (fire, disking, flooding, mowing, etc.) to accelerate the return of native plant communities. As part of these ongoing evaluations an assessment of the changes in animal communities (birds, amphibians, and insects) as *L. salicaria* is controlled will help evaluate whether invaded and degraded wetlands can be successfully restored Attack of native parasitoids on *H. transversovittatus* larvae in the stems and attack of a nematode on adult *Galerucella* remains at 10% (B. Blossey, unpublished data); however, in some instances native predators appear to limit leaf-beetle population growth in cages (T. Hunt, unpublished data) or at dry sites. In Europe, specialized egg, larval and adult parasitoids can have dramatic impacts (attack rates of up to 90%) on the leaf beetles and flower-feeding weevils. While great care was taken to avoid the introduction of these and other natural enemies from Europe, the impact of native predators on the success of purple loosestrife biocontrol and the contribution of biocontrol agents to the wetland food web dynamics needs to be assessed.

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