The Establishment and Proliferation of the Rare Exotic Plant, *Lythrum hyssopifolia*, Hyssop-leaved Loosestrife, at a Pond in Guelph, Ontario

MARC T. JOHNSON[1], and CARL J. ROTHFELS[2]

[1]Department of Botany, University of Toronto, 25 Willcocks Street, Toronto, Ontario M5S 3B2 Canada; email: johnson@botany.utoronto.ca [author for correspondence]
[2]R.R. 1, Pefferlaw, Ontario L0E 1N0 Canada

Johnson, Marc T., and Carl J. Rothfels. 2001. The establishment and proliferation of the rare exotic plant, *Lythrum hyssopifolia*, Hyssop-leaved Loosestrife, at a pond in Guelph, Ontario. Canadian Field-Naturalist 115(2): 229–233.

Understanding the biology of exotic species and their potential to be invasive is of interest to both theoretical and applied ecologists. We studied the establishment and proliferation of the exotic *Lythrum hyssopifolia*, Hyssop-leaved Loosestrife, over three years (1998 to 2000) at a recently dug pond in the city of Guelph, Ontario. This location is the second record of the species in Ontario. In each year we recorded the location of plants, the number of stems and their density within discrete sites. In 1998 we found a single plant with 15 stems that bore numerous flowers and mature fruits. By 2000, plants were growing at 10 discrete sites around the pond; there were an estimated 1 556 plants giving rise to a total of 2090 stems. Although *L. hyssopifolia* may become more frequent in Guelph and Ontario, it is unlikely that it will be as abundant and invasive as its congener *Lythrum salicaria*, Purple Loosestrife.

Key Words: *Lythrum hyssopifolia*, Hyssop-leaved Loosestrife, non-native, exotic, alien, introduced, biological invasions, rarity, establishment, population growth.

Understanding the biology of exotic plant species is of major interest for ecologists, largely because of the ability of some exotic species to compete with and displace native and agricultural ones (Holm et al. 1977; D'Antonio and Mahall 1991; US Congress 1993; Williamson and Fitter 1996; Vitousek et al. 1996). Much effort has been made to determine which exotic species will successfully invade and where they will become pests (Lodge 1993; Williamson 1996; Crawley et al. 1996; Reichard and Hamilton 1997; Horvitz et al. 1998; Kotanen et al. 1998). Theoretical models have been formulated (Watkinson 1986; Higgins and Richardson 1996; Williamson 1996) and empirical studies have tested these theories of invasion (Crawley et al. 1996; reviewed in Williamson 1996; Kotanen et al. 1998). As a result, there are now generalized conceptual frameworks on biological invasions (Lodge 1993; Williamson 1996), as well as statistical generalizations on the habitats and traits most often associated with exotic species (Crawley et al. 1996; Kotanen et al. 1998). Despite these advancements, predicting the future outcome of a specific introduction remains difficult (Lodge 1993; Williamson 1996). Generalized predictions are possible if observations are made on the initial processes of an introduction (whether or not establishment occurs; fecundity; rate of population increase; rate of spread; and community interactions) and these data are coupled with further knowledge of life history traits of the species (Williamson 1996). To do this, one must witness the initial stages of an introduction , which we have done with *Lythrum hyssopifolia* L. (Lythraceae), Hyssop-leaved Loosestrife, a rare exotic in Canada.

Lythrum hyssopifolia is a summer annual; details of its morphology and identification can be found in Gleason and Cronquist (1991) and Callaghan (1998). *Lythrum hyssopifolia* can cross-fertilize, but it readily self-pollinates (Preston and Whitehouse 1986; Callaghan 1998). Plants can increase in numbers rapidly because they produce copious seeds as well as new clonal shoots from adventitious roots (Callaghan 1998). Originally an Old-World species, *L. hyssopifolia* is now found on every continent except Antarctica (Callaghan 1998). It was first recorded in North America from Boston in ca. 1815 (Shinners 1953) and now occurs frequently on the west coast of the United States and on the east coast from Maine to New Jersey and eastern Pennsylvania (Steere 1966; Gleason and Cronquist 1991). Inland there are historic records from Detroit, Michigan (Voss 1985) and southern Ohio (Gleason and Cronquist 1991; S. Graham, personal communication), which are discussed in detail by Blaney et al. (1997). To our knowledge, *L. hyssopifolia* is only known from three localities in Canada. The first record was a collection made in 1992 from a farmer's field north of Belleville, Ontario (Blaney et al. 1997). Since 1992, *L. hyssopifolia* has also been reported in Canada from two locations in British Columbia: Vancouver Island and south-central British Columbia (Douglas et al. 1998; Douglas et al. 1999).

Lythrum hyssopifolia appears characteristically in areas that are periodically flooded in winter and spring, are frequently disturbed, and contain few other plants (Preston and Whitehouse 1986; Bliss and Zedler 1998; Callaghan 1998). Commonly a pioneer of exposed soil, it does well in arable fields that are moist or experience periodic flooding (Blaney et al. 1997; Callaghan 1998). *Lythrum hyssopifolia* can proliferate quickly if conditions are favourable for its growth, but populations are also prone to precipitous decline (Preston and Whitehouse 1986; Callaghan 1998). Despite these population fluctuations, *L. hyssopifolia* is somewhat protected from local extirpation by the long-lived seed bank characteristic of this species (Preston and Whitehouse 1986).

We report the results from a three-year observational study of a population of *L. hyssopifolia* in Guelph, Ontario, Canada. These observations document the establishment from the presumed first reproducing plant in the population, followed by the proliferation of this species in a localized area. Our discovery of *L. hyssopifolia* in Guelph represents the second record of this species in Ontario (Blaney et al. 1997), the fourth in Canada (Douglas et al. 1999).

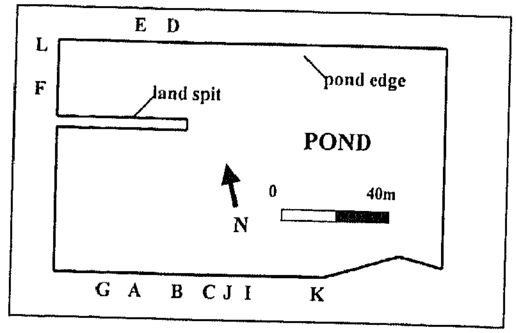

FIGURE 1. Diagram of the pond where *Lythrum hyssopifolia* was observed. Letters A through L represent discrete locations at the pond's edge where plants were found between 1998 and 2000. In 1998, a single *L. hyssopifolia* plant found was found at site A. In 1999, *L. hyssopifolia* plants were found at seven sites, A-G. In 2000, *L. hyssopifolia* plants were found at 10 sites, A-L; except E and G.

Methods

All observations and data were collected in the mid-summer or fall of 1998, 1999 and 2000. The study site was an artificial pond in the south-west section of the city of Guelph, Ontario, 43° 30.6′ N, 80° 13.1′ W, which is south-west of the intersection of Edinburgh Rd. and South Creek Trail, between "Preservation Park" (the south and west border of the pond) and a subdivision constructed in 1996 (the north border of the pond).

The pond was dug in 1995 or 1996 as part of a series of ponds scattered throughout Guelph to capture overflow from suburban storm gutters (Guelph Public Works Commission, personal communication). The pond measures approximately 145 m (east-west) by 85 m (north-south) (Figure 1). It contained water throughout the study and has probably contained water since its creation, although the water level fluctuated within and between years of our study. A band of exposed soil narrowly lined the perimeter of the pond, but changed in width as the water level fluctuated. The width of the exposed soil narrowed from 1998 to 2000 as perennial species increased in abundance around the pond's margin.

The plant community at the pond was typical of species associated with exposed water-saturated soil as well as old fields (see Results for a list of most common species).

Sampling

Lythrum hyssopifolia was first discovered on 2 October 1998. On this date the pond's margin was searched for additional plants. On 6 October of the same year, the margin of the pond was searched again. Neither search located any additional plants, nor were any found in nearby ponds.

On 7 October 1999 and 31 July and 1 August 2000, the pond was revisited and the exposed soil at the pond margin and 1m back in thicker vegetation were searched to locate *L. hyssopifolia* plants. Discrete sites separated by at least 3 m between plants were delineated and the numbers of stems within each site were counted. Stems were counted instead of the number of plants because prolific branching, high stem densities and clonal propagation made the identification and counting of individual plants impractical. If it was obvious that a single plant contained branches, the branches were recorded as "stems" provided that the branching occurred at the base of the plant. Counting each aggregation of stems as a single plant made a conservative estimate of the number of plants. Stem densities (stems/m^2) were calculated for sites with multiple "plants". In 1998 and 1999, the number of stems bearing fruits or flowers were counted, but this was not done in 2000 since most stems were not yet in flower on the sampling date.

Results

The single *L. hyssopifolia* plant observed in October 1998 was composed of 15 branches, each 20–40 cm long, that diverged at the plant base. These branches bore numerous flowers (in the apical leaf axes) and fruits (present nearly to the base of the stems). One stem that was collected (now deposited at OAC, see below) had 25 flowers and 28 mature fruits. Many smaller stems (less than 5 cm in length) were present at the base of the plant. Two of the larger branches were collected and are now deposited at Kent State University in Dr. Shirley Graham's personal Lythraceae research herbarium (*M.T. Johnson s.n. & C. J. Rothfels*, KE-Graham) and the

University of Guelph Herbarium (*M.T. Johnson s.n. & C. J. Rothfels*, OAC).

In October 1999, *L. hyssopifolia* was found at seven sites around the margin of the pond (Figure 1). Among the seven sites, we estimated a total of 100 individual plants and counted 426 stems, of which 292 (69%) bore either fruits or flowers. The number of stems in a site ranged from 1 to 252, while the number of fruiting/flowering stems ranged between 0 and 201. Densities of stems at sites A, C and D, ranged from 68.6 stems/m^2 to 187.0 stems/m^2 (Table 1), but within site D one area had 166 stems at a density of 319 stems/m^2. Most plants grew in the exposed soil or were rooted in soil but partially submerged. A smaller number grew in more dense vegetation, but never far from the edge of the exposed soil.

Many stems bore mature fruit, but some stems appeared to have shed entire fruits; fruits fell away when gently manipulated by hand. We also observed that parts of stems were missing from some plants, possibly broken off or consumed.

In July 2000, *L. hyssopifolia* plants were at 10 sites around the pond, four of which were new (Figure 1). Among these sites were an estimated 1556 plants and 2090 stems. Some stems had begun to flower, but none bore mature fruits. The number of stems within a site ranged from 1 to 1 487 (Table 1). Stem density was calculated at 6 sites and ranged from 157 stems/m^2 to 2750 stems/m^2 (Table 1), but stem density of immature plants was recorded as high as 10 500 stems/m^2 in a 0.1 m × 0.1 m quadrat. As in 1999, all stems were found at the pond's margin, but unlike the previous year no plants were found in the more heavily vegetated areas. All stems grew within a 0.6 m band of exposed soil around the pond.

TABLE 1. The sites (A-L) where *Lythrum hyssopifolia* plants were found, the number and density (stems/m^2) of stems (for sites with more than a single "plant") in 1999 and 2000. The total number of stems among all sites is also included. Sites that contained at least one stem with fruit or flower in 1999 are indicated by an *. In 1998 there was only a single plant with 15 stems, located at site A.

	Number of Stems		Stem Density (stems/m^2)	
Site	1999	2000	1999	2000
A	36*	31	69	157
B	2*	44		2750
C	118*	409	171	228
D	252*	1487	187	292
E	14	0		
F	3*	101		28
G	1	0		
H	0	1		
I	0	4		
J	0	1		
K	0	11		550
L	0	1		
All	426	2090		

*at least one stem in flower/fruit.

Discussion

The single plant of *L. hyssopifolia* found in 1998 was likely the first fertile individual to occur at this site, because the pond was only 2-3 years old, and *L. hyssopifolia* is an annual that can increase in numbers rapidly when colonizing exposed soil (Preston and Whitehouse 1986; Callaghan 1998; Bliss and Zedler 1998). Therefore, we would have expected more than a single plant in 1998 if fruiting plants had previously existed in the area. Although its mode of transportation to the pond is unknowable, seeds could have been transported on birds' feet or in feces.

There was a large proliferation of *L. hyssopifolia* around the pond from 1998 to 1999 (Table 1). Either seeds from the 1998 plant dispersed and germinated at the sites found in 1999, or a seed bank was present in 1998 that did not germinate until 1999. These hypotheses are not necessarily mutually exclusive. We believe that the first hypothesis best explains the population structure observed in 1999 and 2000. This hypothesis would be improbable if only independent dispersal of individual seeds accounted for the distribution of all stems in 1999. It is not improbable, however, if entire fruits and/or branches containing fruits were dispersed to these sites. We did observe stems in which fruits appeared to have been shed and branches were broken off. Preliminary tests confirm that fruits are buoyant. Despite this, we cannot completely dismiss the second hypothesis – proliferation due to the germination of a seed bank. *Lythrum hyssopifolia* is known to form seed banks (Bliss and Zedler 1998) and seeds can remain dormant for many years prior to germination (Preston and Whitehouse 1986). Since the habitat in 1998 appeared ideal for *L. hyssopifolia* we would have expected more plants in 1998, but only one plant was found, therefore the presence of a large seed bank prior to 1998 is unlikely.

From 1999 to 2000 there was an increase in the number of sites, plants, and stems, as well as an increase in stem density (Table 1). This increase is not surprising based on the amount of available habitat and the number of stems fruiting in 1998 and 1999. It is surprising, however, that only four additional sites were found between 1999 and 2000 and none of these sites contained more than 11 stems.

This is in contrast to the colonization pattern observed from 1998 and 1999.

The habitat at the site was consistent with the habitats reported from other populations of *L. hyssopifolia*: anthropogenic disturbance, fluctuating water levels, annual-dominated zone (Steere 1966; Tutin et al. 1968; Preston and Whitehouse 1986; Blaney et al. 1997; Bliss and Zedler 1998; Callaghan 1998). The vascular flora around the pond was similar to other studies (Preston and Whitehouse 1986; Callaghan 1998). The most common species* were *Anagallis arvensis* (Pimpernel), *Euthamia graminifolia* (Grass-leaved Goldenrod), *Juncus bufonius* (Toad Rush), *Juncus dudleyi* (Dudley's Rush), *Juncus effusus* (Soft Rush), *Lolium* spp. (Ryegrass), *Panicum capillare* (Witch Grass), *Plantago major* (Common Plantain), *Trifolium hybridum* (Alsike Clover) and *Typha angustifolia* (Narrow-leaved Cattail).

The data collected in this study can be related to theoretical conceptual frameworks on exotic species and biological invasions (Lodge 1993; Williamson 1996). On the one hand, *L. hyssopifolia* has traits traditionally attributed to many invasive exotic species (Lodge 1993): r-selection; annual; self-reproduction; high dispersal rate; vegetative reproduction and human commensalism. It also occurs in ruderal habitats with low species diversity, a characteristic of many exotics (Lodge 1993; Crawley et al. 1996). On the other hand, it has traits that are not consistent with recent generalizations made about exotic species (Crawley et al. 1996). Crawley et al. (1996) found that exotic taxa were significantly more likely to have larger seeds, perennial growth, taller shoots, cross-pollinated reproduction and earlier flowering. The reverse is true for each of these traits if we compare *L. hyssopifolia* with its native congener, *L. alatum* (Winged Loosestrife). Although Crawley et al. (1996) were using data from the British flora and based their conclusions on robust statistical tests, it should be noted that their conclusions are a rule of thumb and exceptions exist.

Closely related species often have traits that covary (Felsenstein 1985). Because of this covariation the invasive ability of related exotic species may be similar (Crawley et al. 1996; Kotanen et al. 1998), and potentially used as a predictor of invasion (Williamson 1996). A comparison between *L. hyssopifolia* and its congener *Lythrum salicaria* (Purple Loosestrife) provides a test of this prediction. *Lythrum salicaria* is known as an invader of wetlands and mesic habitats in North America, although its ability to displace other organisms is under debate (Anderson 1995; Hager and McCoy 1998). *Lythrum hyssopifolia* is potentially a minor pest in some circumstances (Blaney et al. 1997; Callaghan 1998), but its ecological requirements are more restricted than those of *L. salicaria*, and therefore it has not proliferated in North America as successfully as *L. salicaria*, especially at northern latitudes. It is clear that the invasive ability of these congeners is not equal. *L. hyssopifolia*'s smaller size, high self-pollination rate and its annual growth habit may all contribute to this difference in invasive ability. The difference in invasive ability between the two species supports Williamson's belief (1996) that the differences between related taxa are more important than their similarities, which suggests relatedness can not be used reliably as a predictor of invasiveness.

Prognosis

What will happen to *L. hyssopifolia* in the Guelph area and will it spread further in Ontario? It is likely that *L. hyssopifolia* will become more frequent in Guelph and elsewhere in Ontario, but unlike its congener, *L. salicaria*, it will rarely be common or displace native plant species. Four points support this prediction. First, *L. hyssopifolia* has specific habitat requirements (i.e. periodically flooded ruderal areas and arable fields) that typically have a low density and diversity of native species (Preston and Whitehouse 1986; Bliss and Zedler 1998; Callaghan 1998). Second, *L. hyssopifolia* appears to compete poorly with perennials (Preston and Whitehouse 1986; MTJ, unpublished data). Third, *L. hyssopifolia* is usually rare in north-temperate climates like that of southern Ontario, even if small populations persist for many years (Tutin et al. 1968; Blaney et al. 1997; Callaghan 1998; Douglas et al. 1999). Finally, despite a long history of introductions in eastern North America, this species has so far failed to establish abundant inland populations.

We suspect that *L. hyssopifolia* will remain restricted to ruderal habitats including vernal pools, ponds and waterways with exposed soil, or arable land that is frequently ploughed and contains areas with winter/spring flooding. The status of *L. hyssopifolia* in Canada should continue to be monitored and further research should concentrate on determining the ability of *L. hyssopifolia* to compete with and displace other plant species as well as its potential to act as an agricultural pest.

Acknowledgments

Shirley Graham and Michael Oldham provided comments and discussion on historical records and the natural history of *Lythrum hyssopifolia*. Paul Kron assisted with fieldwork. Peter Kotanen and three anonymous reviewers provided helpful comments on earlier versions of this manuscript.

*Nomenclature follows Morton and Venn (1990) for all species except *L. hyssopifolia* for which Gleason and Cronquist (1991) was used.

Literature Cited

Anderson, M. G. 1995. Interactions between *Lythrum salicaria* and native organisms: A critical review. Environmental Management 19: 225–231.

Blaney, C. S., M. J. Oldham, and **A. A. Reznicek.** 1997. Hyssop-leaved Loosestrife, *Lythrum hyssopifolia* L. (Lythraceae), new to Canada. Canadian Field-Naturalist 111: 664–665.

Bliss, S. A., and **P. H. Zedler.** 1998. The germination process in vernal pools: sensitivity to environmental conditions and effects on community structure. Oecologia 113: 67–73.

Callaghan, D. A. 1998. Biological flora of the British Isles Number 203: *Lythrum hyssopifolia* L. Journal of Ecology 86: 1065–1072.

Crawley, M. J., P. H. Harvey, and **A. Purvis.** 1996. Comparative ecology of the native and alien floras of the British Isles. Philosophical Transactions of the Royal Society of London B: Biology Sciences 351: 1251–1259.

D'Antonio, C. M., and **B. E. Mahall.** 1991. Root profiles and competition between the invasive, exotic perennial, *Carpobrotus edulis*, and two native shrub species in California coastal scrub. American Journal of Botany 78: 885–894.

Douglas, G. W., G. B. Straley, and **D. V. Meidinger.** 1998. Rare Native Vascular Plants of British Columbia. Ministry of the Environment, British Columbia.

Douglas, G. W., D. Meidinger, and **J. Pojar.** *Editors.* 1999. Illustrated Flora of British Columbia. [Pages 310–311]. Ministry of the Environment, British Columbia, and Ministry of Forests, British Columbia.

Felsenstein, J. 1985. Phylogenies and the comparative method. American Naturalist 125: 1–15.

Gleason, H. A., and **A. Cronquist.** 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Second Edition. The New York Botanical Garden, Bronx, New York.

Hager, H. A., and **K. D. McCoy.** 1998. The implications of accepting untested hypotheses: a review of the effects of purple loosestrife (*Lythrum salicaria*) in North America. Biodiversity and Conservation 7: 1069–1079.

Higgins, S. I., and **D. M. Richardson.** 1996. A review of models of alien plant spread. Ecological Modeling 87: 249–265.

Holm, L. G., D. L. Plucknett, J. V. Pancho, and **J. P. Herberger.** 1977. The World's Worst Weeds: Distribution and Biology. University Press of Hawaii, Honolulu, Hawaii.

Horvitz, C. C., J. B. Pascarella, S. McMann, A. Freedman, and **R. H. Hofstetter.** 1998. Functional roles of invasive non-indigenous plants in hurricane-effected subtropical hardwood forests. Ecological Applications 8: 947–974.

Kotanen, P. M, J. Bergelson, and **D. L. Hazlett.** 1998. Habitats of native and exotic plants in Colorado shortgrass steppe: a comparative approach. Canadian Journal of Botany 76: 664–672.

Lodge, D. M. 1993. Biological invasions: lessons for ecology. Trends in Ecology and Evolution 8: 133–137.

Morton, J. K., and **J. M. Venn.** 1990. University of Waterloo Biology Series Number 34: A Checklist of the Flora of Ontario Vascular Plants. Department of Biology, Waterloo, Ontario.

Preston, C. D., and **H. L. K. Whitehouse.** 1986. The habitat of *Lythrum hyssopifolia* L. in Cambridgeshire, its only surviving English locality. Biological Conservation 35: 41–62.

Reichard, S. H., and **C. W. Hamilton.** 1997. Predicting invasions of woody plants introduced into North America. Conservation Biology 11: 193–203.

Shinners, L. H. 1953. Synopsis of the United States species of *Lythrum* (Lythraceae). Field and Laboratory 21: 80–80.

Steere, W. C. *General Editor.* 1966. Wildflowers of the United States (Volumes 4 and 5). New York Botanical Gardens, McGraw-Hill, New York.

Tutin, T. G., V. H. Heywood, N. A. Burges, D. M. Moore, D. H. Valentine, S. M. Walters, and **D. A. Webb.** *Editors.* 1968. Flora Europaea. Volume 2. Rosaceae to Umbelliferae. Cambridge University Press.

U. S. Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States (OTA-F-565). U.S. Government Printing Office, Washington.

Vitousek, P. M., C. M. D'antonio, L. L. Loope, and **R. Westbrooks.** 1996. Biological Invasions as Global Environmental Change. American Scientist 84: 468–478.

Voss, E. G. 1985. Michigan Flora. Part II. Dicots (Saururaceae-Cornaceae). Cranbrook Institute of Science Bulletin 59 and University of Michigan Herbarium.

Watkinson, A. R. 1986. Plant population dynamics. *In* Plant Ecology. *Edited by* M. J. Crawley. Blackwell Scientific Publications, Oxford, England.

Williamson, M. H. 1996. Biological Invasions. Chapman and Hall, London.

Williamson, M. H., and **A. Fitter.** 1996. The characters of successful invaders. Biological Conservation 78: 163–170.

Received 13 August 2000
Accepted 3 May 2001