Proc. VII. Int. Symp. Biol. Contr. Weeds, 6-11 March 1988, Rome, Italy.
Delfosse, E.S. (ed.). Ist. Sper. Patol. Veg. (MAF), pp. 269 - 78 (1989).

Available Feeding Niches in Populations of *Lythrum salicaria* (Purple Loosestrife) in the Northeastern United States

Stephen D. Hight

United States Department of Agriculture, Agricultural Research Service, Beneficial Insects Laboratory, Building 476, BARC-East, Beltsville, Maryland 20705 USA

Abstract

***Lythrum salicaria*, purple loosestrife, a native of Eurasia, was introduced into northeastern North America in the early 19th century. The plant has spread westward into the Great Plains and far West invading wetlands and displacing native emergent vegetation. Biological control is being explored as a control approach. Surveys of natural enemies present on *L. salicaria* were conducted in the northeastern U.S.A., and 59 species of phytophagous insects were collected: 50 species on foliage, three species on stems, six species on reproductive parts, and no species on roots. None of these arthropods reduced populations of *L. salicaria* or caused appreciable damage to the plant. Therefore, all observed niches of *L. salicaria* studied are available for exploitation by introduced natural enemies.**

Introduction

The study reported here was conducted to gain an understanding of the natural enemies associated with *Lythrum salicaria* L. (Lythraceae), purple loosestrife, in its naturalized North American home. Before introducing exotic natural enemies, it is important to determine what, if any, feeding niches on North American *L. salicaria* are presently occupied. Introductions of greatest interest will be those utilizing parts of the plant that are not attacked, or at most lightly attacked, in North American. Also, a survey of these insects could avoid the unnecessary research of a biological control agent that was previously introduced accidentally.

Hultén (1971) considered *L. salicaria* as a native of Eurasia, with primarily European distribution. The plant is common throughout Great Britain, extending across central and southern Europe to central Russia as far north as the 65th parallel. The main islands of Japan are the center of the Asian distribution, with populations extending into the lowlands of Manchuria and China, and to southeast Asia and northern India. The plant has spread into northern and eastern Africa, Australia (including Tasmania), and North America (Thompson *et al.* 1987).

The introduction of *L. salicaria* into North America most likely occurred from European sources in the early 19th Century as contaminates in ship ballasts. However, later introductions to the Western Hemisphere were as cultivated ornamentals and herbs (Stuckey 1980). Recently, the propagation of *L. salicaria* as a honey bee forage has increased the range of the weed (Pellett 1977). By the 1830s, *L. salicaria* had become well established along the New England seaboard. During the 1880s the plant spread westward throughout New York and the St. Lawrence Valley via canals and other water-borne commercial routes (Thompson *et al.* 1987). The plant now occurs in scattered locations in the mid-western States and south-central Canada, the Pacific Northwest, Idaho, Wyoming, and California. In the western States, *L. salicaria* infests newly-created irrigation areas.

L. salicaria is an erect, emergent, herbaceous, aquatic plant found in wetlands, coastal areas, ditches, and along stream banks. It grows to an average height of 1.5-2 m, and is most easily identified during the period from late June to early September, when the terminal spike-like panicles are covered with reddish-purple blooms. The flowers are self-incompatible, and insect-pollinated. The three forms of the weed are based on the length of the style (Levin &

Kerster 1973, Teale 1982). Minute seeds are produced in capsules, and a mature plant (average of 30 stems) may annually produce as many as 2.5 million seeds (Thompson *et al.* 1987). Stems die in late autumn but remain standing through the winter. New stems emerge from the perennial rootstocks, and can establish dense stands of the plant within a few years.

Purple loosestrife is a highly competitive weed that can replace native species in the wetland plant community, and, therefore, have an adverse ecological impact on the environment. The disappearance of native plants leads to the elimination of the essential natural foods and cover of many wetland waterfowl inhabitants. Marshes that were once wildlife feeding areas have become degraded as waterfowl production sites due to the invasion and formation of solid stands of *L. salicaria* (McKeon 1959, Smith 1964, Friesen 1966, Rawinski 1982, Pfannmueller & Djupstrom 1983, and Thompson *et al.* 1987). The impact of *L. salicaria* on agriculture is the reduction in quality of wetland pasture and wetland wild hay meadows. The weed is much less palatable to livestock than the grasses and sedges that it has displaced. Furthermore, sites with heavy infestations of the weed are difficult to mow and manage. Also, the invasion of irrigation systems could be devastating. To date, chemical control against *L. salicaria* has been used in irrigated rice in California and seepage pasture in Idaho (Thompson *et al.* 1987). Purple loosestrife is a serious problem for private, state, and federal range and wildlife managers, because the plant can adapt rapidly to disturbed areas, expand its range, and out-compete native flora. Conservative economic loss figures due to *L. salicaria* have been estimated to exceed $ 45 million p.a. (Thompson *et al.* 1987).

No effective method is available to control the weed, except where the plant occurs in small localized stands and can be intensively managed. In those isolated areas, uprooting the plant by hand and insuring the removal of all vegetative parts can eliminate *L. salicaria.* Control techniques that have been used include water level manipulation, mowing or cutting, burning, and herbicide application (McKeon 1959, Smith 1959, and Smith 1964). Although these controls can eliminate small and young stands, they are costly and require continued long-term application. Recently, small plots of *L. salicaria* were controlled through the application of the chemical herbicide glyphosate (isopropylamine salt of N-(phosphonomethyl) glycine) (Malecki & Rawinscki 1985, Malecki 1987). However, this chemical is expensive and unselective. Therefore, the scattered distribution of the weed within stands of undisturbed native vegetation, limits the use of this control method. The wide distribution of uncontrollable stands of *L. salicaria* are sources of seed for invading new lands or recolonizing controlled areas. In this situation, a comprehensive national control strategy, such as a biological control program, is desirable.

Biological control of *L. salicaria* has great potential in North America. This weed has many of the attributes of other aquatic weeds (alligatorweed and waterhyacinth) that have been successfully suppressed with biological agents (Coulson 1977, Center 1982). These attributes include: (1) introduced perennial; (2) control in effect in native region; (3) occupation of specific and relatively stable habitat; (4) more or less continuous distribution; and (5) few economically valuable taxonomically-related plant species.

Foreign surveys for insect biological control agents have been conducted throughout Europe by scientists from the Beneficial Insects Laboratory (BIL), United States Department of Agriculture (USDA), Agricultural Research Service (ARS) in Yugoslavia, from the ARS Rome laboratory in Italy, and from the Commonwealth-International Institute of Biological Control (CIBC) in northern and central Europe (Batra *et al.* 1986, Schroeder & Mendl 1984). As a result of these explorations, several potential biological control agents for *L. salicaria* have been identified.

Host preference screening tests will begin for three insect species in 1988 through an arrangement with ARS, the Fish and Wildlife Service (FWS), United States Department of Interior (USDI), CIBC, and Virginia Polytechnic Institute & State University (VPISU). The weevil *Hylobius transversovittatus* (Goeze) (Coleoptera: Curculionidae) causes the greatest damage to *L. salicaria* by internally feeding on the roots. Two chrysomelids, *Galerucella calmariensis* (L.) and *G. pusilla* (Duftschmidt) (Coleoptera: Chrysomelidae), feed on leaves and flowers, often at high enough densities to cause defoliation and destruction of flower spikes. Providing these three insect species pass the host-specificity tests, the outlook for a

successful biological control program against *L. salicaria* in North America is "excellent" (Blossey & Schroeder 1986).

Materials and Methods

Field surveys for insects found on North American populations of *L. salicaria* were conducted in 1986 and 1987. During the summers of both years, sporadic surveys were made at three sites in New York (NY; Ithaca, Glens Falls, and Newbourgh), one site in Maryland (MD; Beltsville), and one site in Massachusettes (MA; Norton). Three additional primary sites, one site in NY (Harriman) and two sites in MD (Savage and Cheverly), were sampled biweekly or monthly from May through November 1987. The NY site was located in the Hudson River Valley where *L. salicaria* was prevalent throughout. The site itself was in an abandoned gravel fill area and *L. salicaria* occupied approximately 20 ha of lowland - 12 ha of dense infestation (two plants/m^2). The MD sites were not as extensive. At the southernmost MD site (Cheverly), *L. salicaria* occupied approximately 15 ha in scattered patches in a drainage area near the Anacostia River. Plants at the northern MD site (Savage) were growing around a small 1.5 ha pond in the median strip of a highway. Also, individual plants were scattered both upstream and downstream for at least 1 km. The climate of these areas in similar to that of the native area of *L. salicaria* in Europe.

Insects were collected by hand, aspirating or netting from field plants, dissecting stem and root material, and holding field collected plant material in the laboratory for insect emergence. The type and amount of feeding damage, and the abundance of the collected insects in the field were noted. Immature insects were reared to the adult stage in the laboratory and submitted to taxonomic specialists for identifications. Laboratory-reared insects were held in plastic cages on bouquets of *L. salicaria*, that were replaced daily. Voucher specimens of the host plants from each site and of the insects are maintained at this laboratory and the USDA-ARS, Systematic Entomology Laboratory, Beltsville, MD.

Results and Discussion

A total of 94 phytophagous insect species were found to be associated with *L. salicaria* in the collection areas of North America. Of these, 34 species represented one-time single collections, or were known to be specific to other plants and, therefore, considered to be incidental collections. The remaining 60 species were definitely phytophagous on *L. salicaria*, and represented five orders, 22 families, and 55 genera (Table 1). The insects were arranged in Table 1 according to the part of the plant they utilized; i.e., foliage, stem, or reproductive. Inclusion in Table 1 was based either on direct observation of feeding damage, or consistent occurrence on the plant in numbers and/or throughout the collection period. This represented a first-time survey for natural enemies outside of Europe. A literature search for agents attacking North American *L. salicaria* revealed no pertinent records.

The eight collection sites were separated into regions as follows: the Northern region- sites at Norton, MA, Glens Falls, and Ithaca, NY; the Central region- sites at Newburgh and Harriman, NY; and the Southern region- sites at Savage, Beltsville, and Cheverly, MD. The majority of insects were collected from the primary sites at Harriman, Savage, and Cheverly. Both Harriman and Cheverly were areas of old *L. salicaria* infestations. Specimens of *L. salicaria* were collected from the lower Hudson River Valley, NY in 1870, and along the Anacostia River, MD in 1896 (Stuckey 1980). The establishment of purple loosestrife around the 1.5 ha pond near Savage was much more recent (probably 10 to 20 yrs). Native North American natural enemies have had 100 years to adapt to *L. salicaria* as a resource at the two older sites.

Foliage-Feeders

The greatest number of phytophagous insects collected from *L. salicaria* were feeding on leaves (Table 1, Part A). A total of 50 species were identified: 18 species of Coleoptera, nine

Table 1. Phytophagous insects associated with *Lythrum salicaria* L. at collection sites in the Northeastern United States.

Taxon	Stage[1]	Collection Data Month	Region[2]	Relative Abundance[3]	Other Hosts[4]	Remarks/References
			A. LEAVES			
Coleoptera						
Chrysomelidae						
Altica sp.	A	VI	C	1	P	Genus on European *L. salicaria*;
	A	VII-X	S	2		Schroeder & Mendl (1984); Batra *et al.* (1986)
Crepidodera nana (Say)	A	VII	C	1	U	
	A	V-IX	S	3		
Cryptocephalus venustus (F.)	A	VI	S	2	U	Genus on European *L. salicaria*; Batra *et al.* (1986)
C. notatus quadrimaculatus (Say)	A	VI	S	2	U	
Diabrotica undecimpunctata howardi (Barber)	A	VI	C	2	P	Economic pest
	A	VII-VIII	S	2		
Galerucella nymphaeae (L.)	L, A	VII	N	3	*Nymphaea*	Genus on European *L. salicaria*; Schroeder & Mendl (1984); Arnett (1985)
Nodonota puncticollis (Say)	A	V-VI	S	2	U	
N. tristis (Olivier)	A	VII-VIII	S	1	P	Essig (1958)
Paria fragariae (Wilcox)	A	VI-VII	C	2	U	
	A	VI	S	2		
Plagiodera versicolora (Laich.)	A	VI-VIII	S	2	P	Immigrant; economic pest; Arnett (1985)
Systena frontalis (F.)	A	VII-VIII	S	2	P	Economic pest; Arnett (1985)
Curculionidae						
Calomycterus setarius (Roelofs)	A	VII-VIII	S	1	P	Immigrant; Arnett (1985)
Cyrtepistomus castaneus (Roelofs)	A	IX	S	1	P	Immigrant; Arnett (1985)
Hypera punctata (F.)	A	IX	C	2	P; Legumes	European immigrant; economic pest; Essig (1958)
Myllocerus hilleri (Faust)	A	VII	S	1	P	Immigrant
Sitona hispidulus (F.)	A	IX	C	1	P; Legumes	European immigrant; Essig (1958)
Tyloderma foveolatum (Say)	A	VI	S	1	*Oenothera*; *Epilobium*	
Scarabaeidae						
Popilla japonica (Newman)	A	VI-IX	C	3	P	Economic pest; occasional flower-feeder
	A	VI-VIII	S	3		
Heteroptera						
Coreidae						
Archimerus alternatus (Say)	A	VI-VIII	S	2	P	Borrer & DeLong (1971)

Table 1. Continued.

Taxon	Stage[1]	Collection Data Month	Region[2]	Relative Abundance[3]	Other Hosts[4]	Remarks/References
Cydnidae						
Sehirus cinctus (Palisot)	A	VI	S	1	P	Arnett (1985)
Miridae						
Lopidae media (Say)	A	VI	C	2	P	Knight (1941)
Lygus lineolaris (Palisot)	N, A	VI-IX	C	3	P	Economic pest; genus on European *L. salicaria*; Batra *et al.* (1986)
	N, A	VI-VII	S	3		
Neurocolpus nubilus (Say)	N, A	VII	N	1	P	Economic pest; Henry & Kim (1984)
	N, A	VI-VII	C	3		
	N, A	VI-VIII	S	3		
Plagiognathus obscurus (Uhler)	A	VII	C	2	P	Genus on European *L. salicaria*; Batra *et al.* (1986)
P. politus (Uhler)	A	VII	C	2	P	Knight (1941)
Poecilocapsus lineatus (F.)	N, A	VI-VII	C	3	P; *Ribes*	Borrer & DeLong (1971); Knight (1941)
	N, A	V-VI	S	3		
Pentatomidae						
Euschistus tristigmus (Say)	A	VI	C	1	U	
	A	VI-X	S	2		
Homoptera						
Aphididae						
Aphis spp.	N, A	VI-VII	C	2	P	
	N, A	V-X	S	2		
Cercopidae						
Clastoptera proteus nigricollis (Fitch)	A	VI-VII	C	3	*Cornus*	Arnett (1985)
	N, A	VI-VII	S	3		
C. xanthocephala (Germar)	N, A	VI-VIII	S	3	*Helianthus*	Arnett (1985)
Lepyronia quadrangularis (Say)	N, A	VI-VII	C	2	P	
	N, A	V-IX	S	3		
Cicadellidae						
Draeculacephala portola (Ball, Sensu, Young & Davidson)	A	V-VII	S	3	P	
Graphocephala coccinea (Forster)	N, A	VI-X	S	3	P	Arnett (1985)
Oncometopia orbona (F.)	N, A	V-VIII	S	3	P	
Flatidae						
"light green"	A	VII-X	S	3	U	
"grey"	A	VII	C	2	U	
	A	VI-IX	S	3		

Table 1. Continued.

Taxon	Stage[1]	Collection Data: Month	Collection Data: Region[2]	Relative Abundance[3]	Other Hosts[4]	Remarks/References
Acanaloniidae						
Acanalonia bivittata (Say)	N	VI	S	2	P; grasses	Arnett (1985)
Lepidoptera						
Arctiidae						
Halysidota tessellaris (J.E. Smith)	L	VIII	N	1	P; woody plants	Arnett (1985)
	L	VIII	C	1		
Hyphantria cunea (Drury)	L	VI-VIII	S	1	P; woody plants	Economic pest; Essig (1958)
Spilosoma virginica (F.)	L	VI-VII	C	2	P; herb. plants	Parasites recovered (*Cotesia* sp.)
	L	VIII	S	1		
Gelechiidae						
Dichomeris ligulella (Hübner)	L	VI	C	1	P; woody plants	Forbes (1923)
	L	VI	S	1		
Geometridae						
Anavitrinella pampinaria (Guenee)	L	VI	S	1	P; woody plants	Forbes (1948)
Lymantriidae						
Lymantria dispar (L.)	L	V	S	2	P	Economic pest
Orgyia leucostigma (J.E. Smith)	L	VIII	C	1	P	Economic pest
	E	VIII	S	1		
Noctuidae						
Acronicta oblinita (J.E. Smith)	L	VI	C	1	P; herb. plants	Parasites recovered (*Rogas stigmator* Say)
	L	VII	S	2		
Eudryas unio (Hübner)	L, A	VI-IX	C	3	*Epilobium*;	Tachinid & hymenopterous
	L, A	V-X	S	3	*Lythrum*; *Oenothera*	parasites recovered; Forbes (1954)
Plathypena scabra (F.)	L	VI	S	1	P; legumes	Economic pest; Singh *et al.* (1978)
Saturniidae						
Hyalophora cecropia (L.)	L	VIII	C	1	P	Woody plants
Orthoptera						
Acrididae						
Melanoplus femurrubrum (DeGeer)	A	IX	S	3	P	Economic pest; Arnett (1985)
Gryllidae						
Orocharis saltator (Uhler)	A	VI	S	3	P	

Table 1. Continued.

Taxon	Stage[1]	Collection Data Month	Region[2]	Relative Abundance[3]	Other Hosts[4]	Remarks/References
			B. STEMS			
Coleoptera						
Curculionidae						
Ellescus ephippiatus (Say)	L	VI	S	1	*Salix*	Stem buds; Arnett (1971)
Lepidoptera						
Family undet.						
Species 1	L	VII	C	1	U	Stem-miner; tachinid
	L, P	VI-VII	S	2		parasites recovered
Tortricidae						
Species 1	L	V-VI	S	2	U	Stem bud
			C. REPRODUCTIVE PARTS			
Heteroptera						
Lygaeidae						
Kleidocerys resedae (Panzer)	A	IX	C	1	P	Holarctic; seed
	N, A	VI-XI	S	3		
Lepidoptera						
Geometridae						
Eupithecia mistrulata (Grote)	L	VI, VIII	S	2	P	Flowers
Pleuroprucha asthenaria (Walker)	L	VIII	N	1	U	Flower styles
	L, A	VII-IX	S	3	U	Flowers; parasites recovered
Synchlora aerata (F.)	L, A	VII-IX	S	3	U	Flowers; parasites recovered
Species 1	L	VIII	S	1	U	Flowers
Species 2	L	VIII	S	1	U	Flowers

[1] E = egg; L = larva; N = nymph; P = pupa; A = adult.

[2] N = northern (Norton, MA, Glens Falls & Ithaca, NY); C = central (Newburgh & Harriman, NY); S = southern (Savage, Beltsville & Cheverly, MD).

[3] 1 = < 1 specimen/sample hr; 2 = 1 to 5 specimens/sample hr; 3 = > 5 specimens/sample hr.

[4] P = polyphagous; U = unknown

species of Heteroptera, 10 species of Homoptera, 11 species of Lepidoptera, and two species of Orthoptera. Most of the species were polyphagous. A few species caused extensive defoliation damage to individual shoots, but never to the extent of killing the stem or impacting upon the population of *L. salicaria*. All 11 lepidopteran species completed development on *L. salicaria*.

Among the lepidopterans, only *Eudryas unio* (Hübner) was found at consistently high numbers. Individuals were often collected from heavily defoliated stems. This insect is recorded from native *Lythrum* spp. (Forbes 1954). However, 25% of the larval collections of *E. unio* reared in the laboratory were killed by parasites. Three species of parasites were recovered from *E. unio*: two flies, *Campylochaeta plathypenae* (Sabrosky) and *Sisyropa eudryae* (Townsend) (both Diptera: Tachinidae), and an unidentified ichneumonid wasp. Other parasitic wasps of lepidopteran larvae were also field collected. This parasitism may account for the limited increase of *E. unio* populations despite the abundance of *L. salicaria*.

Another visibly damaging leaf-feeder was the common four-lined plant bug, *Poecilocapsus lineatus* (F.) (Heteroptera: Miridae), which is reported to feed particularly on currants and gooseberries. This insect was abundant early in the season on young shoots of *L. salicaria* at the central and southern collection sites. Feeding by *P. lineatus* caused necrotic rings on the leaves and often withered terminal buds. However, the damaged stems recovered, usually with the continuation of the terminal bud, or the production of lateral shoots. A variety of predators were observed feeding on both nymphs and adults of *P. lineatus*, as well as many of the other collected Heteroptera and Homoptera.

Eighteen species of beetles were phytophagous on *L. salicaria* foliage. The introduced economic pest *Popilla japonica* (Newman) (Japanese beetle; Coleoptera: Scarabaeidae), was the most widespread damaging beetle. A site was rarely visited during mid-season in both the central and southern regions when *P. japonica* was not present. The adults fed on leaves and occasionally flowers. The majority of the other coleopterous species caused minimal damage to the plant, except for one, *Galerucella nymphaeae* (L.) (Coleoptera: Chrysomelidae). At one location (Ithaca), on a few localized plants, both larvae and adults were present in high numbers and substantially defoliated the plants (Malecki, R., pers. comm., 1987). Two European species in the genus *Galerucella*, *G. calmariensis* and *G. pusilla, are* monospecific to purple loosestrife, and have been considered important control agents of the plant in Europe (Blossey & Schroeder 1986). The distribution of *G. nymphaeae* coincides with the distribution of *L. salicaria* in the Northern Hemisphere (Lopatin 1984, Arnett 1985). However, neither Batra *et al.* (1986) or Schroeder & Mendl (1984) recorded this species in their surveys of European phytophagous insects. Further study of this insect will be conducted to determine the extent of the damage that it causes to North American *L. salicaria*. Also, parasites and diseases of the North American *G. nymphaeae* will be investigated to clarify their potential impact on introduced European *Galerucella* spp. (The taxonomy of Galerucinae is somewhat unclear: the species *G. calamariensis* and *G. pusilla* are also recorded in the genus *Pyrrhalta* [Wilcox 1965, Lopatin 1984]).

Stem-Feeders

Few phytophagous insects were found associated with the stems of *L. salicaria* (Table 1, Part B). One species of unidentified Lepidoptera was found mining the stem. This insect killed the shoot above the mined area by destroying the vascular tissue. However, in all cases the shoot subsequently produced several lateral stems which formed flowers and eventually seeds. Damage to *L. salicaria* from stem-miners was infrequent at the southern and the central region collection sites.

Two other insect species, an unidentified but common tortricid and a rarely found weevil, *Ellescus ephippiatus* (Say) (Coleoptera: Curculionidae) were collected as larvae in the terminal bud of young *L. salicaria* plants. These insects caused little damage to the stems, since they only destroyed the terminal buds of plants early in the season, and the stem was able to produce fertile lateral branches.

Damage by the stem-destroying insects represented a potentially substantial delay in growth with a reduction in seeds. However, the plants quickly recovered by producing several healthy lateral branches. Therefore, an effective control agent would need to destroy the whole stem at the root crown, preferably late in the season but before the seed was mature.

Flower- and Seed-Feeders

A single mature plant can produce over 2 million viable seeds resulting in a carpet of young *L. salicaria* seedlings in the surrounding muddy substrate. Therefore, damage to the reproductive structures of *L. salicaria* would be an important limitation to the plants' ability to spread and dominate infested wetlands. Five species of lepidopteran larvae were observed feeding on the petals, anthers and pistils of mature flowers (Table 1, Part C). This attack limited, if not completely prevented, seed formation from the attacked flower. However, with an average production of 1000 flowers/stem, the populations of the flower-feeding insects were too low to result in a substantial reduction of flowers. The most common lepidopteran species collected, *Pleuroprucha asthenaria* (Walker) and *Synchlora aerata* (F.) Lepidoptera: Geometridae), were found primarily in the southern collection sites. Parasitism of laboratory reared specimens of "Snake skin" and "Flower covered" was under 12%. Any introduced flower-feeding natural enemy of North American *L. salicaria* would have an abundant food source with little competition.

Only one seed-feeding arthropod was collected: a Holarctic generalist, *Kleidocerys resedae* (Panzer) (Heteroptera: Lygaeidae) (Table 1, Part C). This insect was extremely abundant at the southern collection sites, especially late in the season from August through September. In fact, this was the most abundantly collected insect in this study. As many as 30 nymphs and adults of *K. resedae* were seen on a single fruiting stalk, but they appeared to have minimal impact on *L. salicaria* seed production. Because, *K. resedae* populations were not nearly as abundant in other collection regions, their potential impact would have represented at best a localized deterrent to *L. salicaria* seed production. However, the extent of damage to *L. salicaria* seeds from *K. resedae* needs to be quantified with additional investigations.

Root-Feeders

Mature root crowns produce 30 to 50 herbaceous stems/yr and have a diameter spread of nearly 0.5 m (Thompson *et al.* 1987). The diameter of an average large root is about 2 cm. Roots of *L. salicaria*, from the three primary collection sites, were dug up, dissected, and examined for damage from natural enemies, but no evidence of natural enemies or damage was found. Therefore, it appears that the root system of North American *L. salicaria* plants represents a completely empty niche available to any natural enemy introduced as part of a biological control program.

Conclusions

The spread and often eventual dominance of *L. salicaria* into much of the wetlands of North America is continuing, and is apt to have a seriously negative impact on the agricultural systems and the waterfowl that utilize this habitat. A biological control program has the potential for controlling *L. salicaria* in the most effective and least environmentally-damaging way. Several species of phytophagous insects were collected from North American *L. salicaria*, but none of these arthropods caused appreciable damage. The plant compensated for stem-miners by producing abundant lateral shoots, and the numbers of foliage- and flower-feeders were too low to adversely effect the plant. No insects were found associated with the roots. However, two species deserve additional investigation: the impact of *K. resedae* on seed production, and the relationship of North American populations of leaf-feeding *G. nymphaeae* and its parasites and disease with other *Galerucella* spp. being considered for introduction as biological control agents. Because the feeding niches of *L. salicaria* are not occupied to any extent by native insects, at least not to the extent of offering any significant population control, it appears that any introduced phytophage would be

essentially free of interspecific competition and would find available niches for their habitation.

Acknowledgments

The following taxonomists are thanked for their identifications and information regarding the insect specimens: D.M. Anderson, R.D. Gordon, J.M. Kingsolver, R.E. White, and D.R. Whitehead (Coleoptera); R.J. Gagné, L.V. Knutson, A.L. Norrbom, C.W. Sabrosky, F.C. Thompson and N.E. Woodley (Diptera); T.J. Henry (Heteroptera); J.P. Kramer (Homoptera); G.E. Grissell, P.M. Marsh, A.S. Menke and D.R. Smith (Hymenoptera); D.C. Ferguson, R.W. Hodges and R.W. Poole (Lepidoptera); D.A. Nickle (Orthoptera) - Systematic Entomology Laboratory, USDA-ARS; W.F. Barr (Cleridae) - University of Idaho; O.S. Flint (Neuroptera); W.E. Steiner (Phalacridae) - Smithsonian Institution; and A.L. Hicks (Homoptera) - Insect Pathology Laboratory, USDA-ARS. I also thank P.D. Cubbage and J.F. Yuill for providing expert assistance with the field collections, insect rearing, and data compiling, and J.R. Coulson and C.J. DeLoach for reviewing the manuscript. Special thanks to J.J. Drea for his thorough suggestions and editorial comments.

References

Arnett, R.H. 1985. *American Insects.* Van Nostrand Reinhold Co., New York, 850 p.
Arnett, R.H. 1971. *The Beetles of the United States. Am. Ent. Inst.*, Ann Arbor, Michigan, 973 p.
Batra, S.W.T., D. Schroeder, P.E. Boldt and W. Mendl. 1986. Insects associated with purple loosestrife (*Lythrum salicaria* L.) in Europe. *Proc. Ent. Soc. Wash.* **88**:748-59.
Blossey, B. and D. Schroeder. 1986. Final Report. A survey of arthropods and fungi associated with *Lythrum salicaria* in selected areas in northern Europe. European Sta., CIBC, Delémont, 38 p.
Borror, D.J. and D.M. DeLong. 1971. *An Introduction to the Study of Insects.* Holt, Rinehart and Winston, Inc., New York, 812 p.
Center, T.D. 1982. The waterhyacinth weevils. *Aquatics* **4**:816-9.
Coulson, J.R. 1977. Biological control of alligatorweed, 1959-1972. A review and evaluation. *U.S. Dept. Agric., Tech. Bull. No.* **1547**, Wash., D.C., 98 p.
Essig, E.O. 1958. *Insects and Mites of Western North America.* MacMillan Co., New York, 1959 p.
Forbes, W.T.M. 1923. *The Lepidoptera of New York and Neighboring States. Part I.* Cornell Univ. Agric. Exp. Sta., Ithaca, New York, 263 p.
Forbes, W.T.M. 1948. *The Lepidoptera of New York and Neighboring States. Part II.* Cornell Univ. Agric. Exp. Sta., Ithaca, New York, 263 p.
Forbes, W.T.M. 1954. *The Lepidoptera of New York and Neighboring States. Part III.* Cornell Univ. Agric. Exp. Sta., Ithaca, New York, 433 p.
Friesen, G. 1966. Aquatic weed control studies in Manitoba. *N. Cent. Weed Contr. Conf.* **21**:42-3.
Henry, T.J. and K.C. Kim. 1984. Genus *Neurocolpus* Reuter (Heteroptera: Miridae): Taxonomy, economic implications, hosts, and phylogenetic review. *Trans. Am. Ent. Soc.* **110**:1-75.
Hultén, E. 1971. The circumpolar plants. II Dicotyledons. *Sv. Vet. Akad. Handl.* **13**:1-463.
Knight, H.H. 1941. *The Plant Bugs or Miridae of Illinois. Illinois Dept. Regis. Educ.* **22**:1-234.
Levin, D.A. and H.W. Kerster. 1973. Assortative pollination for stature in *Lythrum salicaria. Evolution* **27**:144-52.
Lopatin, I.K. 1984. *Leaf Beetles (Chrysomelidae) of Central Asia and Kazakhstan.* P.M. Rao (Trans.). Amerind Pub. Co., New Delhi, 416 p.
Malecki, R.A. 1987. Purple loosestrife (*Lythrum salicaria*). *In*: Decker, D.J. and J.W. Enck (eds.). *Exotic Plants with Identified Detrimental Impacts on Wildlife Habitats in New York State. Nat. Res. Ext. Series* **29**, Ithaca, pp. 39-45.
Malecki, R.A. and T.J. Rawinski. 1985. New methods for controlling purple loosestrife. *NY Fish Game J.* **32**:9-19.
McKeon, W.H. 1959. A preliminary report on the use of chemical herbicides to control purple loosestrife (*Lythrum salicaria*) on a small marsh. *Proc. Northeast. Weed Contr. Conf.* **13**:329-32.
Pellett, M. 1977. Purple loosestrife spreads down river. *Am. Bee J.* **117**:214-215.
Pfannmueller, L. and B. Djupstrom. 1983. Purple loosestrife: aggressive invader of meadow and wetland. *MN Volunteer* **46**:36-9.
Rawinski, T.J. 1985. The ecology and management of purple loosestrife (*Lythrum salicaria* L.) in central New York. M.S. Thesis, Cornell Univ., Ithaca, NY, 88 p.
Schroeder, D. and W. Mendl. 1984. Report. A survey of phytophagous insects and pathogens associated with purple loosestrife, *Lythrum salicaria*, in Europe. European Sta., CIBC, Delémont, 32 p.
Singh, S.R., H.F. Van Emden and T.A. Taylor. 1978. *Pests of Grain Legumes: Ecology and Control.* Academic Press, Inc., New York, 454 p.
Smith, L.S. 1959. Some experiences with control of purple loosestrife at the Montezuma National Wildlife Refuge. *Proc. NE Weed Contr. Conf.* **13**:333-6.
Smith. R.H. 1964. Experimental control of purple loosestrife (*Lythrum salicaria*). *NY Fish Game J.* **11**:35-46.
Stuckey, R.L. 1980. Distributional history of *Lythrum salicaria* (purple loosestrife) in North America. *Bartonia* **47**:3-20.
Teale, E.W. 1982. Stems beyond counting, flowers unknown. *Audubon* **84**:38-43.
Thompson, D.Q., R.L. Stuckey and E.B. Thompson. 1987. Spread, impact, and control of purple loosestrife (*Lythrum salicaria*) in North American wetlands. *Fish & Wildl. Res.* **2**. U.S. Dept. Int., Wash., D.C., 55 p.
Wilcox, J.A. 1965. A synopsis of the North American Galerucinae (Coleoptera: Chrysomelidae). *NY Mus. Sci. Center Bull.* **No. 400**, New York, 226 p.