# AN ECOLOGICAL STUDY OF *Filipendula rubra* (Hill) B.L. Robinson (ROSACEAE)

by

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**An ecological study of *Filipendula rubra* (Hill) B.L. Robinson (Rosaceae)**

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## ABSTRACT

Seed production, plant density, and pollinator abundance of *Filipendula rubra* were measured during the summer of 2002 at four fens: Jackson Bog in northeast Ohio and Gallagher/Springfield Fen, Kiser Lake Wetlands, and Prairie Road Fen in west-central Ohio. In addition, total plant density was measured to assess the effects of competition on seed production. Soil nutrients and associated plant species were also examined at the study sites. Herbarium records were then used to determine the characteristic habitat and geographical distribution of *F. rubra*.

Pollinator abundance was significantly correlated with *F. rubra* plant density ($P < 0.01$) and the population size of *F. rubra* ($P < 0.01$), and tended to be correlated with viable seed production ($P = 0.10$). In addition, total plant density tended to be correlated with seed production ($P = 0.10$). These results suggest that plant density, the population size of *F. rubra*, and pollinator abundance may influence the reproduction and establishment of this fen species.

The plant species associated with *F. rubra* were *Thelypteris palustris*, *Steironema quadriflora*, *Potentilla fruticosa*, *Lythrum salicaria*, *Phlox maculata*, *Prunella vulgaris*, *Pychathemum tenuifolium*, *Galium aparine*, *Andropogon gerardi*, and *Smilacina stellata*. Soil pH ranged from 5.6-7.5, phosphate ($P_2O_5$) and potash ($K_2O$) levels were below optimum and magnesium (MgO) and calcium (CaO) levels were above optimum at the study sites. The characteristic habitat of *F. rubra* includes bogs, marshes, meadows, swamps, fens, and prairies in open areas that are wet or moist with limey or calcareous soil. The geographical distribution of *F. rubra* has remained the same, but it is found in five fewer counties since historic times (<1960).

## ACKNOWLEDGMENTS

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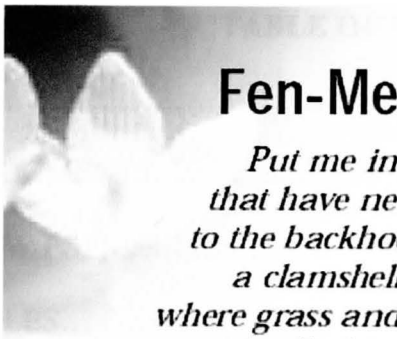

# Fen-Meadow

*Put me in places*
*that have never fallen*
*to the backhoe, nor seen*
*a clamshell shovel,*
*where grass and sedge dance*
*with silk-skinned orchid*
*to heaven's delight*
*in tunes carried through the eons*
*and dropped to earth*
*from the pure, moistened hands of angels...*
*Beyond the sweep of tree line,*
*below the hill,*
*nestled where sweet springs*
*pour out their sacred jewels*
*as silver braids*
*across shining marl flats*
*amongst verdant cushions*
*of cool, deep sphagnum;*
*and there, in naked beauty,*
*to blush in praise*
*of summer's pliant kisses;*
*huckleberried and sundewed,*
*bubbling with boundless joy as they*
*toss their clear, cold waters*
*through unseen gardens*
*and across the still secret landscapes...*

*Emliss Ricks*

**(Ohio Department of Natural Resources 2001)**

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# INTRODUCTION

## Goals and Objectives

Knowledge of plant life history traits, such as seed production, can provide insight into the factors that influence the reproductive success and distribution of plants. Plant density has long been assumed to be a major factor influencing seed production (Abrahamson 1975a and b, Holler and Abrahamson 1977, Ogden 1974). However, pollinator abundance may also be important (Gomez 1996, Mustajarvi et al. 2001, Steffan-Dewenter and Tscharntke 1999).

The goal of this study was to investigate factors that influence the reproductive success and distribution of *Filipendula rubra* at Jackson Bog, Gallagher/Springfield Fen, Kiser Lake Wetlands, and Prairie Road Fen. The objectives of this study were to examine (1) factors that influence seed production (2) habitat characteristics and (3) geographical distribution of *F. rubra*.

## Relevance of Species

Queen of the prairie, *Filipendula rubra* (Hill) B.L. Robinson (Rosaceae) (Gleason and Cronquist 1991), is a perennial rhizomatous herb native to spring-fed calcareous fens, spring seeps, and wet prairies in the north-central United States. It is distributed from Iowa to Missouri, eastward to Pennsylvania and New York, and southward to North Carolina, and sometimes escapes cultivation elsewhere (Aspinwall and Christian 1992a and b, Gleason and Cronquist 1991). *Filipendula* comes from the Latin words *filum* for "thread" and *pendulus* for "hanging" referring to the European species *Filipendula vulgaris* Moench.(*Filipendula hexapetala*) (dropwort), which has

small tubers that are strung together by fibrous roots (Fernald 1950). The word *rubra* means "red" and refers to the color of the inflorescence (Runkel and Roosa 1989). The plant was first described by British botanist and medical doctor John Hill (1716-1775) and was originally named *Ulmaria rubra* Hill in 1768. The type specimen for the species is an illustration, which was printed in Hill's Hortus Kewensis (1769) (Fig. A1). The plant was later named *Filipendula rubra* by Benjamin Lincoln Robinson (1864-1935), a well-known botanist and curator of the herbarium at Harvard University. The current name of *Filipendula rubra* (Hill) B.L. Robinson was first published in 1906 as a new binomial. In his description of the plant Robinson remarked that, "Few of the native plants of the Middle West exceed in beauty the "Queen of the Prairie, " with its pinnate leaves, palmately lobed leaflets, and numerous gracefully panicled flowers, which according to the apt description of Dr. Gray are "deep peach-blossom color." The synonyms for *F. rubra* are *Spiraea lobata*, *Spiraea palmata*, *Ulmaria lobata*, and *Filipendula lobata* (Robinson 1906).

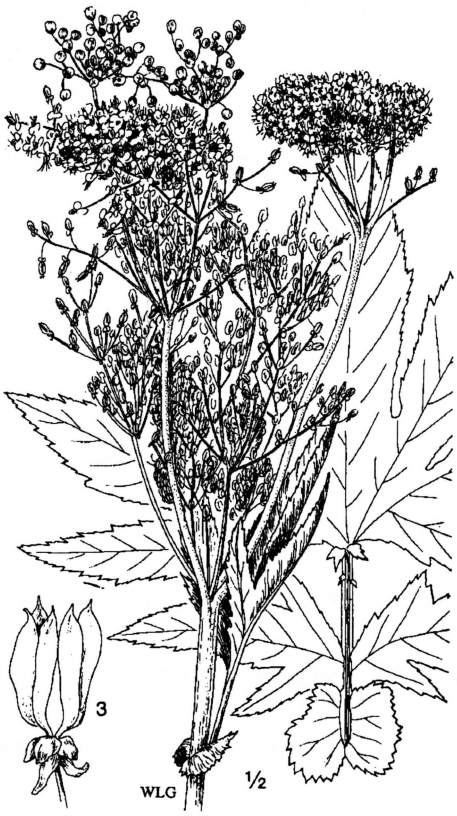
*F. rubra* has antiseptic properties due to the content of salicylic acid and is similar to aspirin in its pain-relieving ability. It was used for the treatment of influenza, gout rheumatism, arthritis, fever, bladder and kidney illnesses, diarrhea, dropsy, and water retention. It was also used as a wash for wounds. The plant has astringent properties due to its tannin content and the Plains Indians used it for the treatment of skin rashes and illnesses. The roots of *F. rubra* were used as an ingredient in love potion and as a treatment for heart problems. The European species, *Filipendula ulmaria* (L.) Maxim. (queen of the meadow), was used to flavor mead, an alcoholic beverage of fermented

honey and water (Runkel and Roosa 1989). *F. rubra* is also grown as a garden plant, sometimes escaping cultivation.

The plants of *F. rubra* are glabrous, 1-2 m high, and bloom from late June through early August. The leaves are interruptedly pinnate, green and paler green beneath. The terminal leaflets are 10-20 cm broad, and 7-9 parted. The lobes are lance-oblong, incised, and toothed. The lateral leaflets are sessile, 3-5 parted, and occur in pairs of 2-5. The inflorescence is 10-25 cm across and about 38 cm long, and panicled, flowering from the bottom upward. They consist of 200 to 1,000 slightly fragrant flowers with 5-15 erect pistils (Aspinwall and Christian 1992a) and numerous stamens (Runkel and Roosa 1989). Each flower possesses five, 2-4 mm long, pink petals with narrowed bases. The infrutescence, which is an aggregate of achenes, can produce over 5,000 seeds that develop in late August and mature in early September. The achenes, which are small, dry, one-seeded fruits, are glabrous, erect, lanceolate, and 3-10 mm in length (Gleason and Cronquist 1991, Fernald 1950). Line drawings of *F. rubra* can be found in Fig. 1, photographs of the plant and inflorescence can be found in Fig. A2, and micrographs of the flower bud, seed, filament, anther, and leaf can be found in Fig. A3.

*F. rubra* represents a suitable species to investigate factors that influence plant reproductive success and distribution because it is clonal, self-incompatible, occurs in small population sizes at the study sites, and has the potential for abundant seed production. As a clonal species, *F. rubra* reproduces both asexually through rhizomes and sexually from seed. Although each inflorescence can produce substantial amounts of seed, most seeds are inviable because *F. rubra* is self-incompatible (Aspinwall and Christian 1992a). Even though some pollination can occur through wind-dispersed

Figure 1. Line drawings of *Filipendula rubra* (Holmgren 1998, Strausbaugh and Core 1971) and hand drawing of *F. rubra* from herbarium specimen (A. Mariolle Biltmore Herbarium, New York Botanical Garden, July 27, 1897).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pollen, the majority of pollination occurs by insects such as sweat bees and solitary bees (Halictidae), honeybees (Apidae), soldier beetles (Cantharidae), house flies (Muscidae), and flower flies (Syrphidae) (Aspinwall and Christian 1992a). Knowledge of the life history of *F. rubra* will provide insight into the conservation of this species and its unique habitat.

### ***Filipendula rubra* in Fens**

Stuckey and Denny (1981) described fens as "alkaline wetlands occurring within the glaciated regions of North America." In comparison, Mitsch and Gosselink (2000) referred to fens as "open peatland systems that generally receive some drainage from surrounding mineral soils and are often covered by grasses, sedges, or reeds." Fens are characterized by plant species especially adapted to areas adjacent to, on, or at the base of somewhat porous, calcareous gravel (Stuckey and Denny 1981). Artesian springs supply these wetlands with moderately hard, cold, clear, and oxygen deficient groundwater containing bicarbonates of calcium, magnesium, and sometimes sulfates (Denny 2003). The main substrate of fens is marl, a grayish-white lime-rich substance formed by precipitated compounds and organic matter, which has a pH between 8 and 8.5 (Stuckey and Denny 1981). Fens typically consist of three zones: 1) the open marl zone, 2) the sedge-meadow zone, and 3) the shrub-meadow zone. *F. rubra* occurs in the sedge-meadow zone which has the largest number of plants with the greatest diversity of species and density of individuals. The sedge-meadow zone is characterized by sedge peat that covers the marl substrate and is dominated by taller herbaceous plants and some small shrubs. The typical pH of a rich or minerotrophic fen is between 5.6 and 7.5

(Mitsch and Gosselink 2000). Fens in Ohio occur primarily in the west-central and northeastern glaciated regions of the state. In west-central Ohio, fens occur in the Miami region (mainly a calcareous, glaciated region; till plain) in Champaign, Clark, Greene, Logan, and Miami counties. In northeastern Ohio, fens occur in the northeastern or glaciated Allegheny Plateau in Holmes, Portage, Stark, and Summit counties (Schaffner 1932). Location of nature preserves where *F. rubra* occurs within the glaciated region of Ohio can be found in Fig. 2.

The fens in west-central Ohio are considered prairie fens because the plant species found there are typically associated with wet prairies. Fens in northeast Ohio are considered bog fens because the plant species found there are typically associated with acidic bogs (Stuckey and Denny 1981). However, some fens in Ohio contain plant species of both bog and prairie fens regardless of geographic area. Although most commonly found in prairie fens, *F. rubra* can also tolerate bog fens and is a plant indicator of wet prairies (Sears 1926, Stuckey and Denney 1981) and fens (Gordon 1969). In addition, *F. rubra* is considered a plant species typical of the western prairies (Forsyth 2003) and a plant relict of the postglacial Xerothermic Period (Denny 2003). Although only potentially threatened in Ohio (Choesin and Boerner 2000, Cooperrider 1982, Ohio Department of Natural Resources 1987), *F. rubra* is listed as threatened in Iowa (Iowa Department of Natural Resources 1999) and Michigan (Michigan Department of Natural Resources 1999), endangered in Illinois (Illinois Department of Natural Resources 1999), Maryland (Maryland Department of Natural Resources 1997), New Jersey (New Jersey Department of Environmental Protection and Energy 2001) and

Figure 2. Location of nature preserves where *Filipendula rubra* occurs within the glaciated region of Ohio. The following are abbreviations for the preserves: Betsch (Betsch Fen), Gallagher (Gallagher/Springfield Fen), Jackson (Jackson Bog), Kiser (Kiser Lake Wetlands), Liberty (Owens/Liberty Fen), Prairie (Prairie Road Fen), and Zimmerman (Zimmerman Prairie). All nature preserves are managed by the Ohio Department of Natural Resources (ODNR), Division of Natural Areas and Preserves (DNAP) except for Betsch Fen which is managed by the Nature Conservancy. Privately owned land where *F. rubra* occurs is not included on this map (Garono 1986).


ASHTABULA
LAKE
GEAUGA
TRUMBULL
CUYAHOGA
LORAIN
MEDINA
SUMMIT
MAHONING
STARK
COLUMBIANA
Jackson
WAYNE
ASHLAND
RICHLAND
WILLIAMS
FULTON
LUCAS
OTTAWA
SANDUSKY
ERIE
HURON
SENECA
WOOD
HENRY
DEFIANCE
PAULDING
PUTNAM
HANCOCK
VAN WERT
WYANDOT
CRAWFORD
ALLEN
HARDIN
MARION
MERCER
AUGLAIZE
MORROW
KNOX
Liberty
LOGAN
SHELBY
UNION
DELAWARE
CHAMPAIGN
Kiser
MIAMI
DARKE
LICKING
Gallagher
CLARK
FRANKLIN
MADISON
Prairie
PREBLE
MONTGOMERY
Zimmerman
GREENE
FAYETTE
PICKAWAY
FAIRFIELD
Betsch
BUTLER
WARREN
CLINTON
ROSS
HAMILTON
CLERMONT
HIGHLAND
BROWN
ADAMS
SCIOTO
PIKE
JACKSON
VINTON
HOCKING
ATHENS
MEIGS
GALLIA
LAWRENCE
PERRY
MORGAN
WASHINGTON
NOBLE
MONROE
BELMONT
GUERNSEY
MUSKINGUM
COSHOCTON
TUSCARAWAS
HARRISON
JEFFERSON
CARROLL
HOLMES
UNGLACIATED
Wisconsinan
Illinoian
Kansan

North Carolina (North Carolina Department of Agriculture 1998), imperiled in Missouri (Missouri Department of Natural Resources 2001), and rare in the southern Appalachian wetlands (Murdock 1994).

**Factors Influencing Seed Production**

Recent studies have tested hypotheses regarding the influence of various factors on seed production (Agren 1996, Aspinwall and Christian 1992 a and b, Bosch and Waser 1999 and 2001, de Jong and Klinkhamer 1989, Garwood and Horvitz 1985, Gomez 1996, Ishii and Kadono 2002, Kunin 1992, 1993, and 1997, Mustajarvi et al. 2001, Platt et al. 1974, Snow 1982, Steffan-Dewenter and Tscharntke 1999, Zimmerman and Pyke 1988). These factors may be biotic or abiotic. Biotic factors include competition, pollination, predation, and disease. Abiotic factors include water availability, soil nutrients and sunlight. The biotic factors that were investigated in this study were competition and pollination.

*Competition*

The aspect of competition that was investigated in this study was the effect of surrounding plant density on seed production. In habitats with high plant densities, more energy is allocated to producing seed than allocated to vegetative growth (Platt et al. 1974). This theory is based on a model proposed by Williams (1977) whereby seed production is favored as a way to spread to new and more favorable sites and to provide genetic variability for clonal species (Abrahamson 1975a, Ogden 1974). In habitats with low plant densities, more energy is allocated to vegetative growth than to producing seed

(Abrahamson 1975b, Ogden 1974). Vegetative reproduction is favored at low plant densities by clonal species as a low risk way to spread locally and become successfully established in an area (Abrahamson 1975a, Holler and Abrahamson 1977). Therefore, seed production is expected to increase as plant density increases (Ogden 1974, Abrahamson 1975a).

However, in a study of two shortgrass species, blue grama (*Bouteloua gracilis* (H.B.K) Lag. Ex Steud.) (Poaceae) and buffalo grass (*Buchloe dactyloides* (Nutt.) Engelm.) (Poaceae), seed production was found to be higher for plants growing at low densities (Aguiar et al. 2001). In a similar study of the Virginia strawberry (*Fragaria virginiana* Duchesne) (Rosaceae), seed production did not differ between high and low plant densities (Holler and Abrahamson 1977).

*Pollination*

The aspect of pollination that was investigated in this study was pollinator abundance. In particular, self-incompatible plants are susceptible to changes in pollinator abundance because they cannot compensate by self-pollinating (Mustajarvi et al. 2001). Lack of cross-pollination can cause self-incompatible, clonal plants to have decreased seed production (Ishii and Kadono 2002).

In a study of two self-incompatible crucifers, charlock mustard (*Sinapis arvensis* L.) (Brassicaceae) and the cultivated radish (*Raphanus sativus* L.) (Brassicaceae), seed production was positively correlated with pollinator abundance. This was due to habitat isolation, which contributed to decreased pollinator abundance and seed production (Steffan-Dewenter and Tscharntke 1999). However, in a study of the crucifer

*Moricandia moricandioides* (Boiss) Heywood (Brassicaceae), pollinator abundance was not correlated with seed production. Decreased seed production was caused by herbivory, which in turn affected the distribution of the plant species (Gomez 1996).

# METHODS

## Study Design

To evaluate the factors that influence the reproductive success and distribution of *F. rubra*, seed production, *F. rubra* plant density, total plant density, and pollinator abundance were measured at four fens from June through September of 2002: Jackson Bog in northeast Ohio and Gallagher/Springfield Fen, Kiser Lake Wetlands, and Prairie Road Fen in west-central Ohio. Plants (n = 20) at each site were selected and tagged in order to determine seed production and pollinator abundance. Plots (n = 15) were selected that included the 20 tagged plants in order to determine *F. rubra* plant density and total plant density. Because certain habitat features may be associated with the reproductive success of *F. rubra*, associated plant species and soil composition were collected to investigate indirect influences on seed production. In addition, the geographical distribution was determined based on herbarium records for both historic (<1960) and recent (≥1960) time periods, a distribution map was generated, and the characteristic habitat was determined.

This research was designed to investigate the hypotheses that plant density and pollinator abundance influence the seed production of *F. rubra*. Specifically, the null hypotheses were:

1. Seed production does not differ between populations.
2. *F. rubra* plant density does not differ between populations.
3. Total plant density does not differ between populations.
4. Pollinator abundance does not differ between populations.

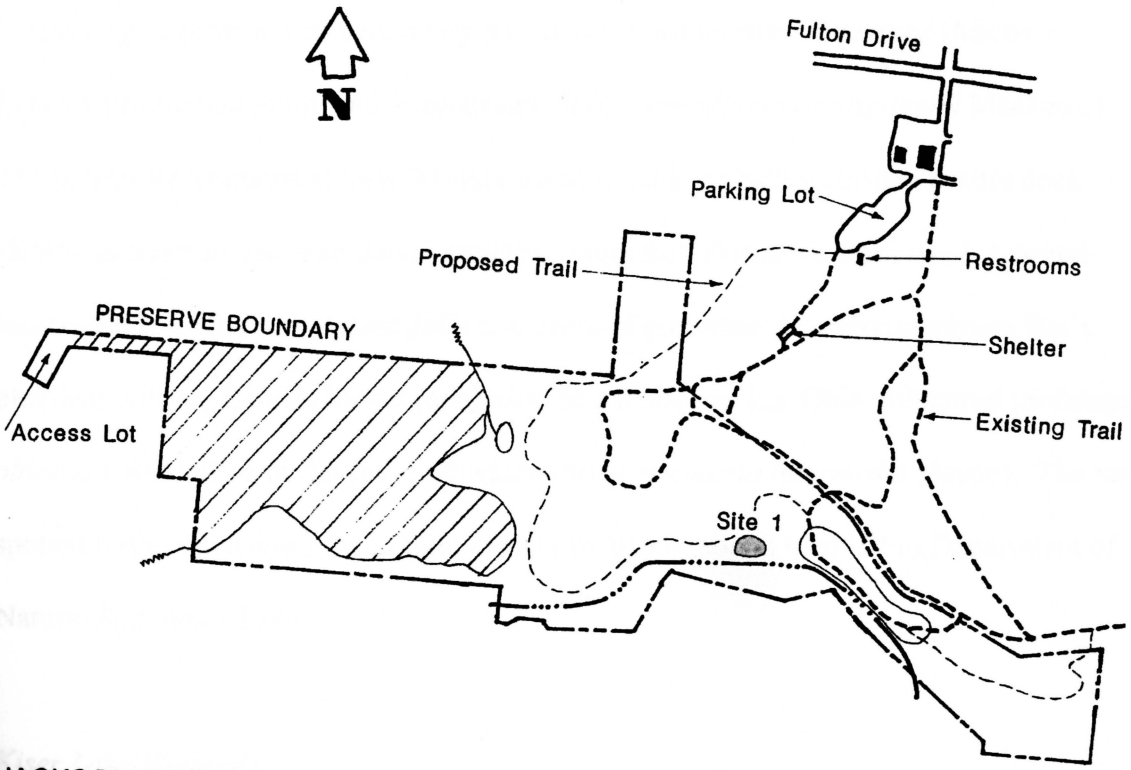
**Study Sites**

Jackson Bog in northeast Ohio and Gallagher/Springfield Fen, Kiser Lake Wetlands, and Prairie Road Fen in west-central Ohio were chosen for the study of *F. rubra*. All study sites are state nature preserves managed by the Ohio Department of Natural Resources (ODNR), Division of Natural Areas and Preserves (DNAP). Three criteria were used for selection of study sites: the presence of *F. rubra*, accessibility, and distance from Mahoning County.

*Jackson Bog*

Jackson Bog, a boreal or northern fen, is a 2.3 ha preserve located in northern Stark County, Ohio (Fig. 3). The fen contains at least 25 state-listed species of plants and is considered one of the finest remaining fens in Ohio by the Ohio Department of Natural Resources. Jackson Bog is only one of two fens in Ohio where the northern pitcher-plant (*Sarracenia purpurea* L.) can be found. The other fen where northern pitcher-plant can be found is Karlo Fen State Nature Preserve in Summit County. Unique plant species found at Jackson Bog include shrubby cinquefoil (*Potentilla fruticosa* L.), smaller fringed gentian (*Gentiana crinita* Froel.), hooded ladies'-tresses (*Spiranthes romanzoffiana* Cham.), tufted hairgrass (*Deschampsia cespitosa* (L.) P. Beauv.), false asphodel (*Tofieldia glutinosa* (Michx.) Pers.), marsh arrow-grass *(Triglochin palustre* L.), round-leaved sundew (*Drosera rotundifolia* L.), grass-of-parnassus (*Parnassia glauca* Raf.), and Kalm's lobelia (*Lobelia kalmii* L.) (Ohio Department of Natural Resources 1996).

Figure 3. Location of Jackson Bog State Nature Preserve, Stark County, Ohio. Site one highlighted in green within Jackson Bog indicates the location of the study site.


**JACKSON BOG**
**Stark County**

**1"=500'**

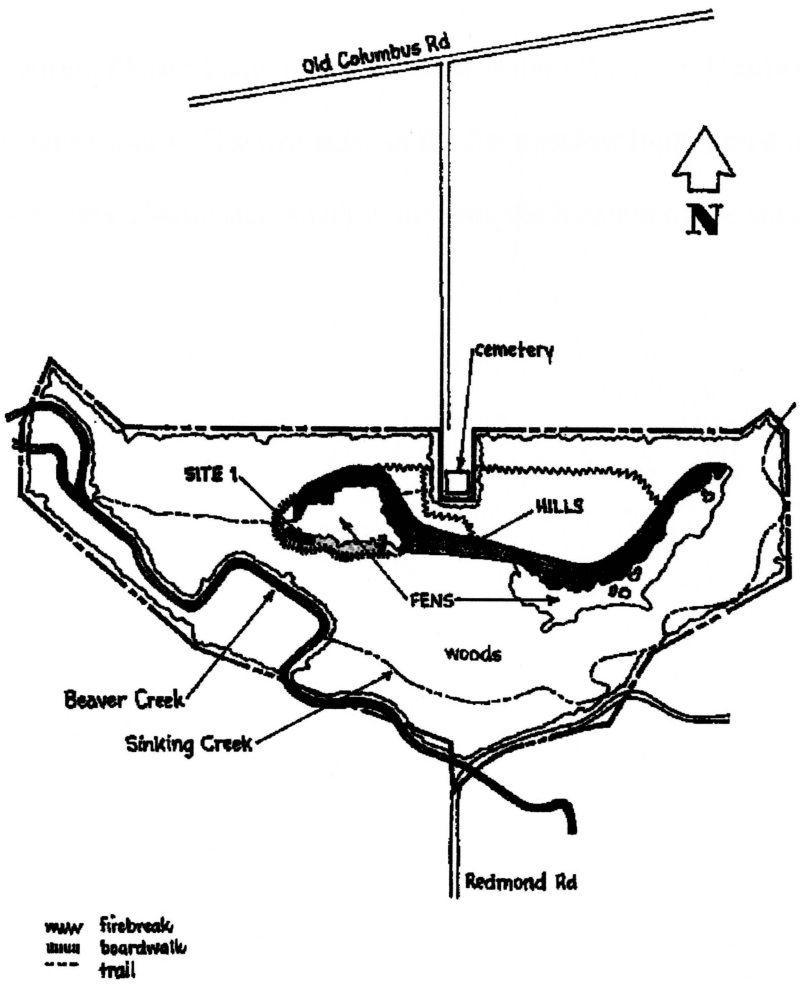
*Gallagher/Springfield Fen*

Gallagher/Springfield Fen is an 81 ha preserve located in Clark County, Ohio (Fig. 4). Although considered a prairie fen, it supports both northern and prairie species. A prairie savanna, considered a rare plant community in Ohio, lies above the fen containing xeric prairie species such as nodding wild onion (*Allium cernuum* Roth), false garlic (*Nothoscordum bivalve* (L.) Britt.), little bluestem (*Andropogon scoparius* Michx.), sideoats gramma grass (*Bouteloua curtipendula* (Michx.) BSP.), big bluestem (*Andropogon gerardi* Vitman), hoary puccoon (*Lithospermum canescens* (Michx.) Lehm.), prairie buttercup, and false gromwell (*Onosmodium hispidissimum* Mackenz.). The prairie fen contains at least 30 state-listed species including cut-leaf prairie dock (*Silphium terebinthinaceum* Jacq.) shrubby cinquefoil (*Potentilla fruticosa* L.), round-leaved sundew (*Drosera rotundifolia* L.), grass-of-parnassus (*Parnassia glauca* Raf.), blue-leaf willow, Canada burnet (*Sanguisorba canadensis* L.), Ohio goldenrod (*Solidago ohioensis* Riddell), and flat-leaved bladderwort (*Utricularia intermedia* Hayne). The rare spotted turtle (*Clemmys guttata* Schneider) can also be found here (Ohio Department of Natural Resources 1996).

*Kiser Lake Wetlands*

Kiser Lake Wetlands, Headwaters section, is a 20.5 ha preserve located in Champaign County, Ohio (Fig. 5). It consists of a fen meadow and marsh. Unique plant species found here include shrubby cinquefoil (*Potentilla fruticosa* L.), Kalm's lobelia (*Lobelia kalmii* L.), grass-of-parnassus (*Parnassia glauca* Raf.), smaller fringed gentian (*Gentiana crinita* Froel.), big bluestem (*Andropogon gerardi* Vitman), Ohio goldenrod

Figure 4. Location of Gallagher/Springfield Fen State Nature Preserve, Clark County, Ohio. Site one highlighted in green within Gallagher/Springfield Fen indicates the location of the study site.

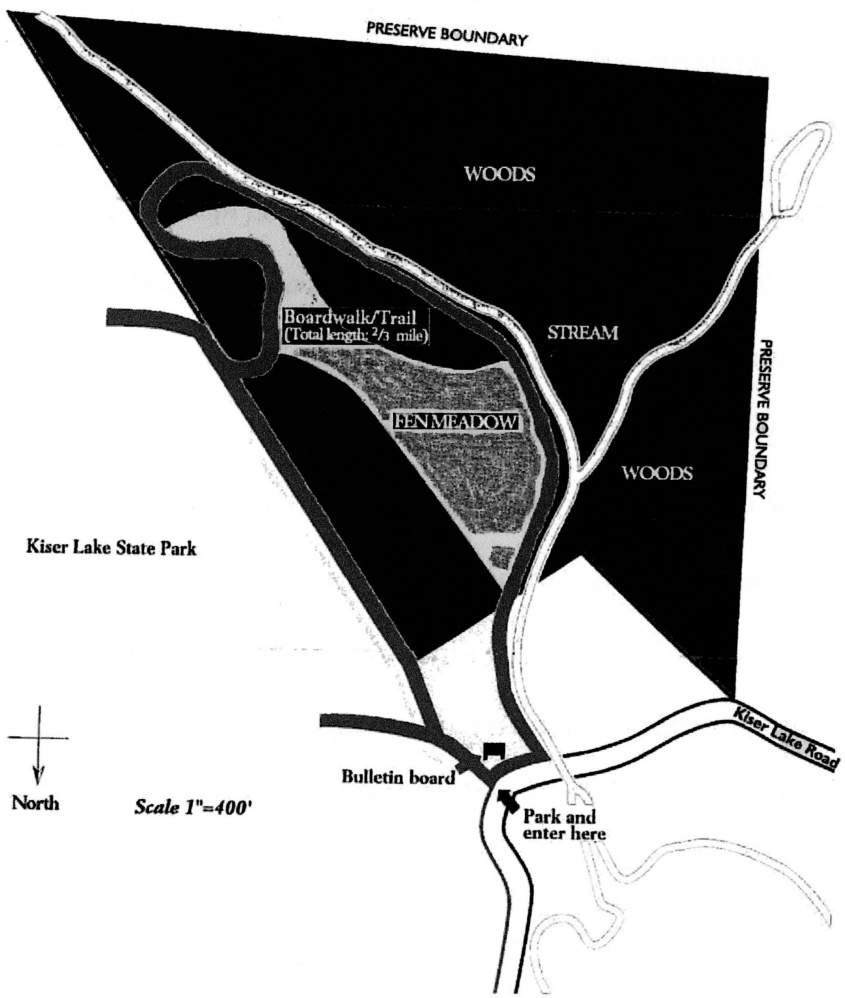




SPRINGFIELD/GALLAGHER FEN
Clark County
1"=620'

Figure 5. Location of Kiser Lake Wetlands, State Nature Preserve, Headwaters section, Champaign County, Ohio. The two areas in the fen meadow highlighted in green within Kiser Lake Wetlands, Headwaters section, indicate the location of the study site.


# Kiser Lake Wetlands

## Headwaters Section



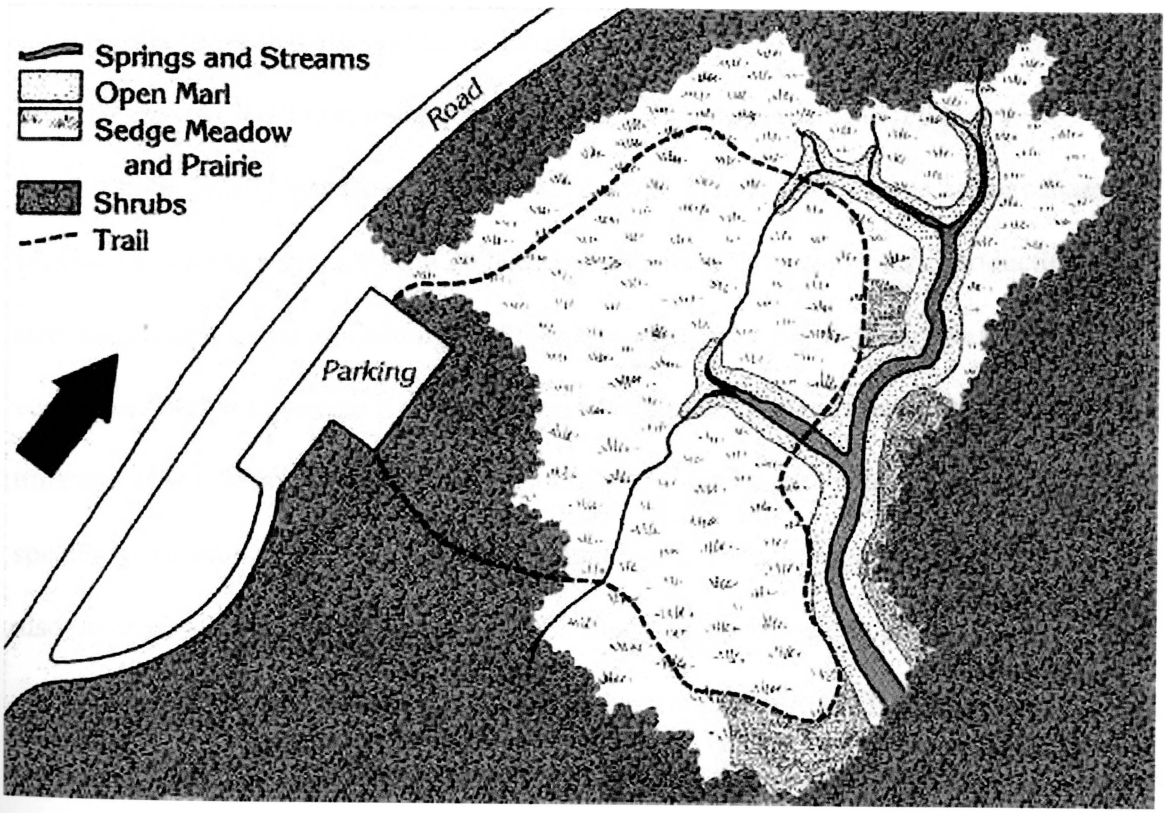
(*Solidago ohioensis* Riddell), and poison sumac (*Rhus [Toxicodendron] vernix* L.) (Ohio Department of Natural Resources 1996).

*Prairie Road Fen*

Prairie Road Fen is a 38.5 ha preserve located in southeastern Clark County, Ohio (Fig. 6). It is considered by the Ohio Department of Natural Resources to be one of Ohio's largest and finest prairie fens supporting at least 25 state-listed plant species. The prairie fen contains both northern species and prairie species. Northern species found here are Canada burnet (*Sanguisorba canadensis* L.), shrubby cinquefoil (*Potentilla fruticosa* L.), Baltic rush (*Juncus balticus* Willd), arrow-grass (*Triglochin maritima* L.), marsh arrow-grass *(Triglochin palustre* L.), grass-of-parnassus (*Parnassia glauca* Raf.), and round-leaved sundew (*Drosera rotundifolia* L.). Prairie species include false gromwell (*Onosmodium hispidissimum* Mackenz.), smaller fringed gentian (*Gentiana procera* Holm), big bluestem (*Andropogon gerardi* Vitman), prairie dropseed (*Sporobolus heterolepis* Gray), spiked blazing-star (*Liatris spicata* (L.) Willd.), prairie rattlesnake-root (*Prenanthes racemosa*), Ohio goldenrod (*Solidago ohioensis* Riddell), and queen of the prairie (*Filipendula rubra* (Hill) B.L. Robinson). The rare spotted turtle (*Clemmys guttata* Schneider) and the massasauga rattlesnake (*Sistrurus catenatus* Rafinesque) can also be found here (Ohio Department of Natural Resources 1996).

Figure 6. Location of Prairie Road Fen State Nature Preserve, Clark County, Ohio. The three areas of the sedge meadow and prairie highlighted in green within Prairie Road Fen indicate the location of the study site.


Clark County
Moorefield Township


Springs and Streams
Open Marl
Sedge Meadow and Prairie
Shrubs
Trail
Road
Parking

**Data Collection**

Seed production was determined in late June 2002 by selecting and tagging 20 flowering *F. rubra* plants with identification labels. In early September 2002, each infructescence per plant was collected in a brown paper bag. Seed production was determined by removing all seeds from the infructescence and counting the total number of seeds per plant. A subsample of 20 seeds per plant were then randomly selected and measured using a metric ruler to determine if they were viable or inviable. Viable seeds are typically those that are four times longer (Aspinwall and Christian 1992a) than inviable seeds or 7-10 mm in length due to the presence of an expanded ovary.

Plant density was determined in late July 2002 in at least 15 one meter square vegetative plots that included the 20 tagged plants used to measure seed production. Plot size was chosen based on Oosting (1956) who suggested 1 $m^2$ plots for medium sized vegetation analysis because it provides data comparable to that of larger plots with less time and effort. Stem-count analysis was utilized to determine the total number of all species by counting each stem as an individual plant. *F. rubra* plant density per plot was also determined at this time by counting the stem of each blooming plant.

Pollinator abundance of *F. rubra* was determined on July 11, 2002 (Jackson Bog), July 16, 2002 (Kiser Lake Wetlands), July 17, 2002 (Prairie Road Fen), and July 18, 2002 (Gallagher/Springfield Fen). At each study site, the 20 tagged plants that were used to measure seed production were observed for 15 min per plant between the hours of 10:00 a.m. and 3:00 p.m. for a total of five hours per study site. Pollinator abundance was determined by counting the total number of insects per plant and recording whether the insects were passive pollinators (stationary on an inflorescence) or active pollinators

(visiting two or more inflorescences). One representative insect specimen from each plant was collected for identification. The insect specimens were identified to genus and species whenever possible by Dr. John Rawlins, Carnegie Museum of Natural History. All insect specimens were deposited at the Carnegie Museum of Natural History. Nomenclature conforms to that of Arnett (1985). Observations were also made at this time for the presence of pests on *F. rubra* plants.

Associated plant species were collected within two meters of *F. rubra* plants at all the study sites from May through September of 2001 and 2002. The specimens were identified, referenced as native or non-native (Weishaupt 1971), and used to generate a list of associated plant species for each study site. Voucher specimens were deposited in the Herbarium of Youngstown State University (YUO). Nomenclature conforms to that of Gleason and Cronquist (1991). The associated plant species lists from each study site were then compared to determine which plant species were found growing in association with *F. rubra*.

Soil samples were collected at Jackson Bog, Gallagher/Springfield Fen, Kiser Lake Wetlands, and Prairie Road Fen in order to compare soil characteristics between the study sites. At each study site, three random soil samples were collected to a depth of 15-20 cm with a hand trowel and placed into plastic bags (Horn 1997). The three samples were then combined into a composite sample for each study site and analyzed by the Pennsylvania State University Agricultural Analytical Services Laboratory for pH, P lb/A, exchangeable cations (acidity, K, Mg, Ca, and CEC), and percentage saturation of the CEC (K, Mg, and Ca) (Isaac 2000). Soil surveys were also used to determine soil descriptions and to generate soil survey maps for the study sites.

The geographical distribution was determined by examining herbarium specimen identification labels from herbaria throughout the expected range of *F. rubra*. Date and location information were recorded and used to compare where the plant occurred historically (<1960) and recently (≥1960). Habitat descriptions from the herbarium specimen identification labels were also used to determine the characteristic habitat of *F. rubra*.

**Statistical Analysis**

To examine the factors that influence the reproductive success of *F. rubra*, the following variables were analyzed: (1) *F. rubra* plant density (2) total plant density (3) pollinator abundance (4) seed production (5) viable seed production, and (6) the population size of *F. rubra*. The data was tested for normality (Kolmogorov-Smirnov test) and heterogeneity of variance (Levene's test) to satisfy assumptions of the statistical tests. Data that contained values of zero were log transformed (log(x+1)) (Zar 1999). Data was analyzed using SPSS software, v.8.0 (SPSS 1998).

A Kruskal-Wallis one-way analysis of variance (ANOVA) and Tukey-type multiple comparisons were used to test for differences in *F. rubra* plant density, total plant density, pollinator abundance, seed production, and viable seed production between the study sites. Spearman rank correlation was used to analyze relationships between *F. rubra* plant density and pollinator abundance, seed production, and viable seed production, pollinator abundance and viable seed production, and the population size of *F. rubra* and pollinator abundance.

# RESULTS

## Factors Influencing Seed Production

*F. rubra* plant density was highest at Jackson Bog and lowest at Kiser Lake Wetlands (Table B1).Total plant density was highest at Jackson Bog and lowest at Prairie Road Fen (Table B2). Pollinator abundance was highest at Gallagher/Springfield Fen and lowest at Jackson Bog (Table B3). Seed production was highest at Kiser Lake Wetlands and lowest at Prairie Road Fen (Table B4). Viable seed production was most abundant at Kiser Lake Wetlands and least abundant at Gallagher/Springfield Fen (Table B5). Mean (± 1 SE) data for *F. rubra* plant density, total plant density, pollinator abundance, seed production and viable seed production at the study sites is listed in Table 1. The population size of blooming *F. rubra* plants was greatest at Gallagher/Springfield Fen and lowest at Jackson Bog. Population sizes were n = 30 (Jackson Bog), n = 269 (Gallagher/Springfield Fen), n = 130 (Kiser Lake Wetlands), and n = 81 (Prairie Road Fen).

Jackson Bog differed significantly from Gallagher/Springfield Fen and Prairie Road Fen in *F. rubra* plant density. Jackson Bog differed significantly from Gallagher/Springfield Fen and Prairie Road Fen, and Kiser Lake Wetlands differed significantly from Prairie Road Fen in plant density ($P < 0.01$). Jackson Bog and Gallagher/Springfield Fen differed significantly in pollinator abundance ($P < 0.01$). Kiser Lake Wetlands differed significantly from Gallagher/Springfield Fen and Prairie Road Fen, and Jackson Bog differed significantly from Prairie Road Fen in seed production ($P < 0.01$). Gallagher/Springfield Fen differed significantly from Jackson

Table 1. Mean (± 1 SE) for *Filipendula rubra* plant density, total plant density, pollinator abundance, seed production, and viable seed production at the study sites.

## Mean (± 1 SE) Data

| Factors | Study Sites | | | |
|---|---|---|---|---|
| | Jackson Bog | Gallagher/Springfield Fen | Kiser Lake Wetlands | Prairie Road Fen |
| ***F. rubra* Plant Density # Plants/1m$^2$** | 4.42 ± 0.61 | 2.06 ± 0.40 | 2.42 ± 0.59 | 3.77 ± 0.39 |
| **Total Plant Density # Plants/1m$^2$** | 119 ± 10.59 | 87 ± 3.29 | 112 ± 8.05 | 70 ± 4.06 |
| **Pollinator Abundance # Insects/15min/Plant** | 1.95 ± 0.27 | 2.90 ± 0.30 | 2.55 ± 0.28 | 2.25 ± 0.16 |
| **Seed Production # Seeds/Plant** | 1483.2 ± 155.42 | 993.4 ± 92.44 | 2166.6 ± 282.96 | 865.2 ± 91.41 |
| **Viable Seed Production # Viable Seeds/20 Seeds/Plant** | 4.80 ± 0.69 | 1.95 ± 0.92 | 8.65 ± 1.80 | 5.00 ± 0.87 |

Bog, Kiser Lake Wetlands and Prairie Road Fen in viable seed production ($P < 0.01$) (Figure 7).

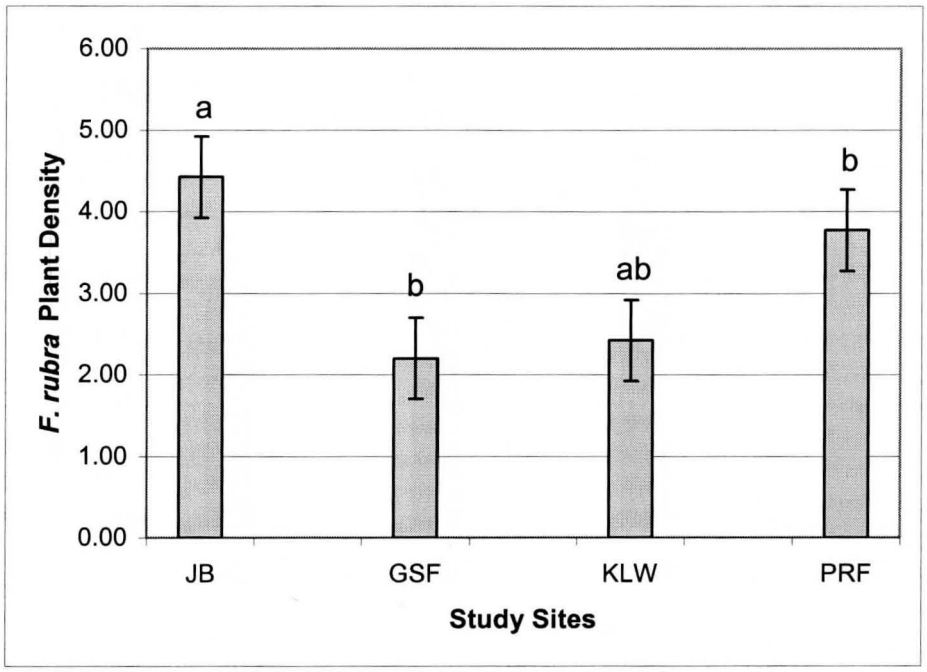
There were no significant correlations between mean *F. rubra* plant density and mean viable seed production ($r_s = 0.0$, $n = 4$, $P = 0.50$), mean pollinator abundance and mean viable seed production ($r_s = -0.8$, $n = 4$, $P = 0.10$), and mean total plant density and mean seed production ($r_s = 0.8$, $n = 4$, $P = 0.10$) (Fig. 8). However, mean *F. rubra* plant density and mean pollinator abundance ($r_s = -1.0$, $n = 4$, $P < 0.01$) and the population size of *F. rubra* and pollinator abundance were significantly correlated ($r_s = 1.0$, $n = 4$, $P < 0.01$) (Fig. 8).

**Pollinators and Pests**

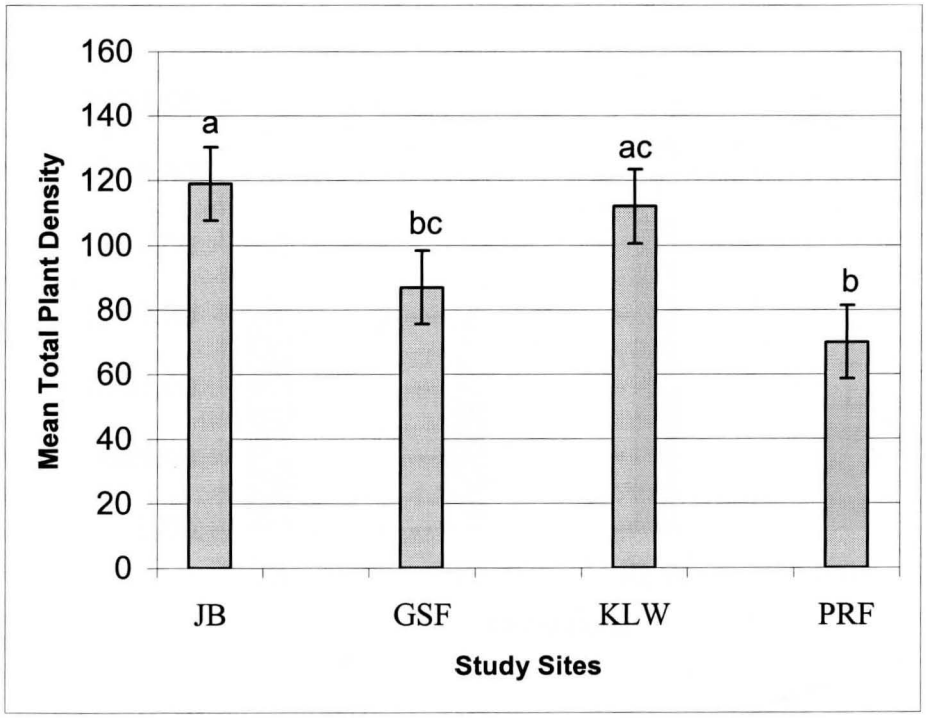
The active pollinators of *F. rubra* were flies (Diptera) and bees (Hymenoptera) and the passive pollinators were beetles (Coleoptera) and true bugs (Hemiptera) (Table 2). Pollinator abundance was relatively low compared to other nearby flowering plants based on observations at the study sites. A total of 39 pollinators were counted at Jackson Bog, 58 at Gallagher/Springfield Fen, 52 at Kiser Lake Wetlands, and 45 at Prairie Road Fen from the 20 plants observed for a total of five hours per study site (Table B3). This data averages to only 1.95 pollinators per plant per 15 min at Jackson Bog, 2.9 at Gallagher/Springfield Fen, 2.55 at Kiser Lake Wetlands, and 2.25 at Prairie Road Fen.

Figure 7. These graphs show comparisons between the study sites: A- mean *Filipendula rubra* plant density ($P < 0.01$), B- total plant density ($P < 0.01$), C- mean pollinator abundance ($P < 0.01$), D- mean seed production ($P < 0.01$), and E- mean viable seed production ($P < 0.01$). The following are abbreviations for the study sites: JB (Jackson Bog), GSF (Gallagher/Springfield Fen), KLW (Kiser Lake Wetlands) and PRF (Prairie Road Fen).

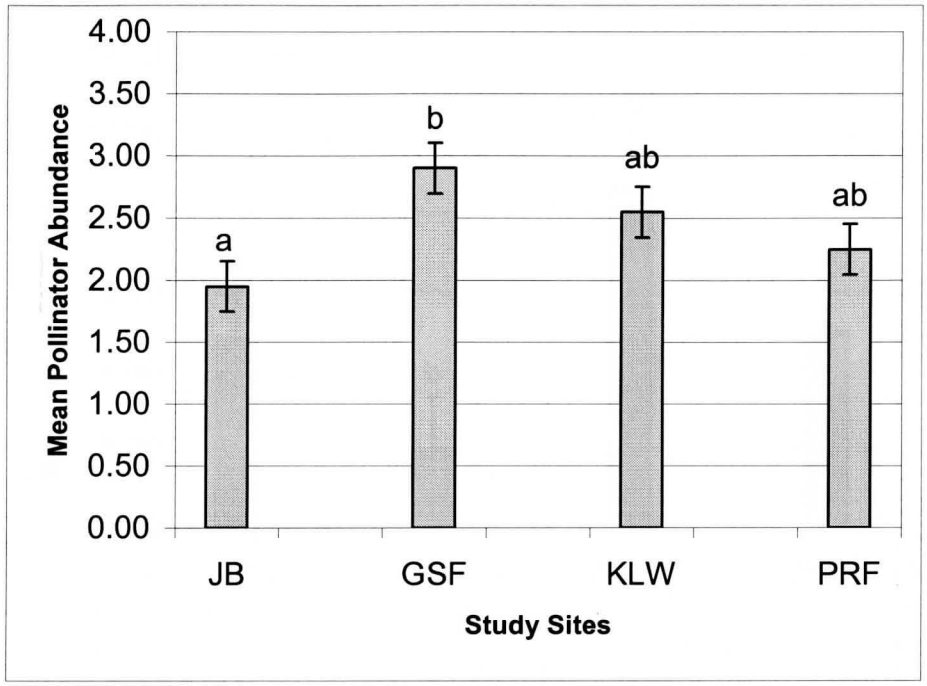
A


6.00
5.00
4.00
3.00
2.00
1.00
0.00
F. rubra Plant Density
a
b
ab
b
JB
GSF
KLW
PRF
Study Sites

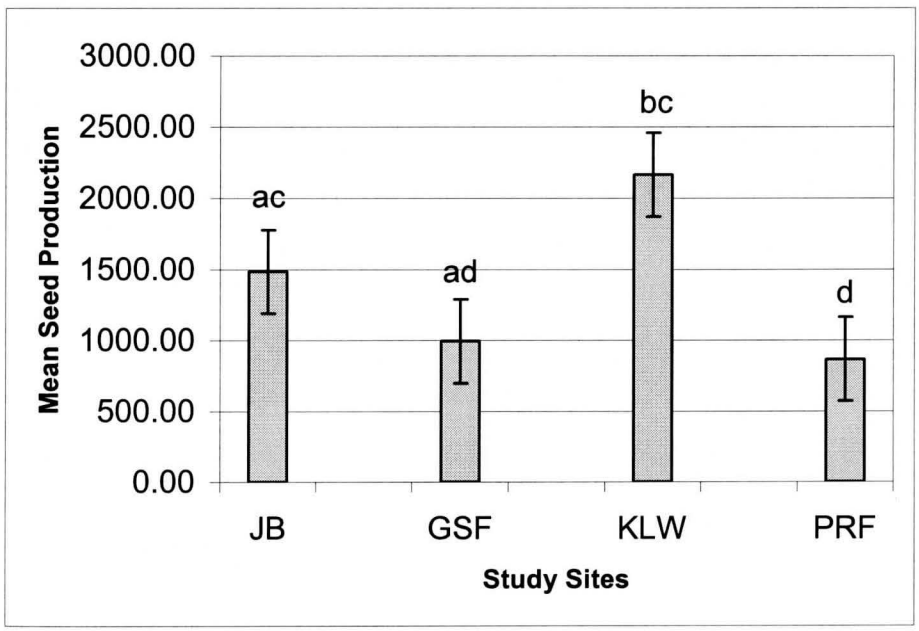
B


160
140
120
100
80
60
40
20
0
Mean Total Plant Density
a
bc
ac
b
JB
GSF
KLW
PRF
Study Sites

C


4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Mean Pollinator Abundance
a
b
ab
ab
JB
GSF
KLW
PRF
Study Sites

D


3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
Mean Seed Production
ac
ad
bc
d
JB
GSF
KLW
PRF
Study Sites

E

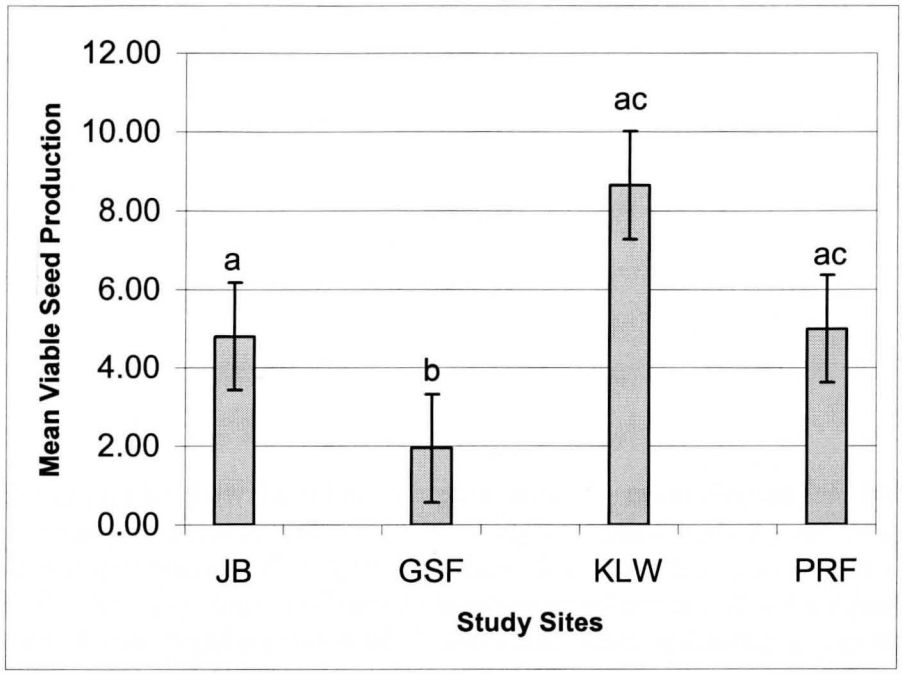
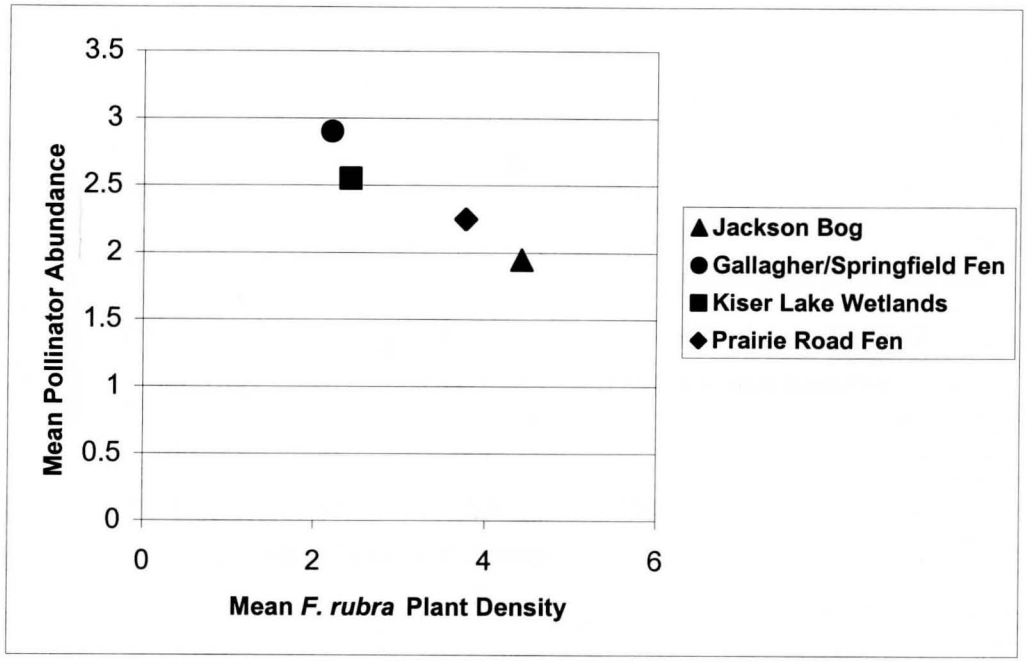
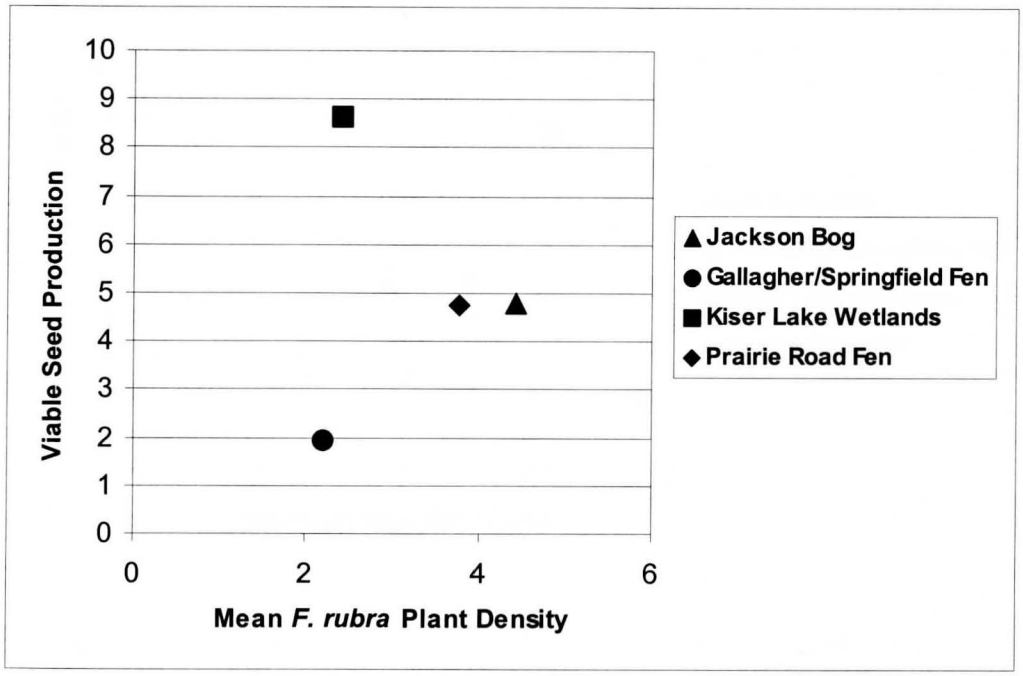

12.00
10.00
8.00
6.00
4.00
2.00
0.00
Mean Viable Seed Production
a
b
ac
ac
JB
GSF
KLW
PRF
Study Sites

Figure 8. These graphs show the relationship between: A- mean *Filipendula rubra* plant density and mean pollinator abundance ($P < 0.01$), B- mean *F. rubra* plant density and mean viable seed production ($P = 0.50$), C- mean total plant density and mean seed production ($P = 0.10$), D- mean pollinator abundance and mean viable seed production ($P = 0.10$), and E- the population size of *F. rubra* and mean pollinator abundance ($P < 0.01$).

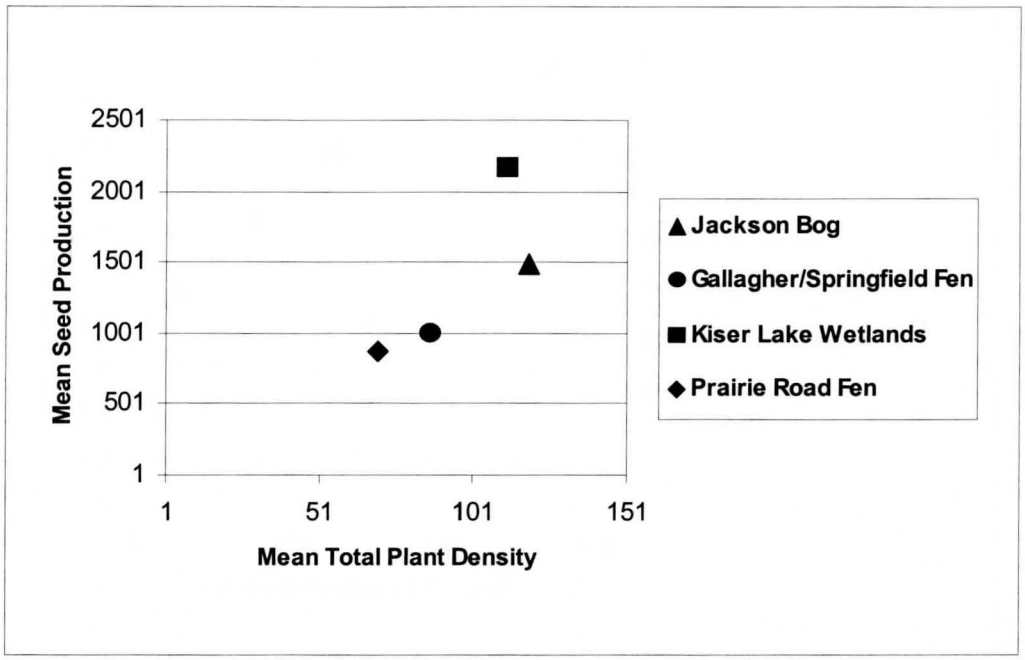
A


3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
Mean Pollinator Abundance
Mean F. rubra Plant Density
Jackson Bog
Gallagher/Springfield Fen
Kiser Lake Wetlands
Prairie Road Fen

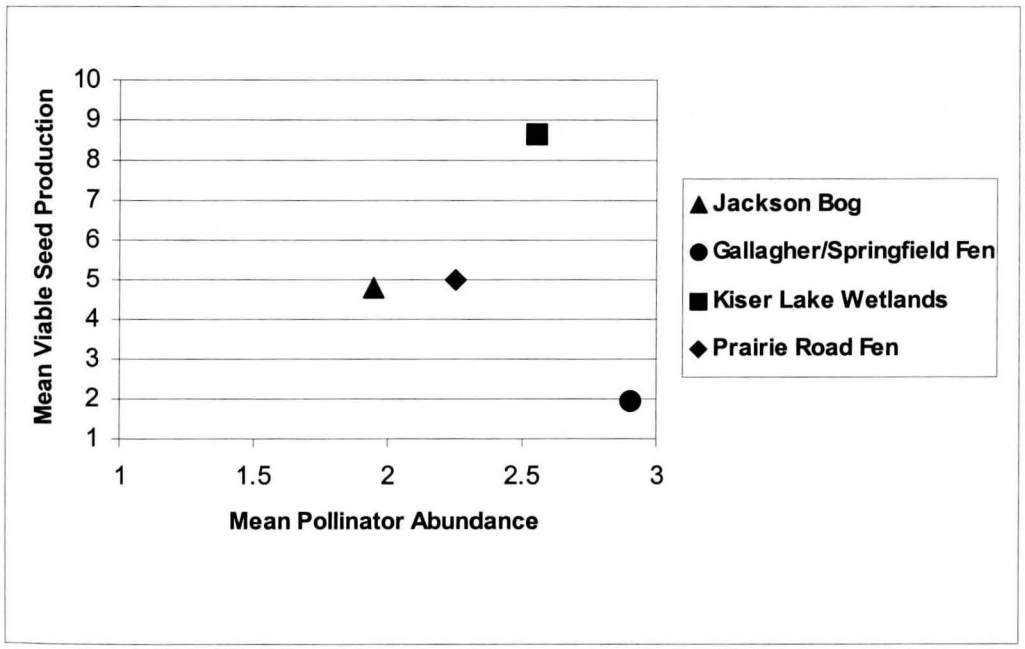
B


10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
Viable Seed Production
Mean F. rubra Plant Density
Jackson Bog
Gallagher/Springfield Fen
Kiser Lake Wetlands
Prairie Road Fen

C


2501
2001
1501
1001
501
1
Mean Seed Production
1
51
101
151
Mean Total Plant Density
Jackson Bog
Gallagher/Springfield Fen
Kiser Lake Wetlands
Prairie Road Fen

D


10
9
8
7
6
5
4
3
2
1
Mean Viable Seed Production
1
1.5
2
2.5
3
Mean Pollinator Abundance
Jackson Bog
Gallagher/Springfield Fen
Kiser Lake Wetlands
Prairie Road Fen

E

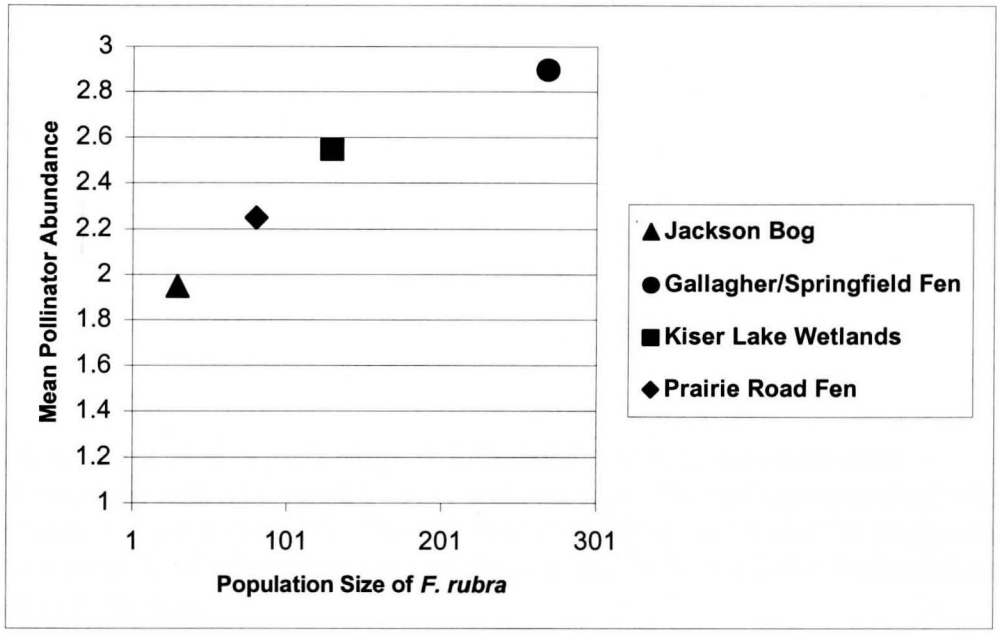

Mean Pollinator Abundance
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
1
101
201
301
Population Size of F. rubra
Jackson Bog
Gallagher/Springfield Fen
Kiser Lake Wetlands
Prairie Road Fen

Table 2. Active and passive pollinators of *Filipendula rubra* at the study sites. Pollinators marked with an asterisk ( * ) are sight records. The pollinator marked with a double asterisk ( ** ) is non-native. The following are abbreviations for the study sites: JB (Jackson Bog), GSF (Gallagher/Springfield Fen), KLW (Kiser Lake Wetlands) and PRF (Prairie Road Fen).

**Active and Passive Pollinators of *Filipendula rubra***

| Taxa | Scientific Name | Common Name | Study Site(s) |
|---|---|---|---|
| ***Active Pollinators*** | | | |
| **Diptera** | | | |
| Asilidae | *Holocephala abdominalis* Jaennicke | robber fly | KLW |
| Bombyliidae | *Anthrax irroratus* Scopoli | bee fly | JB |
| Platystomatidae | *Rivellia quadrifasciata* (Macquart) Robineau-Desvoidy | platystomatid fly | PRF |
| Syrphidae | *Mesograpta* spp. | syrphid fly | JB |
| Syrphidae | *Mesograpta marginata* Say | syrphid fly | GSF, KLW |
| **Hymenoptera** | | | |
| **Apidae | *Apis mellifera* L. | honey bee | KLW |
| *Apidae | *Bombus* spp. | bumblebee | GSF, KLW, PRF |
| Apidae | *Ceratina dupla dupla* (Say) Latreille | small carpenter bee | GSF, PRF |
| Colletidae | *Hylaeus affinis* Smith | yellow-faced bee | PRF |
| Halictidae | *Augochlorella striata* Sandhouse | sweat bee | GSF |
| Halictidae | *Lasioglossum* spp. | sweat bee | JB, KLW |
| Halictidae | *Halictus rubicundus* Latreille | solitary bee | GSF, KLW |
| ***Passive Pollinators*** | | | |
| **Coleoptera** | | | |
| *Chrysomelidae | *Diabrotica* spp. | cucumber beetle | JB, KLW |
| *Cantharidae | *Chauliognathus* spp. | soldier beetle | GSF |
| *Coccinellidae | unidentified | ladybird beetle | GSF, KLW, PRF |
| **Hemiptera** | | | |
| Miridae | unidentified | leaf or plant bug | GSF, KLW |
| Pentatomidae | *Euschistus* spp. | stink bug | JB |
| **Hymenoptera** | | | |
| Formicidae | *Campanotus* spp. | carpenter ant | GSF |

The Japanese beetle *Popillia japonica* Newman from the order Coleoptera (Scarabaeidae) was a common pest of *F. rubra* and was frequently found feeding on the inflorescence and leaves of plants at all the study sites. The pupa of the wavy-lined emerald moth *Synchlora aerata aerata* Fabricius from the order Lepidoptera (Geometridae) was also found in the inflorescence of one *F. rubra* plant at Kiser Lake Wetlands. Crab spiders from the order Arachnida (Thomisidae) were found on the inflorescences of *F. rubra* at all the study sites hunting for insects.

**Associated Plant Species**

The associated plant species collected at Jackson Bog are listed in Table C1. There were a total of 44 associated plant species collected and 9% of the plants were non-native species. Plants collected at Gallagher/Springfield Fen are listed in Table C2. There were a total of 69 associated plant species collected and 6% of the plants were non-native species. The associated plant species collected at Kiser Lake Wetlands are listed in Table C3. There were a total of 49 associated plant species collected and none of the plants were non-native species. The associated plant species collected at Prairie Road Fen are listed in Table C4. There were a total of 57 associated plant species collected and 5% of the plants were non-native species.

Ten species from nine families were associated within two meters of *F. rubra* plants at three of the four study sites and are listed in Table 3. The plant species were marsh fern (*Thelypteris palustris* Schott) (Thelypteridaceae), linear-leaved loosestrife (*Steironema quadriflora* Sims) (Primulaceae), shrubby cinquefoil (*Potentilla fruticosa* L.) (Rosaceae), purple loosestrife (*Lythrum salicaria* L.) (Lythraceae), spotted phlox (*Phlox*

Table 3. Ten plant species associated within two meters of *Filipendula rubra* at the study sites. The following are abbreviations for the study sites: JB (Jackson Bog), GSF (Gallagher/Springfield Fen), KLW (Kiser Lake Wetlands) and PRF (Prairie Road Fen).

## Associated Plant Species Within Two Meters of *Filipendula rubra*

| Study Sites | | | JB | GSF | KLW | PRF |
|---|---|---|---|---|---|---|
| **Family** | **Common Name** | **Scientific Name** | | | | |
| Thelypteridaceae | Marsh Fern | *Thelypteris palustris* Schott | X | | X | X |
| Primulaceae | Linear-leaved Loosestrife | *Steironema quadriflora* Sims | | X | X | X |
| Rosaceae | Shrubby Cinquefoil | *Potentilla fruticosa* L. | X | X | X | X |
| Lythraceae | Purple Loosestrife | *Lythrum salicaria* L. | X | X | | X |
| Polemoniaceae | Spotted Phlox | *Phlox maculata* L. | X | X | X | X |
| Lamiaceae | Self-heal | *Prunella vulgaris* L. | X | X | X | |
| Lamiaceae | Narrow-leaved Mountain Mint | *Pycanthemum tenuifolium* Schrad. | X | | X | X |
| Rubiaceae | Common Cleavers | *Galium aparine* L. | X | X | | X |
| Poaceae | Big Bluestem | *Andropogon gerardi* Vitman | | X | X | X |
| Liliaceae | Starry False Solomon's Seal | *Smilacina stellata* (L.) Desf. | X | X | | X |

*maculata* L.) (Polemoniaceae), self-heal (*Prunella vulgaris* L.) (Lamiaceae), narrow-leaved mountain mint (*Pychathemum tenuifolium* Schrad.) (Lamiaceae), common cleavers (*Galium aparine* L.) (Rubiaceae), big bluestem (*Andropogon gerardi* Vitman) (Poaceae), and starry false Solomon's seal (*Smilacina stellata* (L.) Desf.) (Liliaceae). Two of these species, spotted phlox and shrubby cinquefoil, were found at all four study sites (Table 3).

**Soil Composition**

Analyses from study sites show that the soils in western Ohio are neutral, with a pH of 7.3 at Gallagher/Springfield Fen, 7.4 at Kiser Lake Wetlands, and 7.0 at Prairie Road Fen. Jackson Bog in northeast Ohio was slightly acidic, with a pH of 6.3 (Table 4). All study sites had nutrient levels of phosphate ($P_2O_5$) and potash ($K_2O$) below optimum. The nutrient levels of magnesium (MgO) and calcium (CaO) were above optimum at all the study sites (Table D1). The soils at Jackson Bog are very poorly drained to well drained and level to steep. The soils at Gallagher/Springfield Fen are very poorly drained to well drained and nearly level to sloping. The soils at Kiser Lake Wetlands are very poorly drained to somewhat poorly drained and nearly level to sloping. The soils at Prairie Road Fen are very poorly drained and nearly level. Soil survey descriptions are listed in Table D2. Soil maps and topographical maps for the study sites can be found in Fig. D3 (Jackson Bog), D4 (Gallagher/Springfield Fen), D5 (Kiser Lake Wetlands), and D6 (Prairie Road Fen).

Table 4. Soil composition at the study sites.

| Soil Composition | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Exchangeable Cations | | | | | % Saturation of the CEC | | |
| Study Site | pH | P lb/A | Acidity | K | Mg | Ca | CEC | K | Mg | Ca |
| **Jackson Bog** | 6.3 | 36.0 | 2.5 | 0.3 | 6.8 | 27.9 | 24.6 | 1.3 | 27.6 | 60.9 |
| **Gallagher/Springfield Fen** | 7.3 | 12.0 | 0.0 | 0.1 | 6.9 | 75.0 | 22.1 | 0.6 | 31.4 | 68.0 |
| **Kiser Lake Wetlands** | 7.4 | 2.0 | 0.0 | 0.2 | 7.9 | 75.0 | 23.0 | 0.7 | 34.1 | 65.2 |
| **Prairie Road Fen** | 7.0 | 18.0 | 0.0 | 0.3 | 11.2 | 28.0 | 26.5 | 1.2 | 42.1 | 56.7 |
| Test Methods: 1:1 soil:water pH, Mehlich 3 Extractant, SMP Buffer pH, Summation of Cations | | | | | | | | | | |

**Characteristic Habitat**

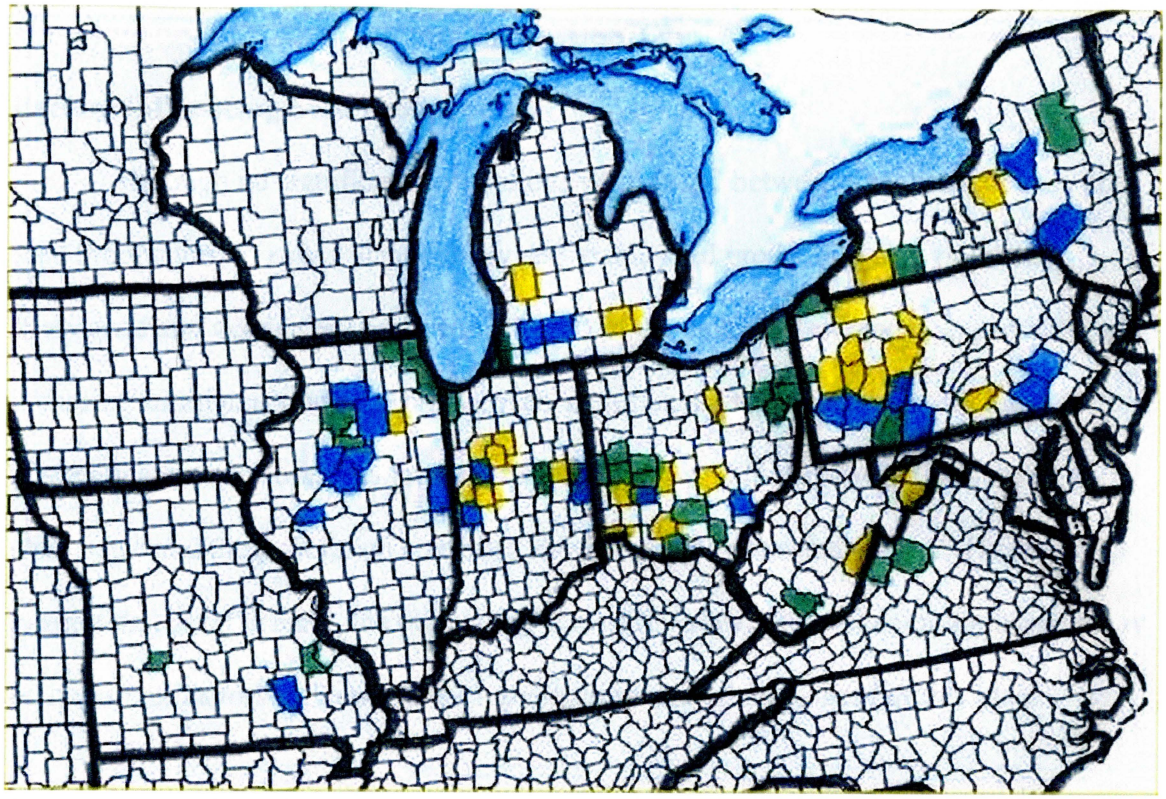
Habitat descriptions from herbarium specimen identification labels were used to determine the characteristic habitat for *F. rubra*. The majority of the sites were bogs, marshes, meadows, swamps, fens, and prairies. However, the species was also found on the banks of creeks, in fields, near springs, and along roadsides and railroads. Habitat characteristics included open areas that were wet or moist with limey or calcareous soil. Herbarium records also indicate that *F. rubra* commonly escapes cultivation.

**Geographical Distribution**

The following herbaria supplied copies of specimen identification labels of *F. rubra*: APSC, BDI, BHO, BUT, CLM, CM, CUP, DEK, DMNH, DUKE, EAR, EIU, GMUF, ILL, ILLS, ISC, ISM, KBSMS, KE, KNK, MO, MOAR, MOR, MSC, MU, MUR, MWI, NCSC, NCU, ND, NEMO, NYS, ODU, OS, PAC, PHIL, PUR, SYRF, TENN, UMBS, UMO, UNCC, VPI, WILLI, WMU, WVA, WVW, and YUO. Acronyms are from Holmgren et al. (1991) and are listed in Table E1. Fourteen states were found to have historic collections (<1960) of *F. rubra*: Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, and Pennsylvania. However, specimens from Iowa, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, and North Carolina collected before 1960 were cultivated plants. Seven states were found to have recent collections (≥1960) of *F. rubra*: Illinois, Indiana, Michigan, Missouri, New York, Ohio, and Pennsylvania. According to herbarium specimen records, *F. rubra* occurred in 35 counties historically and 30 counties recently. In Illinois, Ohio, Missouri, and West Virginia, *F. rubra* is

expanding its distribution. In Indiana, Michigan, and Pennsylvania, *F. rubra* is decreasing its distribution. The distribution of *F. rubra* in New York has continued to remain the same since historic times. The range map of *F. rubra* from herbarium specimens can be found in Fig. 9. Synopsis of exsiccatae of *F. rubra* can be found in Table E2 (by year of collection), Table E3 (by county of collection), and Table E4 (by county of collection divided into historic and recent distributions). The complete exsiccatae of *F. rubra* is listed in Table E5.

Figure 9. Range map of *Filipendula rubra* from herbarium specimens. The blue color indicates counties where the species occurred historically (<1960), the green color indicates counties where the species occurred recently (≥1960), and the yellow color indicates counties where the species occurred historically and recently.



# DISCUSSION

## Factors Influencing Seed Production

Although no significant correlations were found between total plant density and seed production, *F. rubra* plant density and viable seed production, and pollinator abundance and viable seed production, trends in the data suggest that an expanded study including additional study sites may reveal significant correlations between these factors. A significant correlation was found between *F. rubra* plant density and pollinator abundance and the population size of *F. rubra* and pollinator abundance. These results suggest that plant density, the population size of *F. rubra*, and pollinator abundance may be important factors influencing the reproduction and establishment of this plant.

## Pollinators and Pests

Active and passive pollinators found in this study and similar studies at Botkin Fen, Missouri and Helmer Brook Fen, Missouri (Aspinwall and Christian 1992b) are listed in Table 5. Additional records indicate that crane flies *Nephrotoma* (Tipulidae) and non-biting midges (Chironomidae) are pollinators of the European species, *Filipendula ulmaria* (Proctor and Yeo 1972). However, these insects were not found to pollinate *F. rubra* in this study. The importance of identifying insects that pollinate *F. rubra* is to contribute to knowledge of the pollination biology of the plant.

*F. rubra* may be considered bee-pollinated because bees were the most abundant pollinators in this study and may also be the most important. This is consistent with the belief that in temperate areas, bees are the most important pollinators (Steffan-Dewenter

Table 5. Comparison of active and passive pollinators of *Filipendula rubra* from this study and similar studies at Botkin Fen, Missouri and Helmer Brook Fen, Missouri (Aspinwall and Christian 1992b). The pollinator marked with an asterisk ( * ) is non-native.

**Comparison of Active and Passive Pollinators of *Filipendula rubra***

| Taxa | Common Name | This Study | Botkin Fen Study | Helmer Brook Fen |
|---|---|---|---|---|
| ***Active Pollinators*** | | | | |
| **Diptera** | | | | |
| Muscidae | house flies | | | X |
| Syrphidae | flower flies | X | | X |
| **Hymenoptera** | | | | |
| Apidae | bumblebees | X | X | X |
| *Apidae | honeybees | X | X | X |
| Halictidae | solitary bees | X | X | |
| Halictidae | sweat bees | X | X | X |
| ***Passive Pollinators*** | | | | |
| Cantharidae | soldier beetles | X | X | X |

and Tscharntke 1999). One of the most important bee pollinators is the honeybee, which is introduced and non-native. However, pollinator observations during one season have been shown to be inadequate in identifying important pollinators (Kandori 2002). Pollinator abundance can vary among populations of plants during the course of a year and between years (Utelli and Roy 2000). An additional pollination study occurring over the course of several years, many times during the flowering period, and at several sites is needed to determine the quantity and quality of pollinators of *F. rubra* (Utelli and Roy 2000).

The European species, *Filipendula ulmaria* was reported as having nectarless flowers (Proctor and Yeo 1972). The lack of butterflies (Lepidoptera) observed in pollination would indicate the same for *F. rubra*. As a result, no pollination study was conducted at night when the most common insect pollinators are moths (Lepidoptera). However, a pollinator study at dusk and dawn may result in additional pollinators such as crane flies, which are most active at this time and were found to pollinate *Filipendula ulmaria*.

Japanese beetles *Popillia japonica* Newman (Scarabaeidae) were found on *F. rubra* and could be contributing to decreased seed production by feeding on the flowers and leaves. Crab spiders (Thomisidae) that use *F. rubra* for hunting and feeding may also adversely affect seed production by preying on pollinators (Schmalhofer 2001). The most common crab spiders in Ohio, which could also be found in *F. rubra* flowers include *Misumenops asperatus* Hentz, *Misumena vatia* Clerck, *Misumenoides formosipes* Walckenaer, and the diverse genus *Xysticus* (personal communication, R.A. Bradley 2005). In addition, the pupa of the wavy-lined emerald moth *Synchlora aerata aerata*

Fabricius (Geometridae) was found in the inflorescence of one *F. rubra.* The presence of insect pupae can adversely affect seed production by crushing ovules and preventing them from developing (Ishii and Kadono 2002). In the Rocky Mountain perennial elkweed (*Frasera speciosa* Dougl. Ex Griseb.) (Gentianaceae), the ovary of the plant was attacked by tortricid moths which consumed the ovules and pupated within the carpel walls (Beattie et al. 1973).

**Associated Plant Species**

Eight of the ten plant species commonly found growing in association or within two meters of *F. rubra* are typical of fens and prairies and some species are considered plant indicators of these habitats. Plant indicators are species that portray the character of the habitat (Sampson 1939). According to the ODNR, spotted phlox (*Phlox maculata* L.,) (Polemoniaceae), starry false Solomon's seal (*Smilacina stellata* (L.) Desf.) (Liliaceae), and shrubby cinquefoil (*Potentilla fruticosa* L.) (Rosaceae) are plant species typical of Ohio prairies. The invasive non-native plant species, purple loosestrife (*Lythrum salicaria* L.) (Lythraceae), is considered to be a fen species in England (Snowden and Wheeler 1993). Big bluestem (*Andropogon gerardi* Vitman) (Poaceae), linear-leaved loosestrife (*Steironema quadriflora* Sims) (Primulaceae), marsh fern (*Thelypteris palustris* Schott) (Thelypteridaceae), and shrubby cinquefoil (*Potentilla fruticosa* L.) (Rosaceae) are plant indicators for fens in Ohio (Stuckey and Denny 1981). Spotted phlox (*Phlox maculata* L.) (Polemoniaceae), narrow-leaved mountain mint (*Pychathemum tenuifolium* Schrad.) (Lamiaceae), and shrubby cinquefoil (*Potentilla fruticosa* L.) (Rosaceae) are plant indicators for wet prairies in Ohio (Sears 1926). The

plants that were not considered fen or prairie species were self-heal (*Prunella vulgaris* L.) (Lamiaceae) and common cleavers (*Galium aparine* L.) (Rubiaceae). Self-heal can tolerate a variety of habitats (Schmid and Harper 1985) such as woods, fields, lawns, and other disturbed areas and common cleavers is typically found in woodlands, thickets, grassy roadsides, and weed lots (Cooperrider 1995).

The invasion of non-native plant species is considered one of the major threats to endangered plant species and ecosystems (Blossey et al. 2001) due to their rapid growth rate, high fruit production, quick vegetative spread, and efficient seed dispersal and germination (Ohio Department of Natural Resources 2003). Combined with their ability to tolerate a variety of environmental conditions, non-native invasive plant species have many competitive advantages over native plant species and can displace them over time (Morrison 2002).

The non-native invasive plant species that present the greatest danger to *F. rubra* and the fen habitat are garlic mustard (*Alliaria petiolata* [officinalis] (Bieb.) Cavara & Grande.) (Brassicaceae), purple loosestrife (*Lythrum salicaria* L.) (Lythraceae), multiflora rose (*Rosa multiflora* Thunb.) (Rosaceae), and glossy buckthorn (*Rhamnus frangula* L.) (Rhamnaceae). These plants are included in the list of Ohio's top ten invasive non-native plant species (Ohio Department of Natural Resources 2003) and are described in detail below.

Garlic mustard is an herbaceous plant commonly found in woodlands that spreads by dispersal on animal fur and by an advancing front. It forms monotypic stands that reduce the diversity of native plant species, eventually displacing them because of its chemical effects and disturbance of root fungi associations and root growth (Roberts and

Anderson 2001). Garlic mustard is a successful invader because it produces abundant seed. Most seeds are viable and remain viable for over five years. Only a few seeds are needed for establishment. It also grows rapidly and relies on a variety of insects for pollination (Smith et al. 2003).

Purple loosestrife is an herbaceous plant found in wetlands that can tolerate a wide range of environmental conditions including full sun and partial shade. It forms monotypic stands that develop quickly and can last over 20 years. These monotypic stands degrade and eventually eliminate wildlife food and cover, reduce diversity by displacing native plant species, and alter the hydrology and nutrient cycling in a wetland (Morrison 2002, Piper 1996). Purple loosestrife is a successful invader because it has no natural enemies, it has higher and faster germination rates than native plants, it produces up to 300,000 seeds per year, and it spreads aggressively through rhizomes (Blossey et al. 2001).

Multiflora rose is a shrub that thrives in full sun and well-drained soil where it forms dense thickets that displace native plant species. It is a successful invader because it produces up to 500,000 seeds per year, its branches can root upon contact with soil, and its fruit is widely dispersed by birds and mammals (Ohio Department of Natural Resources 2003, Wisconsin Department of Natural Resources 2004).

Glossy buckthorn is a small tree that tolerates full sun or heavy shade and nutrient poor soil. It casts a dense shade that displaces native plant species by preventing seedlings from becoming established. Glossy buckthorn is a successful invader because it produces abundant fruit that is dispersed widely by birds, it spreads aggressively in wet

soil, it leafs out in early spring, and holds its leaves into late fall (Ohio Department of Natural Resources 2003, Wisconsin Department of Natural Resources 2004).

**Soil Composition**

The soil composition of all the study sites, consisting of pH values and nutrient levels, showed little or no difference between the study sites. All the study sites had a pH range between 5.6 and 7.5, typical of rich or minerotrophic fens (Mitsch and Gosselink 2000). The soil nutrient levels of phosphate ($P_2O_5$) and potash ($K_2O$) were below optimum at all the study sites and may be due to uptake by the plants because they utilize these nutrients for growth and flowering. The soil nutrient levels of magnesium (MgO) and calcium (CaO) were above optimum at all the study sites and may be due to the inability of the plants to break down calcium and magnesium bicarbonates present in the groundwater. Calcium and magnesium may also be present in the soil at high levels because plants use only a small amount of these nutrients for their growth and development.

**Characteristic Habitat and Geographical Distribution**

The characteristic habitat of *F. rubra* is spring-fed calcareous fens, spring seeps, and wet prairies. However, herbarium records indicate that it was also commonly found in bogs, marshes, swamps, fields, and on the banks of creeks. *F. rubra* is imperiled, endangered, and threatened in some states, but may be able to tolerate and adapt to a variety of habitats, which in turn may help to increase its geographical distribution. As more nature preserves are cleared of introduced species and the canopy is opened, *F.*

*rubra* may appear in areas where it was previously not recorded. At the Jackson Bog study site when an area of the fen was cleared of woody non-native invasive plants, *F. rubra* began to grow and became established in the area. This indicates that *F. rubra* may possess a delayed germination (Rice and Dyer 2001) that allows viable seed to remain in the seed bank (Van der Valk and Davis 1976). In the yellow-poplar tree *Liriodendron tulipifera* L. (Magnoliaceae), some of the viable seed germinates in the spring while the remaining seed requires two of more years for complete germination (Boyce and Hosner 1963). This may also be the case with *F. rubra*. Members of Rosaceae have been found to require many different conditions for germination such as stratification, disintegration of the seed coat, and chilling and may even undergo a secondary dormancy (Mirov 1936). *F. rubra* has be known to require some period of stratification to induce germination (Aspinwall and Christian 1992a) and could also benefit in a similar manner from scarification from fire or clear cutting. In a study of the European species *Filipendula vulgaris*, seedling emergence and survivorship was greater in disturbed plots than undisturbed plots (Kiviniemi 2001). This is consistent with the belief that plants with small seeds may depend on disturbances for seedling establishment (Kiviniemi 2001). New populations of *F. rubra* could be re-established after additional clearings in suitable habitat throughout its known range, and the plant could be found to be more common than once thought.

An expanded life history study is needed to determine if the habitat descriptions listed on herbarium records correspond with the current habitat of *F. rubra*. Based on herbarium records, the range of *F. rubra* appears to be relatively stable. However, the distribution appears to be changing and it is found in five fewer counties since historic

times (<1960). Herbarium records indicate that *F. rubra* is expanding its distribution in Illinois, Ohio, Missouri, and West Virginia, and has remained constant in New York. In Indiana, Michigan, and Pennsylvania, however, the distribution of *F. rubra* is decreasing. This could be due to habitat destruction, especially to the wetland habitat, where the current rate of loss in the United States is 53% (Mitsch and Gosselink 2000). Invasive species could also be contributing to the decrease of the plant by displacing it due to their competitive strategies (Morrison 2002).

**Conclusion**

Conservation of *F. rubra* and its unique habitat will require managing for the successful reproduction and establishment of this fen species. Conservation of the plant should include protecting areas with large populations of *F. rubra*. The maintenance of larger population sizes of *F. rubra* may also be important because of their attractiveness to pollinators, resulting in higher visitation rates and successful pollination (Mustajarvi et al. 2001). Self-incompatible plants in particular are susceptible to decreased seed production due to inbreeding and reduced pollination success if their population size is small (Mustajarvi et al. 2001). In this study, pollinator abundance was positively correlated with the population size of *F. rubra*. Pollinator abundance has been shown to decrease with decreasing habitat (Mustajarvi et al. 2001) and habitat fragmentation (Steffan-Dewenter and Tscharntke 1999). Habitat connectivity has also been found to be important in influencing pollinator abundance in endangered plant species (Steffan-Dewenter and Tscharntke 1999).

Establishment of *F. rubra* should include utilizing seed from different populations to provide additional genetic variation. In addition, *F. rubra* plants can be transplanted from different habitats taking care to select those plants from different clones. However, transplanting could 1) introduce insects that were not found in the habitat prior which may disrupt the insect dynamics at the new site and 2) introduce plants because of seeds in the soil of the transplanted plant. This could be avoided by instead relocating individual pollinators carrying pollen from *F. rubra* plants or placing a cut inflorescence in water from a different clone in the center of a colony to provide more genetic variation with less impact (personal communication, C.F. Chuey 2004).

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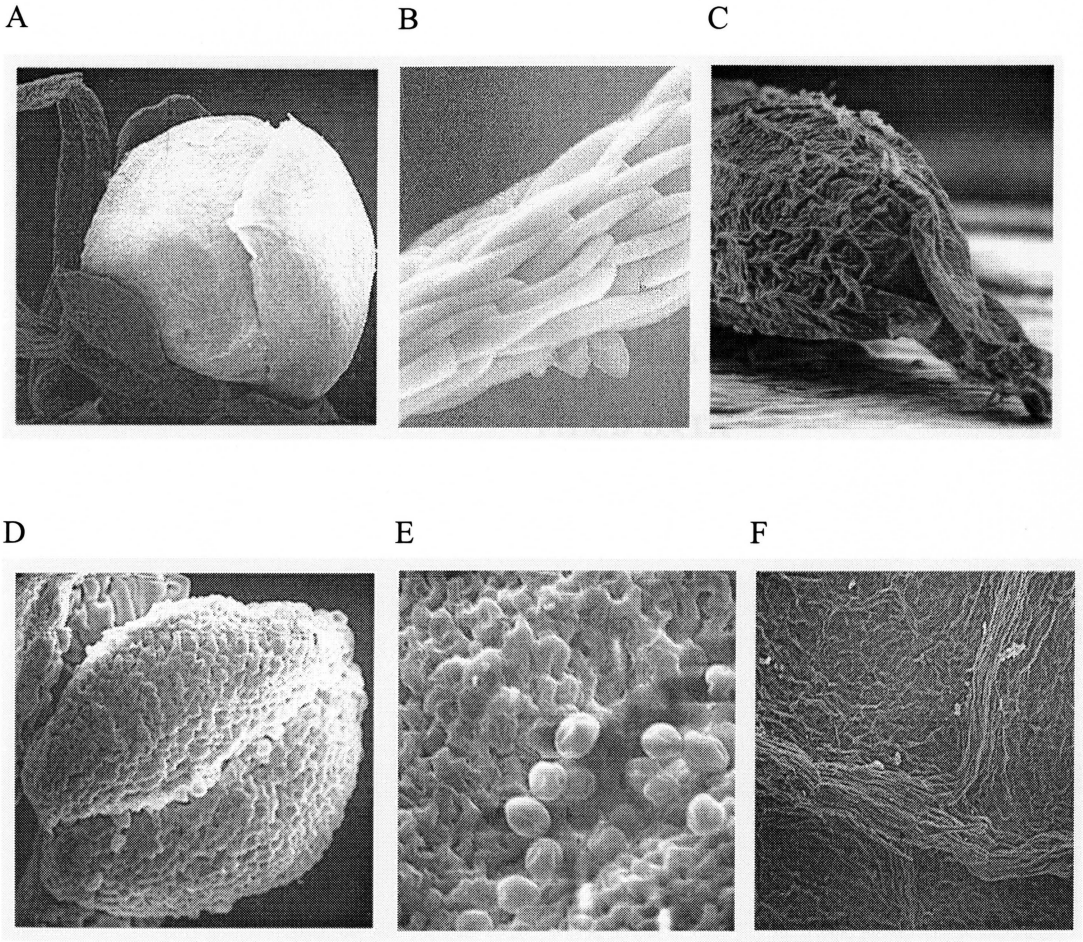
# APPENDIX A

## *Filipendula rubra* DATA

Figure A1. Type specimen illustration for *Filipendula rubra* from the Hortus Kewensis. Sistens herbas exoticas, indigenasque rariores, in area botanica, Hortorum Aug. Pr. Cambriae Dotissae, apud Kew, in comitatu Surreiano, cultas; methodo florali nova dispositas Editio secunda aucta. 1769. John Hill (1716-1775).

Figure A2. Photograph of the author with *Filipendula rubra* at Liberty Fen State Nature Preserve and photograph of an inflorescence of *F. rubra* at Kiser Lake Wetlands State Nature Preserve, Grandview Heights section.

Figure A3. Micrograph of *Filipendula rubra*: A- flower bud at 34X, B- seed at 100X, C- filament at 530X, D- anther at 260X, E- anther at 570X, and F- leaf at 35X.



# APPENDIX B

# FIELD DATA

Table B1. *Filipendula rubra* plant density at the study sites.

| ***F. rubra* Plant Density Study** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Site | Density of *F. rubra* per $1m^2$ Plot | | | | | | | | | | | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| Jackson Bog | 5 | 7 | 8 | 5 | 4 | 1 | 7 | 4 | 4 | 2 | 3 | 3 | | | |
| Gallagher/Springfield Fen | 1 | 6 | 3 | 4 | 1 | 1 | 2 | 3 | 2 | 4 | 2 | 1 | 1 | 1 | 1 |
| Kiser Lake Wetlands | 2 | 5 | 2 | 3 | 2 | 1 | 1 | 1 | 2 | 5 | 3 | 2 | | | |
| Prairie Road Fen | 4 | 9 | 6 | 4 | 6 | 2 | 2 | 2 | 2 | 3 | 2 | 4 | 3 | | |

Table B2. Total plant density at the study sites.

| Total Plant Density Study | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Site | Density of All Plants per 1m$^2$ Plot | | | | | | | | | | | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| Jackson Bog | 139 | 138 | 173 | 150 | 159 | 113 | 114 | 132 | 114 | 67 | 66 | 66 | | | |
| Gallagher/Springfield Fen | 77 | 59 | 86 | 95 | 106 | 97 | 80 | 91 | 110 | 89 | 93 | 77 | 78 | 81 | 84 |
| Kiser Lake Wetlands | 105 | 66 | 125 | 127 | 103 | 97 | 125 | 134 | 152 | 106 | 62 | 142 | | | |
| Prairie Road Fen | 65 | 72 | 79 | 67 | 87 | 50 | 58 | 53 | 65 | 83 | 68 | 103 | 63 | | |

Table B3. Pollinator abundance at the study sites.

| **Pollinator Abundance Study** | | | | |
|---|---|---|---|---|
| | Total Number of Pollinators per 15 min per Plant per Study Site | | | |
| Plant Number | Jackson Bog | Gallagher/Springfield Fen | Kiser Lake Wetlands | Prairie Road Fen |
| 1 | 4 | 2 | 2 | 3 |
| 2 | 2 | 1 | 2 | 3 |
| 3 | 2 | 3 | 1 | 2 |
| 4 | 1 | 4 | 2 | 2 |
| 5 | 1 | 3 | 2 | 3 |
| 6 | 2 | 3 | 2 | 1 |
| 7 | 2 | 4 | 3 | 2 |
| 8 | 0 | 3 | 2 | 2 |
| 9 | 2 | 1 | 4 | 3 |
| 10 | 2 | 5 | 4 | 1 |
| 11 | 1 | 3 | 3 | 3 |
| 12 | 2 | 1 | 3 | 3 |
| 13 | 5 | 2 | 2 | 2 |
| 14 | 3 | 3 | 3 | 2 |
| 15 | 2 | 3 | 1 | 3 |
| 16 | 0 | 5 | 1 | 1 |
| 17 | 2 | 2 | 4 | 2 |
| 18 | 2 | 5 | 2 | 2 |
| 19 | 1 | 1 | 6 | 3 |
| 20 | 3 | 4 | 2 | 2 |

Table B4. Seed production at the study sites.

| Seed Production Study | | | | |
|---|---|---|---|---|
| | Total Number of Seeds per Plant per Study Site | | | |
| Plant Number | Jackson Bog | Gallagher/Springfield Fen | Kiser Lake Wetlands | Prairie Road Fen |
| 1 | 1370 | 1470 | 401 | 1115 |
| 2 | 1623 | 1082 | 2951 | 973 |
| 3 | 1611 | 1102 | 1975 | 1792 |
| 4 | 1774 | 203 | 4078 | 512 |
| 5 | 608 | 1434 | 522 | 1570 |
| 6 | 834 | 1163 | 2127 | 996 |
| 7 | 2336 | 731 | 3047 | 853 |
| 8 | 631 | 879 | 2496 | 207 |
| 9 | 1193 | 886 | 2945 | 829 |
| 10 | 1506 | 661 | 1976 | 914 |
| 11 | 1791 | 1461 | 4613 | 842 |
| 12 | 1024 | 769 | 1674 | 1292 |
| 13 | 3253 | 1255 | 1936 | 614 |
| 14 | 2266 | 704 | 2242 | 605 |
| 15 | 930 | 865 | 4388 | 337 |
| 16 | 2063 | 1684 | 2510 | 627 |
| 17 | 299 | 292 | 875 | 622 |
| 18 | 1148 | 1052 | 1435 | 513 |
| 19 | 1609 | 577 | 313 | 1412 |
| 20 | 1795 | 1598 | 828 | 678 |

Table B5. Viable seed production at the study sites.

| Viable Seed Production Study | | | | |
|---|---|---|---|---|
| | Mean Number of Viable Seeds per 20 Seeds per Study Site | | | |
| Plant Number | Jackson Bog | Gallagher/Springfield Fen | Kiser Lake Wetlands | Prairie Road Fen |
| 1 | 7 | 0 | 5 | 3 |
| 2 | 6 | 0 | 17 | 0 |
| 3 | 8 | 0 | 15 | 8 |
| 4 | 5 | 0 | 4 | 2 |
| 5 | 4 | 7 | 2 | 7 |
| 6 | 2 | 0 | 0 | 0 |
| 7 | 6 | 1 | 1 | 5 |
| 8 | 1 | 0 | 19 | 0 |
| 9 | 5 | 0 | 2 | 6 |
| 10 | 5 | 4 | 10 | 3 |
| 11 | 1 | 0 | 0 | 7 |
| 12 | 1 | 0 | 16 | 12 |
| 13 | 10 | 2 | 0 | 0 |
| 14 | 0 | 10 | 20 | 5 |
| 15 | 2 | 0 | 17 | 7 |
| 16 | 5 | 15 | 20 | 6 |
| 17 | 2 | 0 | 0 | 0 |
| 18 | 8 | 0 | 0 | 2 |
| 19 | 10 | 0 | 8 | 14 |
| 20 | 8 | 0 | 17 | 8 |

# APPENDIX C

# ASSOCIATED PLANT SPECIES DATA

Table C1. Associated plant species within two meters of *Filipendula rubra* at Jackson Bog.

| *Family/Species* | *Native* |
|---|---|
| Dryopteridaceae | |
| *Dryopteris cristata* (L.) Gray | y |
| *Onoclea sensibilis* L. | y |
| Thelypteridaceae | |
| *Thelypteris palustris* Schott | y |
| Equisetaceae | |
| *Equisetum fluviatile* L. | y |
| Ranunculaceae | |
| *Anemone virginiana* L. | y |
| *Caltha palustris* L. | y |
| *Thalictrum polygamum* Muhl. | y |
| Polygonaceae | |
| *Polygonum amphibium* L. | y |
| *Polygonum sagittatum* L. | y |
| Brassicaceae | |
| *Alliaria petiolata* (Bieb.) Cavara & Grande. | n |
| *Cardamine bulbosa* (Schreb.) BSP. | y |
| Rosaceae | |
| *Agrimonia pubescens* Wallr. | y |
| *Filipendula rubra* (Hill) B.L. Robinson | y |
| *Potentilla fruticosa* L. | y |
| *Rosa palustris* Marsh. | y |
| *Sanguisorba canadensis* L. | y |
| Lythraceae | |
| *Lythrum salicaria* L. | n |
| Onagraceae | |
| *Epilobium strictum* Muhl. | y |
| Rhamnaceae | |
| *Rhamnus frangula* L. | n |
| Anacardiaceae | |
| *Rhus vernix* L. | y |
| Balsaminaceae | |
| *Impatiens capensis* Meerb. | y |

| *Family/Species* | *Native* |
|---|---|
| Apiaceae | |
| *Oxypolis rigidior* (L.) Raf. | y |
| Solanaceae | |
| *Solanum dulcamara* L. | n |
| Polemoniaceae | |
| *Phlox maculata* L. | y |
| Lamiaceae | |
| *Prunella vulgaris* L. | y |
| *Pycnanthemum tenuifolium* Schrad. | y |
| Rubiaceae | |
| *Galium aparine* L. | y |
| Caprifoliaceae | |
| *Viburnum recognitum* Fern. | y |
| Asteraceae | |
| *Aster novae-angliae* L. | y |
| *Aster pilosus* Willd. var. pilosus | y |
| *Eupatorium maculatum* L. | y |
| *Senecio aureus* L. | y |
| *Solidago canadensis* L. | y |
| Juncaceae | |
| *Juncus brachycephalus* Engelm. | y |
| Cyperaceae | |
| *Carex cristatella* Britt. | y |
| *Carex cryptolepis* Mackenz. | y |
| *Carex scoparia* Schk. | y |
| *Carex prairea* Dewey | y |
| *Scirpus atrovirens* Willd. | y |
| Poaceae | |
| *Glyceria grandis* S. Wats. | y |
| *Leersia oryzoides* (L.) Swartz | y |
| Liliaceae | |
| *Smilacina stellata* (L.) Desf. | y |
| Sphagnaceae | |
| *Sphagnum fimbriatum* Wils. | y |
| Thuidiaceae | |
| *Thuidium delicatulum* (Hedw.) BSG | y |

Table C2. Associated plant species within two metersof *Filipendula rubra* at Gallagher/Springfield Fen.

| *Family/Species* | *Native* |
|---|---|
| Ranunculaceae | |
| *Anemone canadensis* L. | y |
| *Clematis virginiana* L. | y |
| *Delphinium exaltatum* Ait. | y |
| Polygonaceae | |
| *Polygonum scandens* L. | y |
| Clusiaceae | |
| *Hypericum punctatum* Lam. | y |
| Violaceae | |
| *Viola cucullata* Ait. | y |
| Primulaceae | |
| *Lysimachia ciliata* L. | y |
| *Steironema quadriflora* Sims | y |
| Rosaceae | |
| *Agrimonia pubescens* Wallr. | y |
| *Filipendula rubra* (Hill) B.L. Robinson | y |
| *Fragaria virginiana* Duchesne | y |
| *Potentilla fruticosa* L. | y |
| *Rosa multiflora* Thunb. | n |
| *Rubus allegheniensis* Porter | y |
| *Rubus occidentalis* L. | y |
| Lythraceae | |
| *Lythrum salicaria* L. | y |
| Onagraceae | |
| *Circaea lutetiana* L. | y |
| Oxalidaceae | |
| *Oxalis europaea* Jord. | y |
| Geraniaceae | |
| *Geranium maculatum* L. | y |
| Balsaminaceae | |
| *Impatiens capensis* Meerb. | y |
| Apiaceae | |
| *Daucus carota* L. | n |
| *Osmorhiza longistylis* (Torr.) DC. | y |
| *Sanicula gregaria* Bickn. | y |
| *Zizia aurea* (L.) Koch | y |

| *Family/Species* | *Native* |
|---|---|
| Apocynaceae | |
| *Apocynum cannabinum* L. | y |
| Asclepiadaceae | |
| *Asclepias incarnata* L. | y |
| Solanaceae | |
| *Solanum dulcamara* L. | n |
| Convolvulaceae | |
| Calystegia sepium (L.) R. Br. | y |
| Polemoniaceae | |
| *Phlox maculata* L. | y |
| Verbenaceae | |
| *Verbena hastata* L. | y |
| Lamiaceae | |
| *Lycopus americanus* Muhl. | y |
| *Physostegia virginiana* (L.) Benth. | y |
| *Prunella vulgaris* L. | y |
| Scrophulariaceae | |
| *Agalinis purpurea* L. | y |
| Rubiaceae | |
| *Galium aparine* L. | y |
| *Galium asprellum* Michx. | y |
| Caprifoliaceae | |
| *Lonicera tatarica* L. | y |
| Campanulaceae | |
| *Lobelia siphilitica* L. | y |
| Asteraceae | |
| *Achillia millefolium* L. | n |
| *Aster novae-angliae* L. | y |
| *Aster pilosus* Willd. var. pilosus | y |
| *Aster prenanthoides* Muhl. | y |
| *Cacalia plantaginea* (Raf.) Shinners | y |
| *Cirsium muticum* Michx. | y |
| *Echinacea purpurea* (L.) Moench. | y |
| *Erigeron pulchellus* Michx. | y |
| *Helenium autumnale* L. | y |
| *Helianthus hirsutus* Raf. | y |
| *Heliopsis helianthoides* (L.) Sweet | y |

| *Family/Species* | *Native* |
|---|---|
| Asteraceae | |
| *Rudbeckia hirta* L. | y |
| *Senecio aureus* L. | y |
| *Silphium trifoliatum* L. | y |
| *Solidago ohioensis* Riddell | y |
| *Solidago ulmifolia* Muhl. | y |
| Juncaceae | |
| *Juncus tenuis* var. *anthelatus* Wieg. | y |
| Cyperaceae | |
| *Carex comosa* Boott | y |
| *Carex gracillima* Schwein. | y |
| *Carex lanuginosa* Michx. | y |
| *Carex stipata* Muhl. | y |
| *Carex vulpinoidea* Michx. | y |
| *Scirpus atrovirens* Willd. | y |
| *Scirpus cyperinus* (L.) Kunth. | y |
| Poaceae | |
| *Andropogon gerardi* Vitman | y |
| *Phalaris arundinacea* L. | y |
| *Elymus virginicus* L. | y |
| *Setaria viridis* (L.) Beauv. | y |
| *Sporobolus vaginiflorus* (Torr.) Wood | y |
| Liliaceae | |
| *Smilacina stellata* (L.) Desf. | y |
| *Zygadenus glaucus* Nutt. | y |
| Iridaceae | |
| *Iris shrevei* Small | y |

Table C3. Associated plant species within two meters of *Filipendula rubra* at Kiser Lake Wetlands, Headwaters section.

| *Family/Species* | *Native* |
|---|---|
| Equisetaceae | |
| *Equisetum arvense* L. | y |
| Ophioglossaceae | |
| *Botrychium virginanum* (L.) Sw. | y |
| Thelypteridaceae | |
| *Thelypteris palustris* Schott | y |
| Lauraceae | |
| *Ribes americanum* Mill. | y |
| Ranunculaceae | |
| *Anemone virginiana* L. | y |
| Violaceae | |
| *Viola striata* Ait. | y |
| Salicaceae | |
| *Salix discolor* Muhl. | y |
| Primulaceae | |
| *Steironema quadriflora* Sims | y |
| Rosaceae | |
| *Agrimonia parviflora* Ait. | y |
| *Filipendula rubra* (Hill) B.L. Robinson | y |
| *Geum canadense* Jacq. | y |
| *Physocarpus opulifolius* (L.) Maxim. | y |
| *Potentilla fruticosa* L. | y |
| *Rosa palustris* Marsh. | y |
| Onagraceae | |
| *Circaea lutetiana* L. | y |
| Cornaceae | |
| *Cornus obliqua* Raf. | y |
| Balsaminaceae | |
| *Impatiens capensis* Meerb. | y |
| Apiaceae | |
| *Osmorhiza longistylis* (Torr.) DC. | y |
| Polemoniaceae | |
| *Phlox maculata* L. | y |
| Boraginaceae | |
| *Heliotropium indicum* L. | y |
| Verbenaceae | |
| *Verbena hastata* L. | y |
| Lamiaceae | |
| *Physostegia virginiana* (L.) Benth. | y |
| *Prunella vulgaris* L. | y |
| *Pycnanthemum tenuifolium* Schrad. | y |
| Campanulaceae | |
| *Campanula americana* L. | y |
| Asteraceae | |
| *Aster cordifolius* L. | y |
| *Aster novae-angliae* L. | y |
| *Aster sagittifolius* Willd. | y |
| *Erigeron strigosus* Muhl. | y |
| *Eupatorium fistulosum* Barratt. | y |
| *Eupatorium perfoliatum* L. | y |
| *Helianthus hirsutus* Raf. | y |
| *Heliopsis helianthoides* (L.) Sweet | y |
| *Silphium perfoliatum* L. | y |
| *Solidago uliginosa* Nutt. | y |
| Alismataceae | |
| *Sagittaria latifolia* Willd. | y |
| Cyperaceae | |
| *Carex lupulina* Muhl. | y |
| *Carex stipata* Muhl. | y |
| *Carex stricta* Lam. | y |
| *Carex wildenowii* Schkuhr | y |
| *Scirpus atrovirens* Willd. | y |
| Poaceae | |
| *Andropogon gerardi* Vitman | y |
| *Hystrix patula* Moench | y |
| *Leersia oryzoides* (L.) Swartz | y |
| *Phalaris arundinacea* L. | y |
| Typhaceae | |
| *Typha latifolia* L. | y |
| Liliaceae | |
| *Allium canadense* L. | y |
| Iridaceae | |
| *Iris shrevei* Small | y |
| Brachytheciaceae | |
| *Brachythecium curtum* (Lindb.) Limpr. | y |
| Mniaceae | |
| *Piagiomnium cuspidatum* (Hedw.) Kop. | y |

Table C4. Associated plant species within two meters of *Filipendula rubra* at Prairie Road Fen.

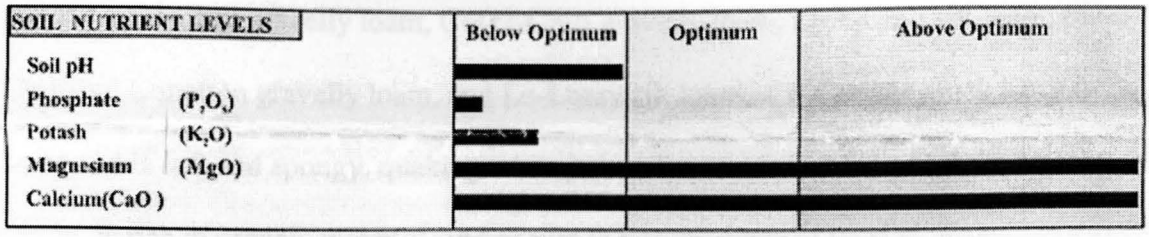
| *Family/Species* | *Native* |
|---|---|
| Equisetaceae | |
| *Equisetum variegatum* Schleich. | y |
| Theylpteridaceae | |
| *Thelypteris palustris* Schott | y |
| Cannabaceae | |
| *Humulus lupulus* L. | y |
| Brassicaceae | |
| *Cardamine bulbosa* (Schreb.) BSP | y |
| Primulaceae | |
| *Steironema quadriflora* Sims | y |
| Rosaceae | |
| *Filipendula rubra* (Hill) B.L. Robinson | y |
| *Potentilla fruticosa* L. | y |
| *Sanguisorba canadensis* L. | y |
| Lythraceae | |
| *Lythrum salicaria* L. | n |
| Onagraceae | |
| *Gaura biennis* L. | y |
| Rhamnaceae | |
| *Rhamnus frangula* L. | n |
| Apiaceae | |
| *Cicuta maculata* L. | y |
| *Daucus carota* L. | n |
| *Oxypolis rigidior* (L.) Raf. | y |
| Convolvulaceae | |
| *Calystegia sepium* L. | y |
| Polemoniaceae | |
| *Phlox maculata* L. | y |
| Lamiaceae | |
| *Pycnanthemum tenuifolium* Schrad. | y |
| Scrophulariaceae | |
| *Agalinis purpurea* L. | y |
| *Chelone glabra* L. | y |
| *Pedicularis lanceolata* Michx. | y |
| Campanulaceae | |
| *Campanula americana* L. | y |
| Campanulaceae | |
| *Lobelia kalmii* L. | y |
| *Lobelia siphilitica* L. | y |
| Rubiaceae | |
| *Galium aparine* L. | y |
| Asteraceae | |
| *Aster lateriflorus* (L.) Britt. | y |
| *Cacalia plantaginea* (Raf.) Shinners | y |
| *Eupatorium perfoliatum* L. | y |
| *Gnaphalium purpureum* L. | y |
| *Helenium autumnale* L. | y |
| *Liatris spicata* (L.) Willd. | y |
| *Ratibida pinnata* (Vent.) Barnh. | y |
| *Rudbeckia laciniata* L. | y |
| *Rudbeckia hirta* L. | y |
| *Silphium terebinthinaceum* Jacq. | y |
| *Silphium trifoliatum* L. | y |
| *Solidago ohioensis* Riddell | y |
| *Solidago riddellii* Frank | y |
| *Solidago uliginosa* Nutt. | y |
| Juncaginaceae | |
| *Triglochin maritima* L. | y |
| Juncaceae | |
| *Juncus brachycephalus* Engelm. | y |
| *Juncus bufonius* L. var. bufonius | y |
| *Juncus tenuis* Willd. var. tenuis | y |
| *Juncus torreyi* Coville | y |
| Cyperaceae | |
| *Carex gravida* Bailey | y |
| *Carex laevivaginata* (Kukenth.) Mackenz. | y |
| *Carex pensylvanica* Lam. | y |
| *Carex sartwellii* Dewey | y |
| *Rhynchospora capitellata* (Michx.) Vahl. | y |
| *Scirpus validus* Vahl. var. creber Fern. | y |
| Poaceae | |
| *Andropogon gerardi* Vitman | y |
| *Bromus japonicus* Thunb. | y |
| *Poa pratensis* L. | y |
| *Sorghastrum nutans* (L.) Nash | y |
| Liliaceae | |
| *Allium cernuum* Roth. | y |
| *Hypoxis hirsuta* (L.) Coville. | y |
| *Smilacina stellata* (L.) Desf. | y |
| *Zygadenus glaucus* Nutt. | y |
| Amblystegiaceae | |
| *Campylium stellatum* (Hedw.) C. Jens. | y |

# APPENDIX D

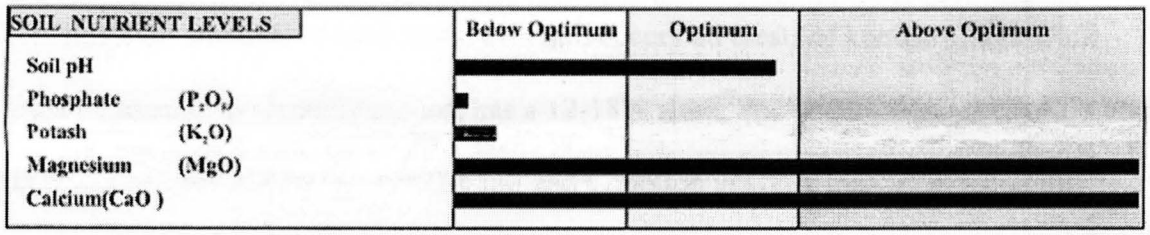
# SOIL AND TOPOGRAPHICAL DATA

Table D1. Soil nutrient levels from the Agricultural Analytical Services Laboratory for: A- Jackson Bog, B- Gallagher/Springfield Fen, C- Kiser Lake Wetlands, Headwaters section, and D- Prairie Road Fen.

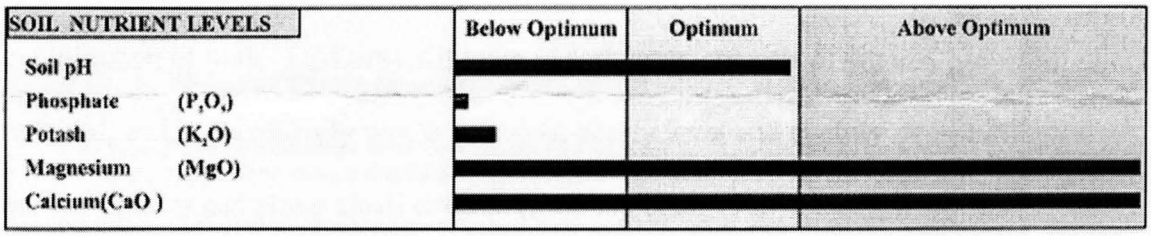
A




B




C




D

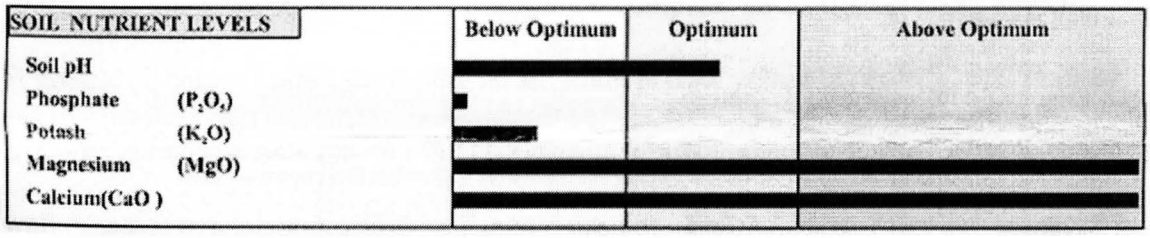


Table D2. Soil survey descriptions for the study sites.

The major soils at Jackson Bog which contain *Filipendula rubra* are: Ch-Carlisle muck, CoC2-Chili gravelly loam, CoD2-Chili gravelly loam, CpA-Chili silt loam, CvF2-Chili and Conotton gravelly loam, and Lz-Luray silt loam. Ch-Carlisle muck has a 0-2% slope and is soft and spongy, quaking when jumped upon. It is saturated in winter and spring, is rich in organic material, and occurs in various sizes of level to depressed areas. CoC2-Chili gravelly loam is light colored, moderately eroded, and has a 6-12% slope. It contains high amounts of sand and gravel and occurs on crests of knolls. CoD2-Chili gravelly loam is moderately eroded, has a 12-18% slope, and occurs along drainways and on banks of stream terraces. CvF2-Chili and Conotton gravelly loam is moderately eroded, has a 25-50% slope, and occurs on banks of terraces and on kames. It is droughty, highly susceptible to erosion, and may contain only Chili or Conotton or a combination of both. Lz-Luray silt loam is dark gray, consists of silt and gravelly material, and is excessively wet. It occurs in nearly level and slightly depressed areas on outwash plains and along small streams (Mooney et al. 1915).

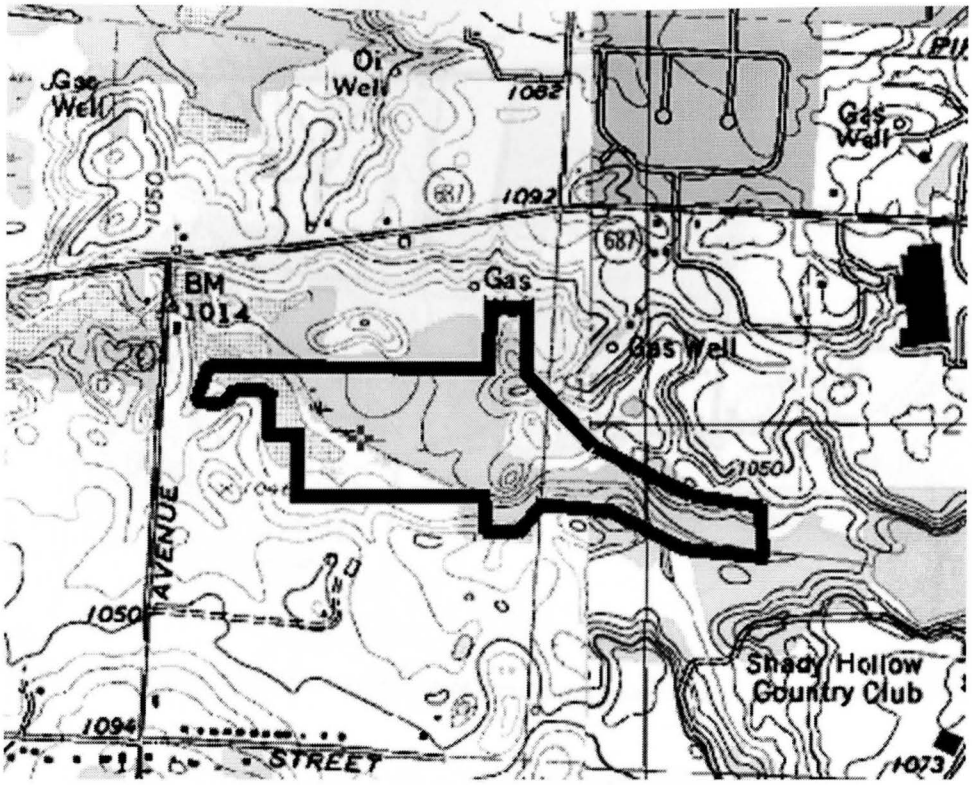
The major soils at Gallagher/Springfield Fen where *F. rubra* occurs are: EmB-Eldean silt loam, EpD2 and 3-Eldean-Miamian complex, So-Sloan silt loam, and Wt-Westland silty clay loam. EmB-Eldean silt loam is dark yellowish brown, well drained, and occurs in outwash terraces. EpD2-Eldean-Miamian complex is dark grayish brown, well drained, eroded, and occurs in Kame moraines. EpD3-Eldean-Miamian complex is brown to dark brown, well drained, severely eroded, and occurs in Kame moraines. So-Sloan silt loam is dark-colored, very poorly drained, nearly level, and occurs on flood plains along streams. It was formed in loamy alluvium that washed from soils underlain

by Wisconsin age calcareous till. So-Sloan silt loam is naturally wet and occasionally flooded, has a sandy substratum and occurs parallel to the stream bed. Wt-Westland silty clay loam is dark gray, very poorly drained, and occurs in outwash plains and terraces (Miller et al. 1999).

The major soils at Kiser Lake Wetlands where *F. rubra* grows are: Ca-Carlisle muck and HoA-Homer silt loam. Ca-Carlisle muck consists of organic soils that are dark colored, very poorly drained, and nearly level. It is composed of muck that has accumulated from the partly decomposed remains of trees, fibrous grasses, sedges, and reeds. Ca-Carlisle muck is saturated with free water and is found in low-lying, swampy areas on bottomlands and uplands. HoA-Homer silt loam is light-colored, seasonally wet, somewhat poorly drained, and nearly level. It occurs on stream terraces and was formed in loamy material over gravelly and sandy outwashes (Ritchie and Powell 1974).

The major soils at Prairie Road Fen that support *F. rubra* are: So-Sloan silt loam. So-Sloan silt loam is dark-colored, very poorly drained, and nearly level. It was formed in loamy alluvium that washed from soils underlain by Wisconsin age calcareous till. So-Sloan silt loam is naturally wet and occasionally flooded, has a sandy substratum and occurs on flood plains parallel to stream beds (Miller et al. 1999).

Figure D3. Topographical map and soil map location of Jackson Bog.



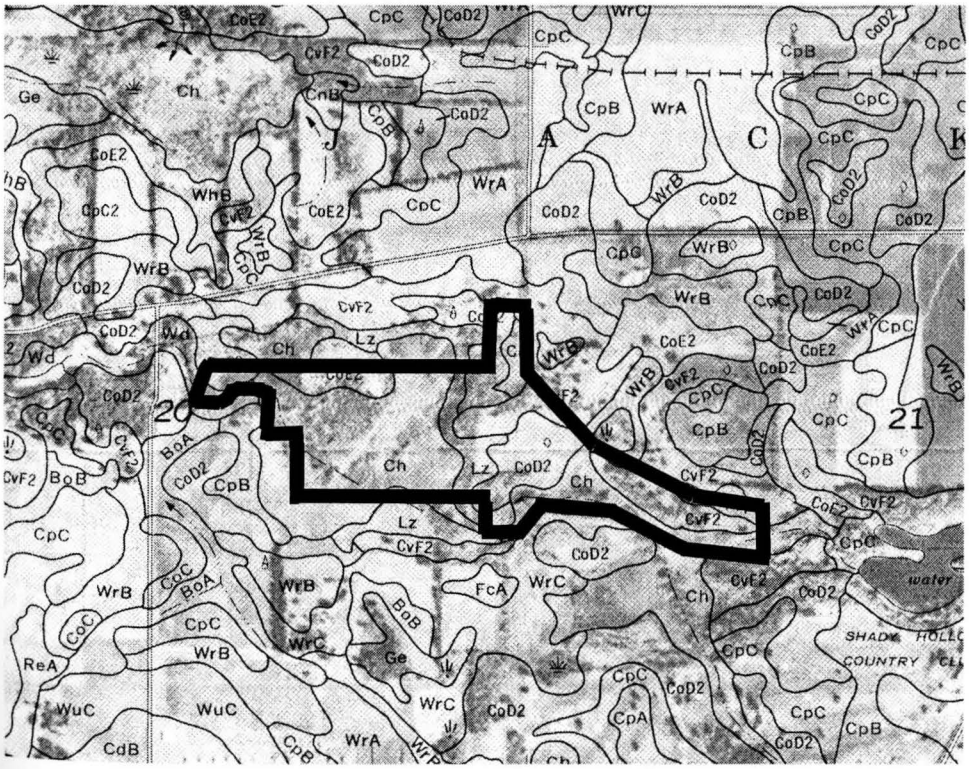
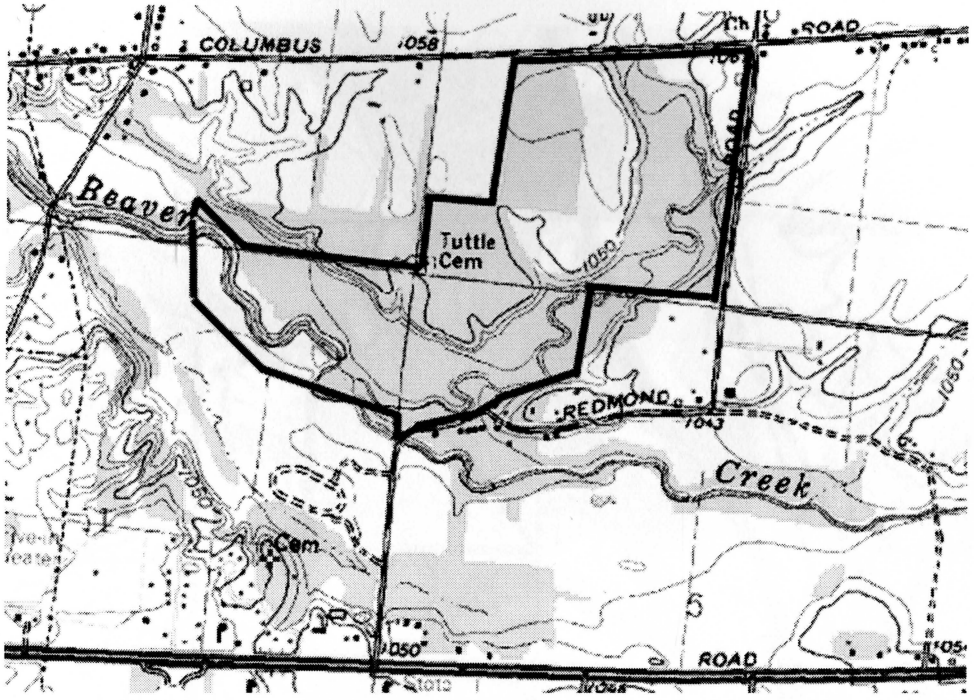



Figure D4. Topographical map and soil map location of Gallagher/Springfield Fen.



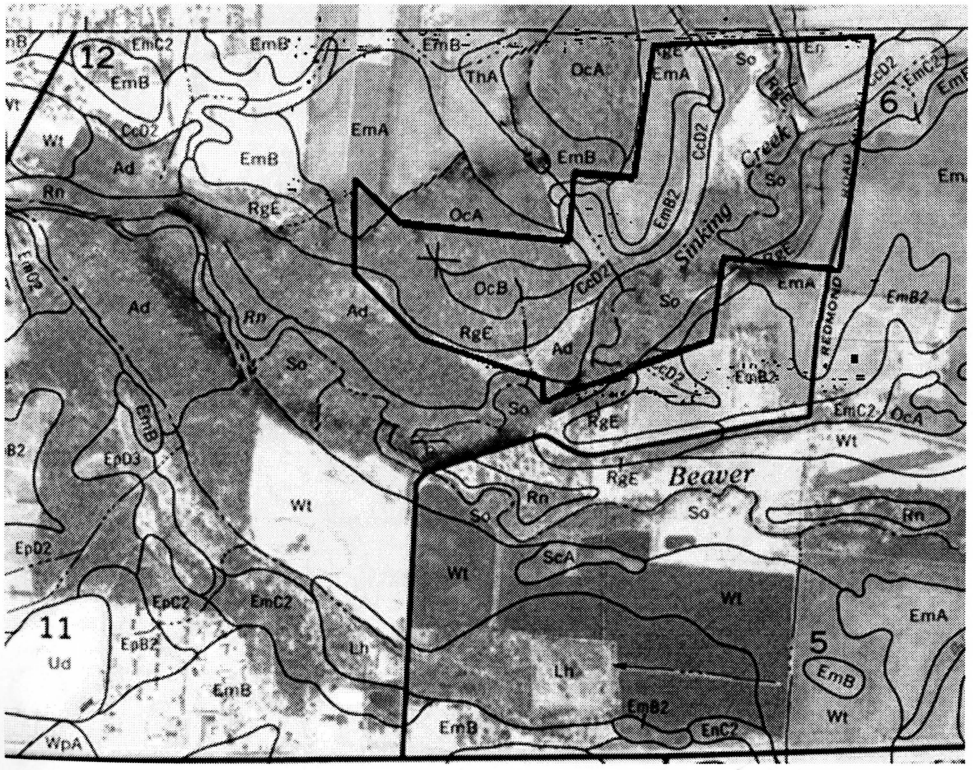
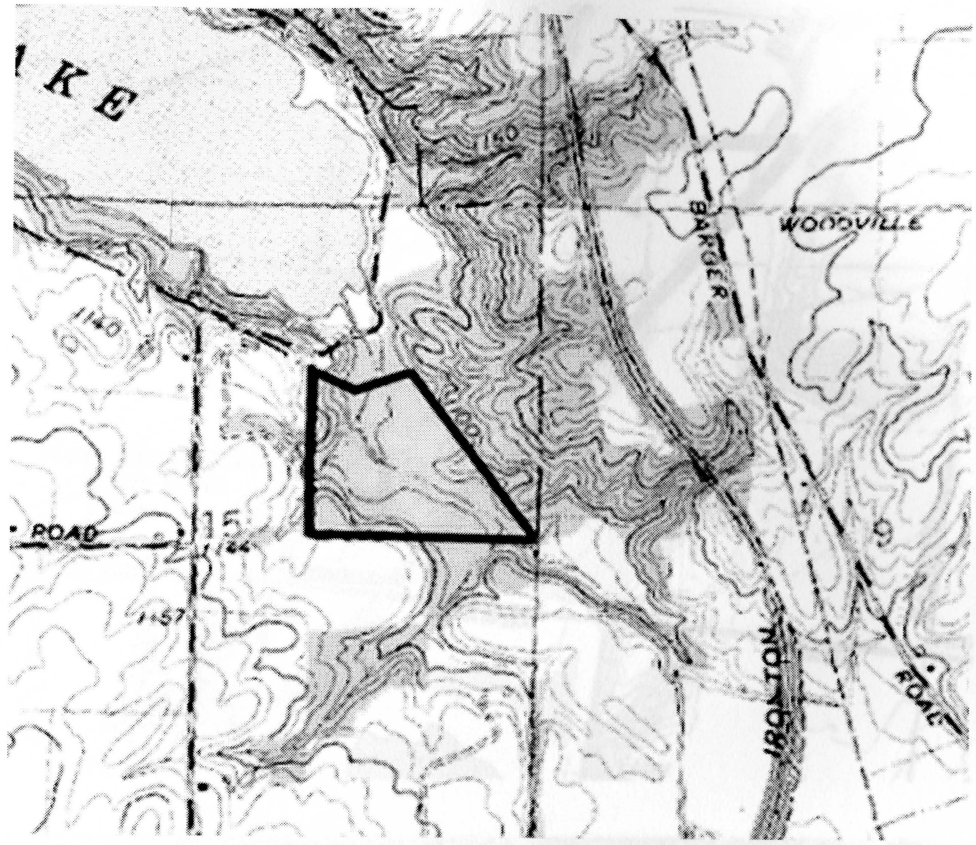



Figure D5. Topographical map and soil map location of Kiser Lake Wetlands, Headwaters section.



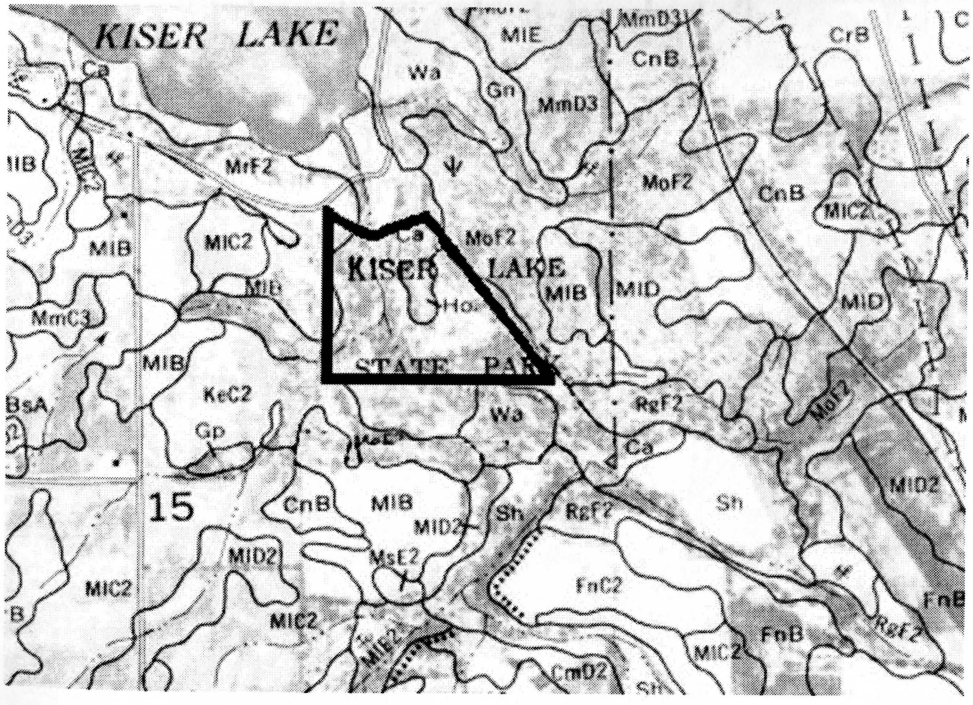
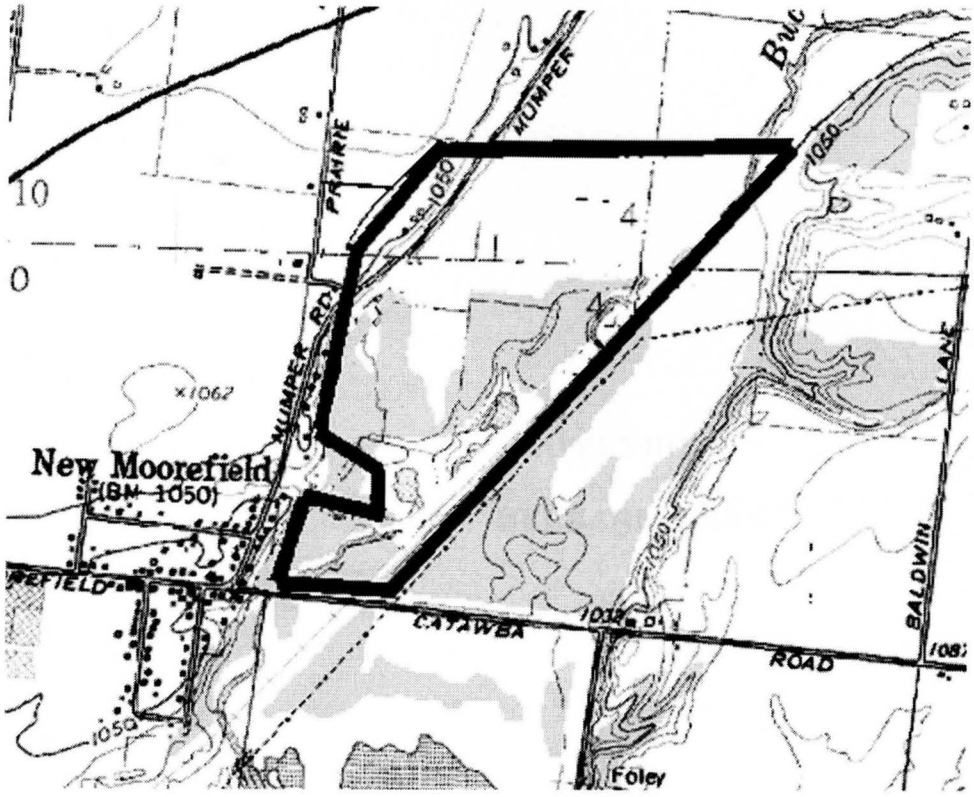
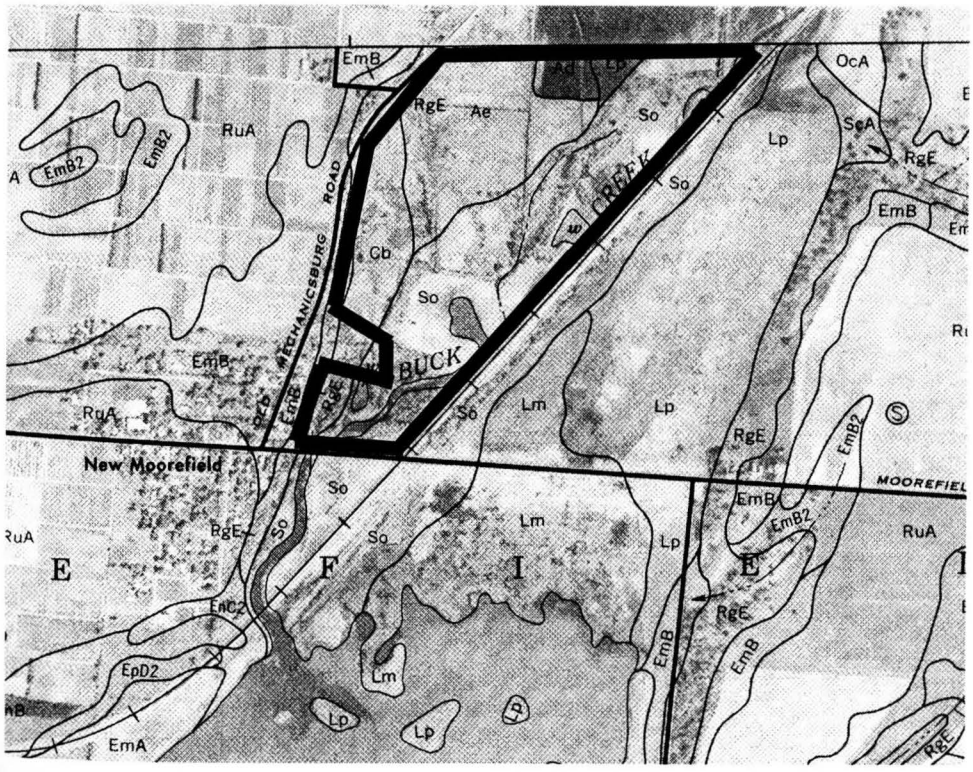



Figure D6. Topographical map and soil map location of Prairie Road Fen.



# APPENDIX E

# HERBARIA DATA

Table E1. Herbarium acronyms.

APSC: Austin Peay State University

BDI: Putnam Museum

BHO: Ohio University

BUT: Butler University

CLM: Cleveland Museum of Natural History

CM: Carnegie Museum of Natural History

CUP: Cornell University

DEK: Northern Illinois University

DMNH: Dayton Museum of Natural History

DUKE: Duke University

EAR: Earlham College

EIU: East Illinois University

GMUF: George Mason University

ILL: University of Illinois

ILLS: Illinois Natural History Survey

ISC: Iowa State University

ISM: Illinois State Museum

KBSMS: Kellogg Biological Station

KE: Kent State University

KNK: Northern Kentucky University

MO: Missouri Botanical Garden

MOAR: University of Pennsylvania

MOR: Morton Arboretum

MSC: Michigan State University

MU: Miami University of Ohio

MUR: Murray State University

MWI: Illinois University

NCSC: North Carolina State College

NCU: University of North Carolina

ND: University of Notre Dame

NEMO: Northeast Missouri State University

NYS: New York State Museum

ODU: Old Dominion University

OS: The Ohio State University

PAC: Pennsylvania State University

PHIL: Philadelphia College of Pharmacy and Science

PUR: Purdue University

SYRF: State University of New York

TENN: University of Tennessee

UMBS: University of Michigan

UMO: University of Missouri

UNCC: University of North Carolina

VPI: Virginia State University

WILLI: College of William and Mary

WMU: Western Michigan University

WVA: West Virginia University

KWVW: West Virginia Wesleyan College

YUO: Youngstown State University

Table E2. Synopsis of exsiccatae by year of collection.

| Year | Count of Year | Year | Count of Year |
|---|---|---|---|
| 1838 | 1 | 1948 | 6 |
| 1842 | 2 | 1949 | 3 |
| 1862 | 2 | 1951 | 3 |
| 1864 | 1 | 1952 | 2 |
| 1867 | 1 | 1953 | 1 |
| 1873 | 1 | 1954 | 2 |
| 1874 | 1 | 1955 | 3 |
| 1879 | 1 | 1956 | 1 |
| 1880 | 1 | 1957 | 2 |
| 1889 | 3 | 1958 | 2 |
| 1891 | 6 | 1959 | 3 |
| 1892 | 2 | 1960 | 1 |
| 1893 | 2 | 1961 | 4 |
| 1894 | 1 | 1962 | 1 |
| 1895 | 2 | 1963 | 1 |
| 1897 | 2 | 1964 | 2 |
| 1900 | 1 | 1965 | 4 |
| 1901 | 1 | 1966 | 1 |
| 1902 | 2 | 1967 | 7 |
| 1904 | 3 | 1968 | 3 |
| 1906 | 1 | 1969 | 2 |
| 1907 | 2 | 1970 | 3 |
| 1908 | 1 | 1971 | 2 |
| 1909 | 1 | 1972 | 1 |
| 1910 | 1 | 1973 | 2 |
| 1915 | 5 | 1974 | 1 |
| 1918 | 2 | 1975 | 2 |
| 1919 | 2 | 1976 | 6 |
| 1920 | 1 | 1977 | 5 |
| 1923 | 1 | 1978 | 2 |
| 1924 | 1 | 1980 | 4 |
| 1925 | 1 | 1981 | 6 |
| 1926 | 1 | 1982 | 2 |
| 1927 | 4 | 1983 | 4 |
| 1930 | 4 | 1985 | 5 |
| 1931 | 2 | 1986 | 4 |
| 1932 | 2 | 1987 | 3 |
| 1933 | 6 | 1988 | 2 |
| 1935 | 4 | 1989 | 2 |
| 1936 | 9 | 1990 | 4 |
| 1937 | 3 | 1991 | 3 |
| 1938 | 1 | 1992 | 2 |
| 1939 | 4 | 1993 | 1 |
| 1940 | 3 | 1994 | 3 |
| 1941 | 3 | 1995 | 1 |
| 1942 | 5 | 1996 | 6 |
| 1943 | 2 | 1997 | 6 |
| 1944 | 3 | 1998 | 1 |
| 1945 | 3 | 1999 | 3 |
| 1946 | 3 | 2000 | 2 |
| 1947 | 1 | No Date | 6 |

Table E3. Synopsis of exsiccatae by county of collection.

| State | County | Count of County |
|---|---|---|
| Illinois | Bureau County | 3 |
| Illinois | Cass County | 3 |
| Illinois | Cook County | 3 |
| Illinois | Ford County | 1 |
| Illinois | Grundy County | 3 |
| Illinois | Lake County | 1 |
| Illinois | LaSalle County | 3 |
| Illinois | Lee County | 7 |
| Illinois | Marshall County | 2 |
| Illinois | McHenry County | 5 |
| Illinois | Peoria County | 2 |
| Illinois | Tazewell County | 11 |
| Illinois | Vermilion County | 4 |
| Illinois | Woodford County | 4 |
| Indiana | Carroll County | 2 |
| Indiana | Cass County | 2 |
| Indiana | Delaware County | 1 |
| Indiana | Fountain County | 1 |
| Indiana | Henry County | 6 |
| Indiana | Huntington County | 1 |
| Indiana | Lake County | 1 |
| Indiana | Madison County | 3 |
| Indiana | Marion County | 1 |
| Indiana | Miami County | 4 |
| Indiana | Montgomery County | 3 |
| Indiana | Morgan County | 4 |
| Indiana | Parke County | 2 |
| Indiana | Randolph County | 4 |
| Indiana | Tippecanoe County | 10 |
| Indiana | Tipton County | 1 |
| Indiana | Wayne County | 4 |
| Indiana | White County | 3 |
| Iowa | Scott County | 1 |
| Iowa | Van Buren County | 1 |
| Maine | Somerset County | 1 |
| Maryland | Garrett County | 1 |
| Massachusetts | Berkshire County | 4 |
| Michigan | Berrien County | 3 |
| Michigan | Calhoun County | 2 |
| Michigan | Emmet County | 1 |
| Michigan | Kalamazoo County | 3 |
| Michigan | Kent | 1 |

| State | County | Count of County |
|---|---|---|
| Michigan | Marquette County | 1 |
| Michigan | Randolph County | 1 |
| Michigan | Washtenaw County | 1 |
| Missouri | Hickory County | 1 |
| Missouri | Reynolds County | 2 |
| Missouri | St. Francis County | 2 |
| New Hampshire | Gilmanton County | 1 |
| New Jersey | Somerset County | 1 |
| New Jersey | Sussex County | 1 |
| New York | Allegheny County | 1 |
| New York | Cattaraugas County | 1 |
| New York | Delaware County | 2 |
| New York | Essex County | 1 |
| New York | Hamilton County | 1 |
| New York | Oneida County | 2 |
| New York | Onondaga County | 1 |
| North Carolina | Buncombe County | 1 |
| Ohio | Adams County | 1 |
| Ohio | Ashland County | 1 |
| Ohio | Ashtabula County | 1 |
| Ohio | Athens County | 3 |
| Ohio | Carroll County | 2 |
| Ohio | Champaign County | 5 |
| Ohio | Clark County | 4 |
| Ohio | Columbiana County | 2 |
| Ohio | Darke County | 1 |
| Ohio | Fairfield County | 2 |
| Ohio | Geauga County | 1 |
| Ohio | Greene County | 6 |
| Ohio | Hamilton County | 2 |
| Ohio | Highland County | 2 |
| Ohio | Madison County | 1 |
| Ohio | Jackson County | 1 |
| Ohio | Mahoning County | 2 |
| Ohio | Miami County | 1 |
| Ohio | Montgomery County | 3 |
| Ohio | Ross County | 3 |
| Ohio | Shelby County | 1 |
| Ohio | Warren County | 1 |
| Pennsylvania | Allegheny County | 4 |
| Pennsylvania | Armstrong County | 2 |
| Pennsylvania | Bedford County | 3 |
| Pennsylvania | Berks County | 1 |
| Pennsylvania | Bradford County | 1 |

| State | County | Count of County |
|---|---|---|
| Pennsylvania | Bucks County | 3 |
| Pennsylvania | Butler County | 2 |
| Pennsylvania | Cambria County | 4 |
| Pennsylvania | Cameron County | 1 |
| Pennsylvania | Clarion County | 1 |
| Pennsylvania | Clearfield County | 1 |
| Pennsylvania | Cumberland County | 1 |
| Pennsylvania | Delaware County | 1 |
| Pennsylvania | Elk County | 2 |
| Pennsylvania | Erie County | 2 |
| Pennsylvania | Hardy County | 1 |
| Pennsylvania | Huntingdon County | 2 |
| Pennsylvania | Indiana County | 1 |
| Pennsylvania | Lancaster County | 6 |
| Pennsylvania | Lawrence County | 1 |
| Pennsylvania | Luzerne County | 2 |
| Pennsylvania | McKean County | 3 |
| Pennsylvania | Northampton County | 3 |
| Pennsylvania | Philadelphia County | 1 |
| Pennsylvania | Pike County | 1 |
| Pennsylvania | Somerset County | 3 |
| Pennsylvania | Susquehanna County | 2 |
| Pennsylvania | Warren County | 2 |
| Pennsylvania | Wayne County | 1 |
| Pennsylvania | Westmoreland County | 3 |
| Pennsylvania | Venango County | 3 |
| Virginia | Augusta County | 1 |
| Virginia | Bath County | 1 |
| Virginia | Essex County | 1 |
| West Virginia | Grant County | 1 |
| West Virginia | Hardy County | 2 |
| West Virginia | Mineral County | 1 |
| West Virginia | Monongalia County | 3 |
| West Virginia | Pocahontas County | 1 |
| West Virginia | Preston County | 1 |
| West Virginia | Raleigh County | 1 |
| West Virginia | Tucker County | 1 |

Table E4. Synopsis of exsiccatae by county of collection: historic distribution (<1960) and recent distribution (≥1960).

| State | County | Historic Count | Recent Count |
|---|---|---|---|
| Illinois | Bureau County | 0 | 3 |
| Illinois | Cass County | 2 | 1 |
| Illinois | Cook County | 0 | 3 |
| Illinois | Ford County | 0 | 1 |
| Illinois | Grundy County | 2 | 0 |
| Illinois | Lake County | 0 | 1 |
| Illinois | LaSalle County | 1 | 2 |
| Illinois | Lee County | 1 | 6 |
| Illinois | Marshall County | 0 | 2 |
| Illinois | McHenry County | 0 | 5 |
| Illinois | Peoria County | 1 | 1 |
| Illinois | Tazewell County | 10 | 2 |
| Illinois | Vermilion County | 1 | 3 |
| Illinois | Woodford County | 2 | 2 |
| Indiana | Carroll County | 2 | 0 |
| Indiana | Cass County | 2 | 0 |
| Indiana | Delaware County | 1 | 0 |
| Indiana | Fountain County | 1 | 0 |
| Indiana | Henry County | 6 | 0 |
| Indiana | Huntington County | 1 | 0 |
| Indiana | Lake County | 0 | 1 |
| Indiana | Madison County | 1 | 2 |
| Indiana | Marion County | 1 | 0 |
| Indiana | Miami County | 4 | 0 |
| Indiana | Montgomery County | 3 | 0 |
| Indiana | Morgan County | 3 | 0 |
| Indiana | Parke County | 1 | 1 |
| Indiana | Randolph County | 2 | 2 |
| Indiana | Tippecanoe County | 8 | 2 |
| Indiana | Tipton County | 1 | 0 |
| Indiana | Wayne County | 2 | 2 |
| Indiana | White County | 3 | 0 |
| Iowa | Scott County | 1 | 0 |
| Iowa | Van Buren County | 1 | 0 |
| Maine | Somerset County | 1 | 0 |
| Maryland | Garrett County | 1 | 0 |
| Massachusetts | Berkshire County | 4 | 0 |
| Michigan | Berrien County | 0 | 3 |
| Michigan | Calhoun County | 1 | 1 |
| Michigan | Emmet County | 1 | 0 |
| Michigan | Kalamazoo County | 1 | 2 |
| Michigan | Kent County | 1 | 0 |

| State | County | Historic Count | Recent Count |
|---|---|---|---|
| Michigan | Marquette County | 0 | 1 |
| Michigan | Randolph County | 0 | 1 |
| Michigan | Washtenaw County | 1 | 0 |
| Missouri | Hickory County | 0 | 1 |
| Missouri | Reynolds County | 1 | 1 |
| Missouri | St. Francis County | 0 | 2 |
| New Hampshire | Gilmanton County | 1 | 0 |
| New Jersey | Somerset County | 1 | 0 |
| New Jersey | Sussex County | 1 | 0 |
| New York | Allegheny County | 0 | 1 |
| New York | Cattaraugas County | 1 | 0 |
| New York | Delaware County | 1 | 1 |
| New York | Essex County | 1 | 0 |
| New York | Hamilton County | 0 | 1 |
| New York | Oneida County | 1 | 1 |
| New York | Onondaga County | 1 | 0 |
| North Carolina | Buncombe County | 1 | 0 |
| Ohio | Adams County | 0 | 1 |
| Ohio | Ashland County | 1 | 0 |
| Ohio | Ashtabula County | 0 | 1 |
| Ohio | Athens County | 1 | 2 |
| Ohio | Carroll County | 0 | 2 |
| Ohio | Champaign County | 2 | 3 |
| Ohio | Clark County | 0 | 4 |
| Ohio | Columbiana County | 0 | 2 |
| Ohio | Darke County | 0 | 1 |
| Ohio | Fairfield County | 2 | 0 |
| Ohio | Geauga County | 0 | 1 |
| Ohio | Greene County | 1 | 4 |
| Ohio | Hamilton County | 2 | 0 |
| Ohio | Highland County | 1 | 0 |
| Ohio | Madison County | 1 | 0 |
| Ohio | Jackson County | 0 | 1 |
| Ohio | Mahoning County | 0 | 2 |
| Ohio | Miami County | 0 | 1 |
| Ohio | Montgomery County | 3 | 0 |
| Ohio | Ross County | 0 | 3 |
| Ohio | Shelby County | 0 | 1 |
| Ohio | Warren County | 0 | 1 |
| Pennsylvania | Allegheny County | 3 | 1 |
| Pennsylvania | Armstrong County | 2 | 0 |
| Pennsylvania | Bedford County | 2 | 1 |
| Pennsylvania | Berks County | 0 | 1 |
| Pennsylvania | Bradford County | 1 | 0 |
| Pennsylvania | Bucks County | 3 | 0 |

| State | County | Historic Count | Recent Count |
|---|---|---|---|
| Pennsylvania | Butler County | 2 | 0 |
| Pennsylvania | Cambria County | 1 | 3 |
| Pennsylvania | Cameron County | 1 | 0 |
| Pennsylvania | Clarion County | 1 | 0 |
| Pennsylvania | Clearfield County | 1 | 0 |
| Pennsylvania | Cumberland County | 1 | 0 |
| Pennsylvania | Delaware County | 1 | 0 |
| Pennsylvania | Elk County | 1 | 1 |
| Pennsylvania | Erie County | 1 | 1 |
| Pennsylvania | Hardy County | 1 | 0 |
| Pennsylvania | Huntingdon County | 0 | 0 |
| Pennsylvania | Indiana County | 1 | 0 |
| Pennsylvania | Lancaster County | 5 | 1 |
| Pennsylvania | Lawrence County | 0 | 1 |
| Pennsylvania | Luzerne County | 2 | 0 |
| Pennsylvania | McKean County | 1 | 2 |
| Pennsylvania | Northampton County | 3 | 0 |
| Pennsylvania | Philadelphia County | 0 | 0 |
| Pennsylvania | Pike County | 1 | 0 |
| Pennsylvania | Somerset County | 0 | 3 |
| Pennsylvania | Susquehanna County | 2 | 0 |
| Pennsylvania | Warren County | 2 | 0 |
| Pennsylvania | Wayne County | 1 | 0 |
| Pennsylvania | Westmoreland County | 3 | 0 |
| Pennsylvania | Venango County | 0 | 3 |
| Virginia | Augusta County | 0 | 1 |
| Virginia | Bath County | 0 | 1 |
| Virginia | Essex County | 1 | 0 |
| West Virginia | Grant County | 0 | 1 |
| West Virginia | Hardy County | 2 | 0 |
| West Virginia | Mineral County | 1 | 0 |
| West Virginia | Monongalia County | 2 | 1 |
| West Virginia | Pocahontas County | 1 | 0 |
| West Virginia | Preston County | 0 | 1 |
| West Virginia | Raleigh County | 0 | 1 |
| West Virginia | Tucker County | 0 | 1 |

Table E5. Exsiccatae of *Filipendula rubra*.

**Illinois**
**Bureau County**: Miller-Anderson Woods Nature Preserve, wet seepage area along base of hills, very disturbed, September 6, 1978; Miller-Anderson Woods Nature Preserve, 1986; Miller-Anderson Woods Nature Preserve, August 10, 1999
**Cass County**: 2 specimens, no locality, July, 1842; 2 specimens, swamp, July, 1842; low ground, June 29, 1965
**Cook County**: marsh, July 17, 1963; Palos Fen, September 13, 1971; Palos Fen Nature Preserve, July, 1992
**Ford County**: Gardner Prairie Restoration, June 26, 1991
**Grundy County**: Hildy Prairies, no date; marsh land, July 9, 1951; marsh land, July 30, 1953
**Lake County**: Prairie White Fringed Orchid Nature Preserve, 1997
**LaSalle County**: marsh land, July 8, 1951; Starved Rock Nature Preserve, August 24, 1994; Starved Rock Nature Preserve, August, 1997
**Lee County**: wet meadow, August 4, 1957; marsh land, September 16, 1965; marsh border, July 29, 1971; no locality, July 1988; Rocky Ford Meadow, June 28, 1990; Nachusa Grasslands, south of Lost Lake, July 20, 1996; no locality, August 3, 1999
**Marshall County**: marsh border, July 3, 1964; wet, peaty soil in a grazed shrub bog, August 25, 1977
**McHenry County**: Wingate Prairie, 1981; no locality, May, 1987; along C&NW railroad, May, 1987; wet prairie with *Equisetum arvense*, *Senecio aureus*, and *Populus tremuloides*, May 8, 1987; no locality, with *Carex trichocarpa*, *Cirsium muticum*, *Rosa blanda*, *Silphium integrifolium*, *S. terebinthinaceum*, *Spartina pectinata, Tradescantia ohioensis*, *Hemerocallis fulva*, and *Phlox paniculata*, July 17, 1992
**Peoria County**: cold springs in Illinois river bottom, July, 1915; no locality, before 1974
**Tazewell County**: no locality, 1889; marshy woodlands, July, 1889; 3 specimens, Spring Mill Bog, June 29, 1919; 2 specimens, Spring Mill Bog, September 1, 1919; 2 specimens, Spring Mill Bog, July 18, 1947; edge of marsh, July 25, 1954; marsh, June 2, 1958; marsh, June 20, 1959; no locality, June 20, 1959; border of marsh, July 3, 1960; marsh, September 1, 1961
**Vermilion County**: moist grassy bank along Lake Vermilion, June 20, 1941; marsh, July 6, 1969; Reddens Woods, in swampy area, September 10, 1996; 2 specimens, no locality, September 5, 1996
**Woodford County**: cold bogs, Adams Mill, July 4, 1891; cold bogs, Spring Mills, July 4, 1893; marsh, July 11, 1965; Spring Bay Fen Nature Preserve, June 2, 1993

**Indiana**
**Carroll County**: no locality, 1874; marsh, August 28, 1930
**Cass County**: small seeping bog above small creek, July 19, 1936; along railroad, August 16, 1940
**Delaware County**: seeping bog, July 7, 1945
**Fountain County**: open swamp, July 5, 1952

**Henry County**: no locality, July 1, 1897; Knightstown Bog, September 4, 1948; roadside ditch, September 18, 1936; swamp, September 26, 1936; no locality, July 21, 1937; spring bank, September 4, 1948
**Huntington County**: springy slope, September 18, 1948
**Lake County**: under high-tension wires, July 11, 1972
**Madison County**: low area, July 8, 1944; springy slope northwest of pavilion, June 9, 1956; wet, calcareous sedge meadow, July 3, 1990
**Marion County**: swamp, July 16, 1935
**Miami County**: no locality, July 19, 1930; small bog, July 19, 1936; low, moist, open place along Wabash Railroad, July 12, 1939; along railroad, July 1, 1942
**Montgomery County**: bank of Monon railroad, July 30, 1927; boggy marsh along Sugar Creek, May 21, 1931; 2 specimens, Darlington Marsh, July 6, 1935
**Morgan County**: no locality, July 5, 1930; no locality, July 19, 1930; no locality, August 21, 1930; Waverly Bog, July 16, 1933
**Parke County**: swamp near Cashet Cemetary, July 6, 1952; marsh, August 7, 1980
**Randolph County**: elevated bog, July 22, 1944; Cabin Creek Bog, July 7, 1945; marshy area near Cabin Creek camp ground, July 8, 1967; wet ground in large colony of *Phragmites*, July 8, 1967
**Tippecanoe County**: swamp east of Wildcat, July 4, 1901; Wildcat Swamp, July 8, 1902; Wildcat Swamp, July 24, 1902; bog along Flint Creek, June 10, 1933; 2 specimens, marly bog on the slope of Flint Creek, July 7, 1933; wet boggy soil above Flint Creek, September 12, 1933; seeping bog, September 12, 1933; swamp ground, July 2, 1936; second terr. marshy old field, Wildcat Creek, June 30, 1965; dry ground, June 28, 1996
**Tipton County**: wet meadow below railway right-of-way in a prairie patch, July 13, 1939
**Wayne County**: Elliott's Mills Bog, limey wetland, September 3, 1955; Clear Creek Bog, open limey sedge meadow community formed on a large groundwater seep, July 15, 1957; Elliott's Mills Bog, boggy area, limey wetland, June 29, 1968; wet bank of ditch, Elliott's Mills Bog, limey wetland, June 29, 1968
**White County**: moist, rich soil, July 7, 1938; 3 specimens, along railroad, June 29, 1940; along roadside, June 29, 1940

**Iowa**
**Scott County**: cultivated and persistent in a fern-bed, July 1, 1959
**Van Buren County**: Utica, June 30, 1891

**Maine**
**Somerset County**: escaped from school house, August 31, 1937

**Maryland**
**Garrett County**: edge of meadow, August 15, 1936

**Massachusetts**
**Berkshire County**: moist grassy roadside, July 19, 1915; no locality, July 22, 1915; wet ground, roadside, July 27, 1920; neglected open spot near schoolhouse, escape, July 27, 1923

**Michigan**
**Berrien County**: Berrien Springs, the "Indian Bowl," September 21, 1975; Indian Bowl Prairie, wet fen, July 13, 1977; Indian Bowl area prairie, July 12, 1980
**Calhoun County**: prairie meadow near the Kalamazoo River, July 18, 1954; 4 specimens, wet meadow, flowers pink with fragrance of roses and lemons, July 24, 1976
**Emmet County**: wet meadow north of Harbor Point, August 10, 1924
**Kalamazoo County**: 2 specimens, Comstock, swamp meadows, July 22, 1936; calcareous muck, growing in less dense *Cornus* shrub-carr with *Potentilla fructicosa*, September 21, 1982; prairie fens in *Cornus* and *Carex* thicket in saturated calcareous muck with *Cornus foem.*, *Carex stricta*, *Calam. Can.*, *Thelpteris palustris*, *Toxicodendron radicans*, August 2, 1994
**Kent County**: Grand Rapids, Plaster Creek, September 2, 1895
**Marquette County**: 2 specimens, Marquette, hillside, perhaps a garden escape, August 5, 1961
**Randolph County**: 2 specimens, calcareous seeping bog, July 23, 1966
**Washtenaw County**: Augusta, no locality, August, 1932

**Missouri**
**Hickory County**: fen or seep below Gasconade dolomite ledges, above spring-fed tributary of Little Niangua River, along East side of drainage in shade of woody associates, August 9, 2000;
**Reynolds County**: swampy meadow along West Fork of Black River, July 6, 1951; pastured prairie fen with *Eupatorium perfoliatum*, *Scirpus atrovirens*, *Juncus effusus* var. *solutus*, *Pycnanthemum virginianum*, *Glyceria striata*, *Carex stricta* var. *strictior*, and *Rudbeckia fulgida* var. umbrosa, spring-fed ditches, July 4, 1982
**St. Francis County**: 2 specimens, calcareous wet area, July 28, 1976; calcareous seep fens association with *Rudbeckia fulgida* var. umbrosa, *Oxypolis rigidior*, *Thelpteris palustris*, and *Carex stricta* var. strictior, June 24, 1981

**New Hampshire**
**Gilmanton County**: no locality, August 7, 1873

**New Jersey**
**Somerset County**: in cultivation, July 10, 1925
**Sussex County**: no locality, July 4, 1907

**New York**
**Allegheny County**: 2 specimens, damp edge of old pasture near roadside ditch, July 13, 1994
**Cattaraugas County**: 2 specimens, thickets, July 20, 1926
**Delaware County**: Arkville, July-August, 1904; open roadside, July 23, 1973
**Essex County**: roadside, upper Minerva Brook, August 20, 1927
**Hamilton County**: along roadside, July 23, 1983
**Oneida County**: no locality, July 15, 1943; old pasture area, obviously escaped, July 24, 1980
**Onondaga County**: no locality, 1949

**North Carolina**
**Buncombe County**: 2 specimens, Asheville, Biltmore, moist grounds, July 27, 1897

**Ohio**
**Adams County**: west bank, July 3, 1985
**Ashland County**: no locality, 1893
**Ashtabula County**: moist ditch between intersection, July 14, 1968
**Athens County**: Plains Swamp, June, 1939; near farm house, July 12, 1961; edge of lawn, August 22, 1961
**Carroll County**: marshy area in bottom of Frog Run Valley, October 3, 1983; 2 specimens, opening between 2 beaver ponds, valley of Frog Run, July 2, 1985
**Champaign County**: no locality, September 10, 1892; Cedar Swamp, September 10, 1892; Cedar Bog, July 29, 1967; *Potentilla* bog, Kiser Lake State Park Nature Preserve, September 13, 1976; 2 specimens, wetlands, Kiser Lake Wetlands, July, 1977
**Clark County**: small fen at base of kame, August 2, 1978; fen, July 8, 1981; fen meadow, Gallagher Fen, July 25, 1989; open fen meadow, Crabill Fen, July 13, 1990
**Columbiana County**: edge of marsh, Watercress Marsh, July 21, 1983; sedge and shrub zones of Watercress Marsh, July 7, 1995
**Darke County**: abandoned B&O railroad track, June 27, 1985
**Fairfield County**: Pleasant Run Swamp, August 25, 1935; 2 specimens, no locality, July 25, 1937
**Geauga County**: in a cattail swale on open wet flats adjacent to the Cuyahoga River, local, a single large stand about 10 feet across, July 17, 1976
**Greene County**: no date, no locality; 3 specimens, Xenia, bog, July 5, 1933; wet opening, August 4, 1976; shrubby meadow, Ankeny Fen, July 10, 1985; Ankeny Fen, June 19, 1986; 2 specimens, fen meadow, Ankeny Fen, July 18, 1988
**Hamilton County**: boggy border of the bank, June 12, 1879; Cincinnati, July 14, 1904
**Highland County**: no date, no locality; no locality, July 12, 1931
**Madison County**: low area, July 8, 1944
**Jackson County**: 2 specimens, very moist field, July 2, 1967
**Mahoning County**: moist, clay soil, escaped from cultivation, July 18, 1967; upright herb, 3.5," average moisture, open exposure, density rate, associated with cultivated plants, located south of state Rt. 165 between Beaver Creek Rd. and Egypt Rd., pink flower color, escaped from old flower bed, July 18, 1967
**Miami County**: in marly "meadow" along sore of Silver Lake, July 29, 1983
**Montgomery County**: no date, marsh; no date, no locality; Dayton, wild prairies, July, 1864; Dayton, July, 1880; Dayton, University of Dayton, moist ground, July 3, 1939
**Ross County**: boggy ground along Blackwater Creek, August 16, 1977; Blackwater Swamp, July 20, 1980; Betsch's Fen, wet prairie, September 7, 1985
**Shelby County**: shaded seepage, July 14, 1981
**Warren County**: marshy area in field, July 30, 1967

**Pennsylvania**
**Allegheny County**: no locality, July 1, 1918; Little Sewickley Creek, June 28, 1945; Little Sewickley Creek, June 22, 1946; along Little Sewickley Creek, June 29, 1977
**Armstrong County**: no locality, July 20, 1927; along Buffalo Creek, July 22, 1932

**Bedford County**: no locality, September 24, 1948; wet abandoned field, September 24, 1948; growing among *Coronilla varia*, along the roadside, July 8, 1986
**Berks County**: growing along the edge of a farm lane, may have escaped from cultivation, June 20, 1989
**Bradford County**: roadside, June 19, 1942
**Bucks County**: no locality, June 28, 1910; moist ground near Rich Hill, June 28, 1915; no locality, July 2, 1915
**Butler County**: roadside bank, formerly cultivated, July 13, 1946; no locality, September 17, 1949
**Cambria County**: brushy bottom along Clearfield Creek, May 14, 1955; no locality, July 5, 1970; no locality, July 10, 1996; no locality, July 28, 1997
**Cameron County**: first fork of Sinnemahoning Creek, July 6, 1918
**Clarion County**: near Cook Forest, July, 1940
**Clearfield County**: no locality, July 13, 1908
**Cumberland County**: no locality, June, 1850
**Delaware County**: no locality, July 4, 1909
**Elk County**: no locality, July 17, 1946; 2 specimens, moist, partially shaded weedy roadside, July 8, 1986
**Erie County**: no locality, 1891; Edinboro Bog, July 17, 1962
**Hardy County**: near Lost River, June 18, 1942
**Huntingdon County**: no locality, no date; Crooked Creek, no date
**Indiana County**: Cherry Run Reservoir, July 11, 1935
**Lancaster County**: 2 specimens, no locality, 1862; no locality, June 24, 1862; 2 specimens, no locality, August 2, 1867; swamp, July 24, 1894; Lancaster, meadow near Mt. Ville, July 1895; roadside thicket, Mt. Ville, 1991
**Lawrence County**: Mt. Jackson, along Hickory Creek, June 9, 2000
**Luzerne County**: 2 specimens, beech haven, June 27, 1889; 2 specimens, wet roadside, July 8, 1936
**McKean County**: no locality, July 21, 1904; along Rt. 59, July 23, 1975; no locality, July 12, 1996
**Northampton County**: no locality, 1838; 2 specimens, no locality, July 13, 1907; naturalized in a fence row, July 19, 1942
**Philadelphia County**: no locality, no date
**Pike County**: brushy meadow, July 5, 1949
**Somerset County**: roadside, August 13, 1964; along the south fork of Ben's Creek, September 7, 1969; moist meadow near the south fork of Ben's Creek, September 7, 1970
**Susquehanna County**: 2 specimens, roadside escape, July 8-20, 1900; wet roadside, June 26, 1936
**Warren County**: Allegheny Forest, July 6, 1941; no locality, July 24, 1948
**Wayne County**: no locality, September 16, 1906
**Westmoreland County**: 4 specimens, no locality, July 2, 1891; no locality, July 21, 1891; Powdermill Nature Reserve, July 3, 1981
**Venango County**: rare and local, open road, July 8, 1997; 2 specimens, no locality, July 25, 1997; seven of these herbs were found just west of Van Free Methodist Church on north side of Rt. 322, Cranberry Township, August 9, 1997

**Virginia**
**Augusta County**: calcareous wet meadow at Mastic (Warehouse) Marsh, September 22, 1991
**Bath County**: 2 specimens, roadside ditch, July 10, 1970
**Essex County**: roadside, July 9, 1941

**West Virginia**
**Grant County**: along the Western Maryland railroad tracks, July 7, 1973
**Hardy County**: 2 specimens, Lost River, July 5, 1927; roadside swamp, near Lost River, June 18, 1942
**Mineral County**: no locality, July, 1955
**Monongalia County**: no locality, May 28, 1891; abandoned homestead, August 1, 1943; appeared in a woman's flower garden one year, July 6, 1976
**Pocahontas County**: along Rt. 28, July 18, 1958
**Preston County**: White Oak Springs, open moist ground, July 22, 1990
**Raleigh County**: no locality, July 9, 1999
**Tucker County**: in an opening, July 7, 1998