

CURRENT AND HISTORIC DISTRIBUTION
OF
GARLIC MUSTARD
(*Alliaria petiolata*)
IN ILLINOIS

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ABSTRACT

Alliaria petiolata is a shade-tolerant obligate biennial European herb that invades forested natural communities in the midwestern and northcentral United States. *Alliaria* was first collected in Illinois in 1918 north of Chicago, and by 1991 had spread to 42 counties in northern and central Illinois. Rate-of-spread has been exponential, with the number of new populations within equi-sized latilong blocks (146 ha²) approximately doubling every 10 years; by June 1991 *Alliaria* occurred in 160 blocks. Regional spread has been by establishment of multiple satellite populations, and by spread as an advancing front from population centers. Seed dispersal is by natural and anthropogenic means. Floodwaters disperse seeds along river corridors, and vehicles and mowers distribute seeds along road corridors. Natural area visitors carry seeds within and between forested sites, and appear to be the primary seed vector among isolated areas. In five northeastern counties *Alliaria* occupies virtually all available habitat. State-wide, *Alliaria* occurs in 57 (29%) dedicated nature preserves and 18 (31%) state parks. Removal of newly established populations prior to seed production may slow the spread of *Alliaria* in counties with few populations. Effective long-term control will likely require development and implementation of biological control.

INTRODUCTION

Garlic mustard (*Alliaria petiolata* (Bieb.) Cavara & Grande) is an erect obligate biennial herb of the Cruciferae. The plant is native to northern Europe south of 68 degrees North (Tutin et al. 1964), ranging from England to Sweden to the western USSR and south to Italy. From this native range, *Alliaria* has spread to North Africa, India, Ceylon (Rai et al. 1972 and Fernaldo 1971, in Cavers et al. 1979), and New Zealand, as well as Canada and the United States.

Alliaria petiolata is frequently referred to as *Alliaria officinalis* Andrzej. Earlier scientific names include *Alliaria alliaria* L. (Britton), *Sisymbrium alliaria* Scop., *Sisymbrium officinalis* DC and *Erysimum alliaria* L. Common English names, in addition to garlic mustard, include hedge garlic, jack-by-the-hedge, and sauce-alone (Georgia 1920).

Alliaria petiolata (hereafter referred to as *Alliaria*) was first recorded in North America in 1868, on Long Island, New York (Leggett, NYS). It is now established in at least 23 northeastern and mid-western states, and adjacent Canada (Nuzzo unpublished). Infrequent collections from western North America indicate that the species may be a sporadic rather than established component of the regional flora, or is in the process of becoming established (Nuzzo unpublished).

In North America *Alliaria* is an aggressive species that invades moist to dry-mesic deciduous forests (Cavers et al. 1979). *Alliaria* also occurs in the partial shade characteristic of oak savanna, forest edges, hedgerows, shaded roadsides, and urban areas, and occasionally occurs in open fields (Nuzzo 1991). The plant commonly enters natural areas in disturbance patches, such as trails, treefalls and flood-

plains. *Alliaria* is one of the few alien herbaceous species that invades shaded communities in the midwest.

Alliaria is recognized as a problem species in northern Illinois forest communities (Schwegman 1989). The plant became a species of management concern in the late 1980's, as field biologists and botanists witnessed a rapid increase in *Alliaria*'s frequency and abundance within natural areas. Field managers and researchers are testing the effectiveness of different management methods to control this plant (Nuzzo 1991; W. McClain, S. Packard, J. Schwegman, personal communication). Little is known concerning the entry of this alien species into the state's flora, the historic rate-of-spread within the state, nor the species' current distribution in Illinois. This project was undertaken to document regional rate-of-spread and current presence of *Alliaria* within Illinois.

METHODS

Entry and Distribution

Historic entry and distribution were determined using two sources of data; herbarium records, and published floras and other literature sources. Current distribution was derived from historical sources and sight observations.

Herbarium Records

One hundred ten collection records obtained from 17 herbaria were compiled by decade and by county (Appendix), and mapped by specific location within each county. When indicated on the herbarium label, habitat and abundance data were compiled. Herbaria data were also collected for adjacent portions of Wisconsin, Indiana, Kentucky, Missouri and Iowa.

Herbarium records are accurate indicators of a species' occurrence at a given time and place, but the use of such collections to document a species spread through time and space are subject to certain limitations (Thompson et al. 1987); the species must be easily seen and identified, collections must be made at random through the entire area, and the area must be uniformly collected through the time period. The first limitation is met as *Alliaria* is highly visible and readily identifiable in flower and fruit. The second and third limitations are less easily met. The Chicago region, the driftless area of northwest Illinois, and the central sand counties were well botanized over a period of years. Other parts of the state were undercollected, and a few locations were repeatedly and sometimes heavily collected (for example, Allerton Park in Piatt County). Collection through time may also be skewed; collectors often focus on unknown species and new county records, and these collections may serve as relatively accurate indicators of a species' entry into a local flora. However, as a species becomes established, it may be undercollected by individuals who avoid weedy and/or common species. Hence, lack of collections may indicate that a species is considered too common to collect, rather than uncommon or absent from the locale.

Literature

All known published floras for Illinois were examined for any reference to *Alliaria*. All potentially applicable papers and reports cited in Risser (1984), and all issues of the Transactions of the

Illinois Academy of Science published between 1982 (hence not included in Risser 1984) and June 1991 were similarly examined. A computerized literature search of Agricola and BIOS databases using the keywords *Alliaria* and/or *garlic mustard* was conducted in 1990 and all citations were reviewed.

Sight Observations

Sight observations of *Alliaria* were made by the author since 1977, and by numerous other individuals for the years 1988-1991. Illinois Department of Conservation Natural Heritage Biologists and Illinois Nature Preserves Commission staff searched for *Alliaria* in IDOC and INPC sites. Forest Preserve staff in DuPage, Kane, Lake, McHenry, Will, and Winnebago Counties contributed information regarding *Alliaria* presence on county-owned lands. Volunteer stewards with the Illinois Nature Conservancy Volunteer Stewardship Network provided presence/absence information for *Alliaria* in individual public and private tracts, primarily in the Chicago region. Additional site records were provided by numerous other individuals.

The majority of observations are assumed to be correct, as *Alliaria* is easily identified and usually distinct from other plant species. However, in fall and winter, small *Geum* and *Viola* plants may be mistaken for small *Alliaria* rosettes by inexperienced observers. When a sight observation was questionable, the observation was confirmed by the author or excluded from the data base.

All three information sources (herbarium records, literature and sight observations) provide useful documentation of the minimum presence of *Alliaria* within the state at any given time, and are assumed to underestimate the actual extent of distribution.

Rate of Spread

Rate of spread was determined by recording, by decade, the first record or observation of *Alliaria* within each 7.5 minute latilong block in Illinois. A latilong block is the area covered by a 7.5 minute topographic map, approximately 146 km². These data were used to map cumulative spread through time, and to graph cumulative occurrence of distribution through time.

RESULTS

Entry into state flora, and first record in each county

1910-1939

The first record of *Alliaria* in Illinois is a 1918 collection from Ravinia, Lake County (Colton 6 [recorded as Cook County on the label], F: Figure 1A). *Alliaria* had not been recorded east of Ohio prior to this collection. *Alliaria* was not included in any Chicago-region flora until 1969 (Swink).

Alliaria was next collected in 1939 in Rockford, Winnebago County (Fuller & Haim 156f ISM). The habitat description ("Roadsides and near habitation") implies multiple locations within the locale.

1940-1949

In the period 1940-1949, *Alliaria* was collected six times from five localities; DuPage, Piatt, Sangamon, and Winnebago Counties, and "near Salt Creek" (no county given; Albright s.n. F) (Figure 1B).

In 1940 the plant was twice collected from 'waste ground' in the city of Rockford (Fuller and Haim 1166H ILL, ISM; Fuller 1695H ISM). In 1945 Eifert (10207 ISM) commented that *Alliaria* was "common" in Washington Park in Springfield, Sangamon County. Fuller's 1943 list of plant species resident within Sangamon County omitted reference to *Alliaria*; the plant was apparently rare or unknown outside of Washington Park prior to 1943. *Alliaria* was included in the 1947 list of additions to the county's flora (Fuller 1947).

Swink (s.n. MOR) collected *Alliaria* from a "partly shaded" roadside in Elmhurst, Du Page Co, in 1947. In 1949 Ahles (1048 ILL) made the first Piatt County collection from Allerton Park. Two years later, Jones (1951, 18985 ILL) wrote on a collection label "rather common and thoroughly established" in Allerton Park.

The first written reference to *Alliaria*'s presence within Illinois is Jones' 1945 Flora of Illinois, with the comment "roadsides and waste places, common". The second written reference to *Alliaria* was the 1949 checklist of vascular plants of Winnebago County (Fuller, Fell and Fell). The species is omitted from the comprehensive Flora of Winnebago County (Fell 1955), indicating that *Alliaria* was not considered naturalized at that time.

Throughout the state, *Alliaria* consistently appeared in herbarium collections prior to inclusion in state or county floras, with the exception of Will County (Swink and Wilhelm 1969). This is in contrast to other invasive species, such as purple loosestrife (*Lythrum salicaria*), which was described in historic floras 16 years prior to the first herbarium collection (Stuckey 1980).

Murley (1951) collected seeds from a "colony of 25" *Alliaria* plants in 1948 in Winnetka (Cook County), 7 km south of the original 1918 location. During this same period, the first Wisconsin collection was made in 1947 from a roadside near Lake Geneva in Walworth County (Fassett 22502 WIS).

1950-1959

Alliaria was collected from four additional counties in the period between 1950-59 (Figure 1C). In 1952 Swink (959 F) recorded *Alliaria* in Kane County, and Lane (682 ISM) collected *Alliaria* from the Great Lakes Naval Station in Lake County. The Station is located some 17 km north of the 1918 collection site. In 1954 Evers (42275 ILL) and Winterringer (11499 ISM) found *Alliaria* growing on Lake Michigan bluffs 2 and 3 km, respectively, south of the 1918 location.

The first record of *Alliaria* in western Illinois was made in 1954. Ahles (8027 ISM, ILL) and Buser (5027 IND) collected *Alliaria* from separate wooded hillsides in the vicinity of Mississippi Palisades State Park, Carroll County. Three years later Chase (14371 ILL) collected *Alliaria* from a roadside in Tazewell County.

Winterringer and Evers (1960) included *Alliaria* on a list of "additional records for infrequently collected plants" [in Illinois], and cited Cook and Tazewell Counties collections. Jones and Fuller (1955) recorded *Alliaria* in Piatt, Sangamon and Winnebago Counties.

1960-1969

Alliaria occurred in five additional counties, and by the end of the decade was known from 14 counties (Figure 1D). The new occurrences were widely spread, and generally distant from other counties known to contain *Alliaria*.

Evers (63884 ILLS) collected *Alliaria* in a moist woods in Grundy

County in 1960. In 1962 Chase (17226 ILL, ILLS) collected multiple specimens from Peoria, Peoria County. Evers (79913 ILLS) collected *Alliaria* in 1964 in Boone County, and Ebinger (4405 EIU) recorded the species along a railroad in Coles County in the same year. In 1966 Jones (42658 ILL) recorded *Alliaria* from Champaign County. This is the first Illinois record of the plant growing in an urban garden. The label information does not indicate if *Alliaria* was present as a weed or as a cultivated species.

Swink (1969) indicated that *Alliaria* was present in Will County by 1969; this record was presumably based on a sight observation.

1970-1979

Alliaria was collected more often in the 1970's than in any other decade. Forty-two collections were made in 22 counties, nine of which provided new county records (Figure 1E).

Schulenberg collected three of the nine county records: in 1971 in McHenry County (s.n. MOR), in 1974 from a railroad ditch in DeKalb County (74-038 MOR), and in 1976 from a "large population" along the Des Plaines River in Hamel Woods Forest Preserve in Will County (76-314 MOR).

Shildneck (C-3502 ILLS ILL) recorded the species from Spitler State Park in Macon County in 1972, and six years later made the first DeWitt County collection (Shildneck C-11810 ILL). In 1974 Maier (s.n. ILL) recorded the species from Sand Ridge State Forest in Mason County. The first Ogle County collection was made in 1975 by Muller (97 DEK), just south of the Winnebago County line, and Evers (114796 ILLS) collected *Alliaria* for the first time in LaSalle County in the same year. In 1976 Ebinger (15778 EIU) recorded *Alliaria* from a wooded hillside in Clark County.

In this same decade collections were made in Kenosha (Schulenberg 75-424 MOR), Rock (Rice 3475 WIS), and Grant (Hansen 2477 WIS) Counties in Wisconsin; in LaPorte (Schulenberg 74-063 MOR) and Lake Counties (Schulenberg 74-108 MOR DEK) in Indiana; and in St. Louis County (Boufford 18953 CM) in Missouri.

1980-1989

Alliaria was recorded from 12 new counties in the 1980's (Figure 1F). Five records are documented by herbaria specimens, one is reported in literature, and six are based on sight observations.

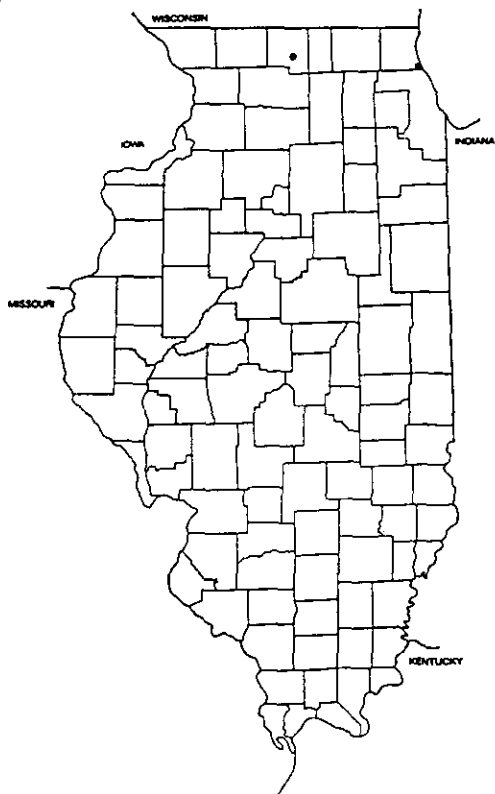
Ebinger (20557 EIU) collected *Alliaria* in a "lowland woods" in Putnam County. Henry and Scott (s.n. MWI) collected *Alliaria* in Fulton County in 1984, and in Hancock County (s.n. MWI) in 1988. In 1987 Swink and Shimp (7552 MOR) recorded *Alliaria* in Kankakee River State Park in Kankakee County, and in 1987 Horton (25 EIU) collected *Alliaria* in Wolf Creek State Park in Shelby County.

Mohlenbrock (1986) wrote that *Alliaria* occurred in Jackson County, and J. Faulkner and E. Cypher reported it from Thompson Woods, SIU campus, in Carbondale. This was the first record of *Alliaria* in the southern third of the state.

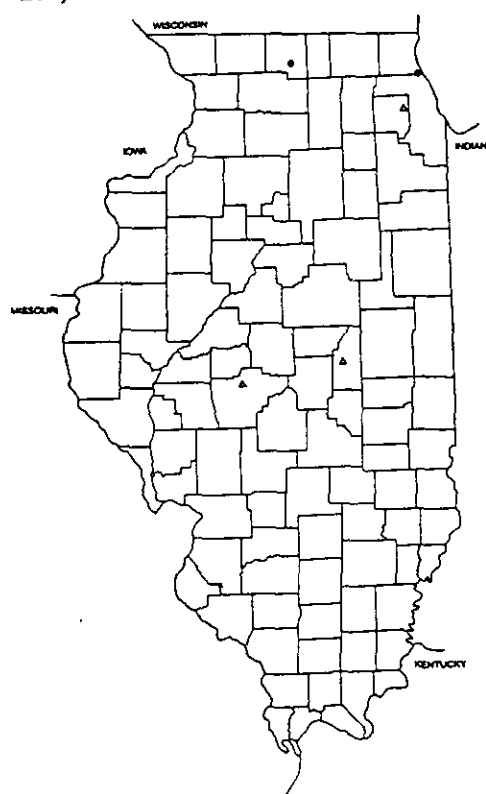
C. Moser observed *Alliaria* in a "small timber area" in central Woodford County in 1985, and in 1987 C. Bonny found *Alliaria* in Knox County. In 1988 R. Nýboer observed *Alliaria* in Page Park, Dixon, in Lee County, and in the Oak Valley Eagle Refuge in Rock Island County. In 1988 *Alliaria* was also observed in two locations in Jo Daviess County; in Apple River Canyon by R. Nýboer, and on an algific slope near Hanover Bluff Nature Preserve by G. Burnett. In Stephenson County

FIGURE 1: *Alliaria petiolata* Distribution in Illinois 1918 - 1991

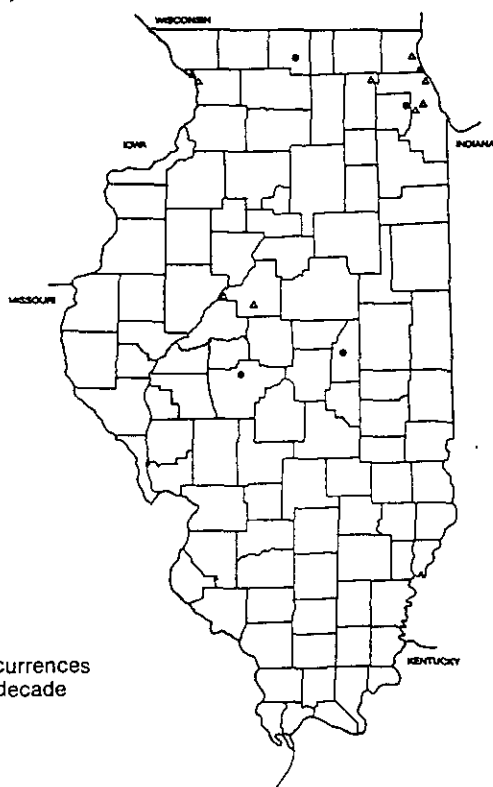
1A) 1918-1939



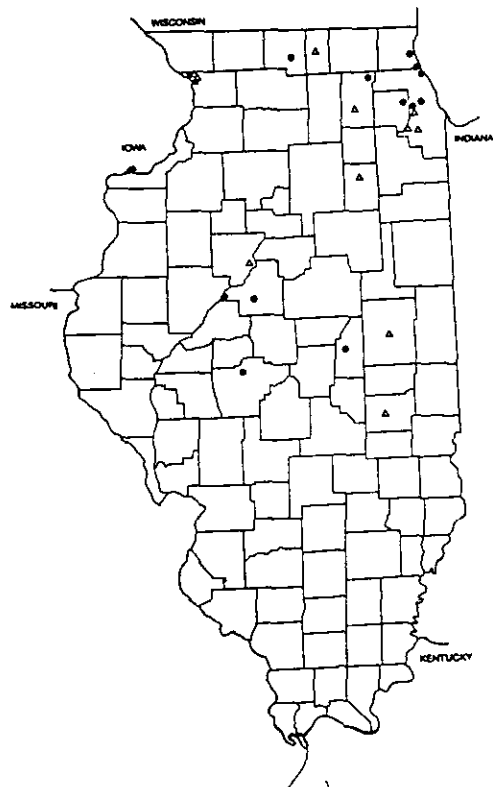
1B) 1918-1949



1C) 1918-1959

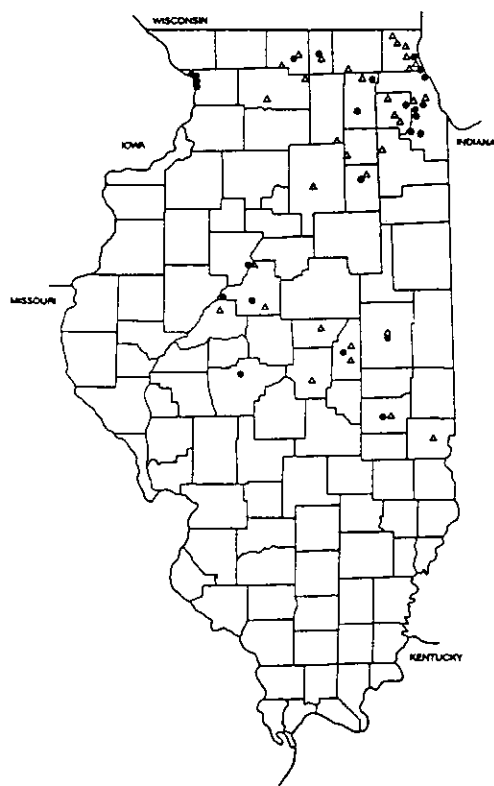


1D) 1918-1969

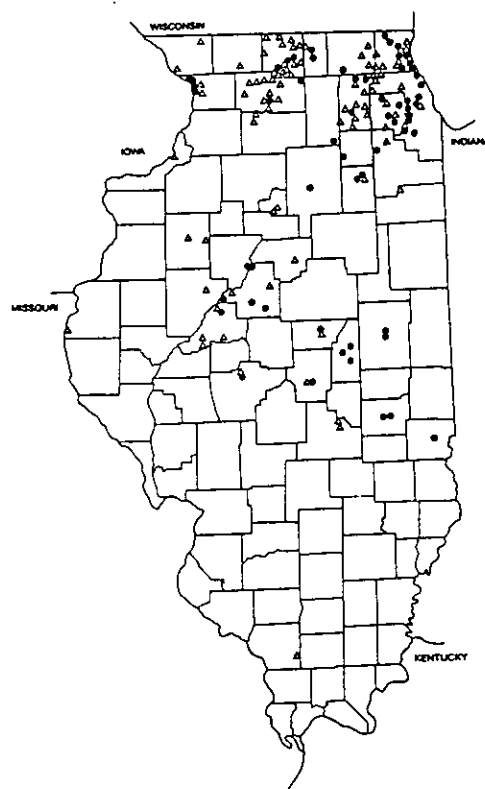


△ New occurrences
in each decade

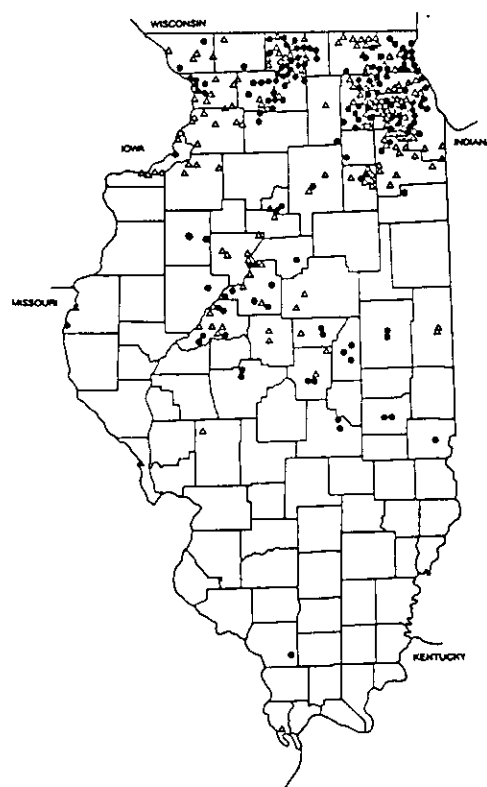
1E) 1918-1979



1F) 1918-1989



1G) 1918-1991



Alliaria was observed in 1989 by V. Nuzzo at the Oakdale Nature Center south of Freeport.

1990/1991

By June 1991 *Alliaria* occurred in 43 counties, occupying the three northern tiers of counties in Illinois (Figure 1G), and the lowest tier of counties in Wisconsin.

During this time period all but one of the records were based on sight observations (Table 1); no herbaria records were obtained. *Alliaria* was recorded for the first time in 1990 in five counties, and in 1991 in a sixth county. R. Szafoni and V. Nuzzo found scattered plants growing in Kickapoo State Park in Vermillion County. J. Alesandrini observed large patches growing along a regional trail near Fulton in Whiteside County. R. Szafoni and E. Dietz reported "abundant" *Alliaria* in the floodplain of Funk's Grove, McLean County. T. Strole observed *Alliaria* in Solomon Creek Woods in Macoupin County, and R. Lindsey found the plant at Red's Landing in Calhoun County. In 1991 R. Lindsey observed a large stand of *Alliaria* at Horseshoe Lake State Park in Alexander County.

Peterson (1991) listed *Alliaria* as "rare" at Lovets Pond, Jackson County, the second recorded occurrence of *Alliaria* in the county.

Rate of Spread

Alliaria has spread exponentially through Illinois. Figure 2 depicts the first record of occurrence, by decade, of *Alliaria* within 162 equi-sized latilong blocks in Illinois (each block represents the area covered by a 7.5 minute topographic map). It is important to note that the 1990 records indicate expansion in 1 1/2 years (January 1990-June 1991) based primarily on sight observations, in contrast to the other records which represent expansion over a ten year period and are based primarily on herbarium records (Table 1). Cook County is under-represented in this map; *Alliaria* is present throughout the county, but verification of occurrence within specific sites was unavailable.

Cumulative number of occurrences by decade are graphed in Figure 3. The steep upper slope of this "J-curve" indicates that the rate at which *Alliaria* is spreading through the state is on the increase, with and without inclusion of the 1990/91 sight observations.

TABLE 1: First record of *Alliaria petiolata* occurrence within 7.5' topographic quadrangles (latilong blocks); number of herbaria collections, sight observations, and literature references by decade.

	1918- 1939	1940- 1949	1950- 1959	1960- 1969	1970- 1979	1980- 1989	1990- 1991
Herbarium Record	2	3	6	8	17	9	0
Sight Observation	0	0	0	0	3	38	69
Literature	0	1	0	0	1	2	1
TOTAL	2	4	6	8	21	49	70

Figure 2:

Alliaria petiolata Distribution in Illinois 1918 - 1991

mapped by first record of occurrence
within 7.5' topographic quadrangles

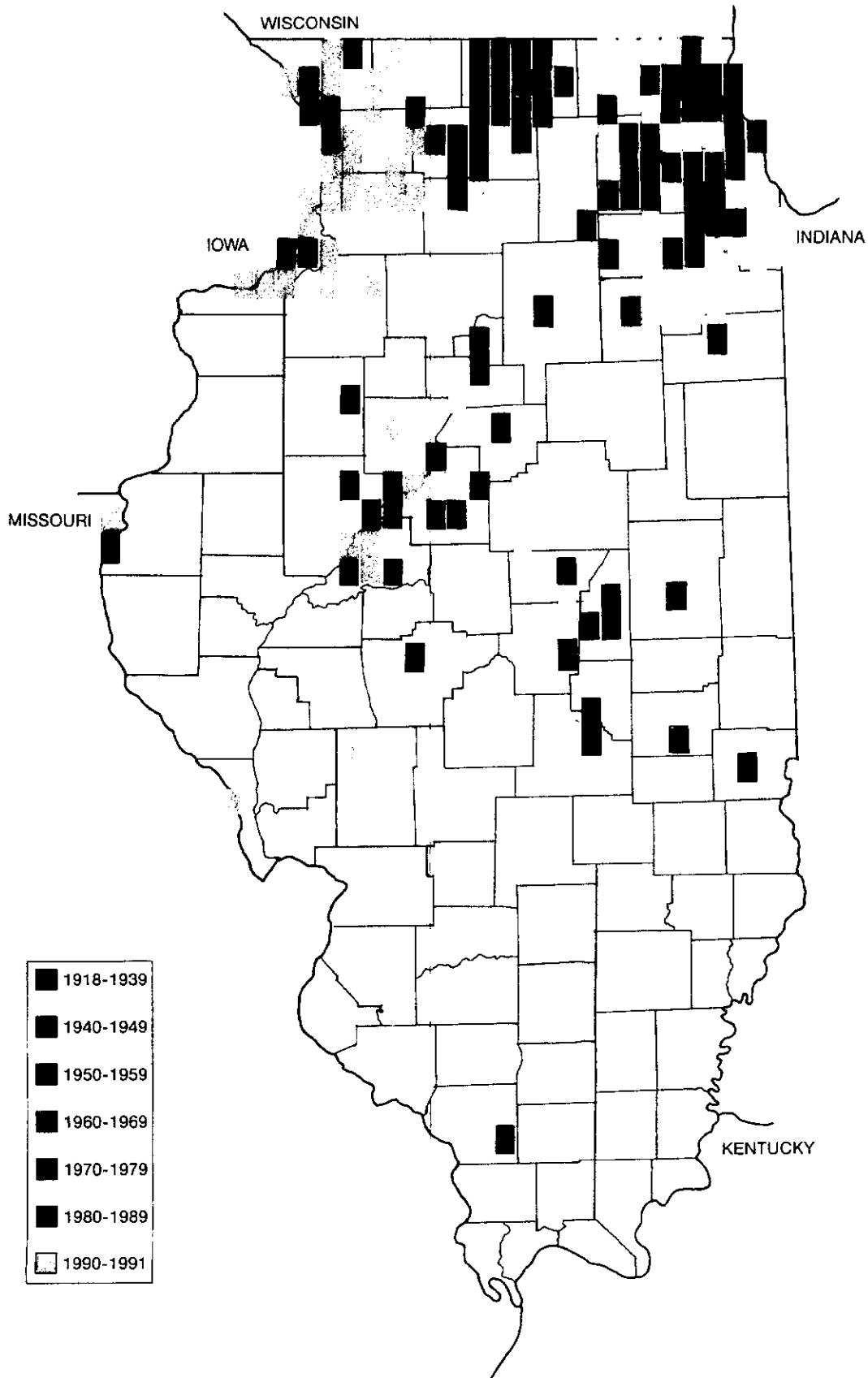
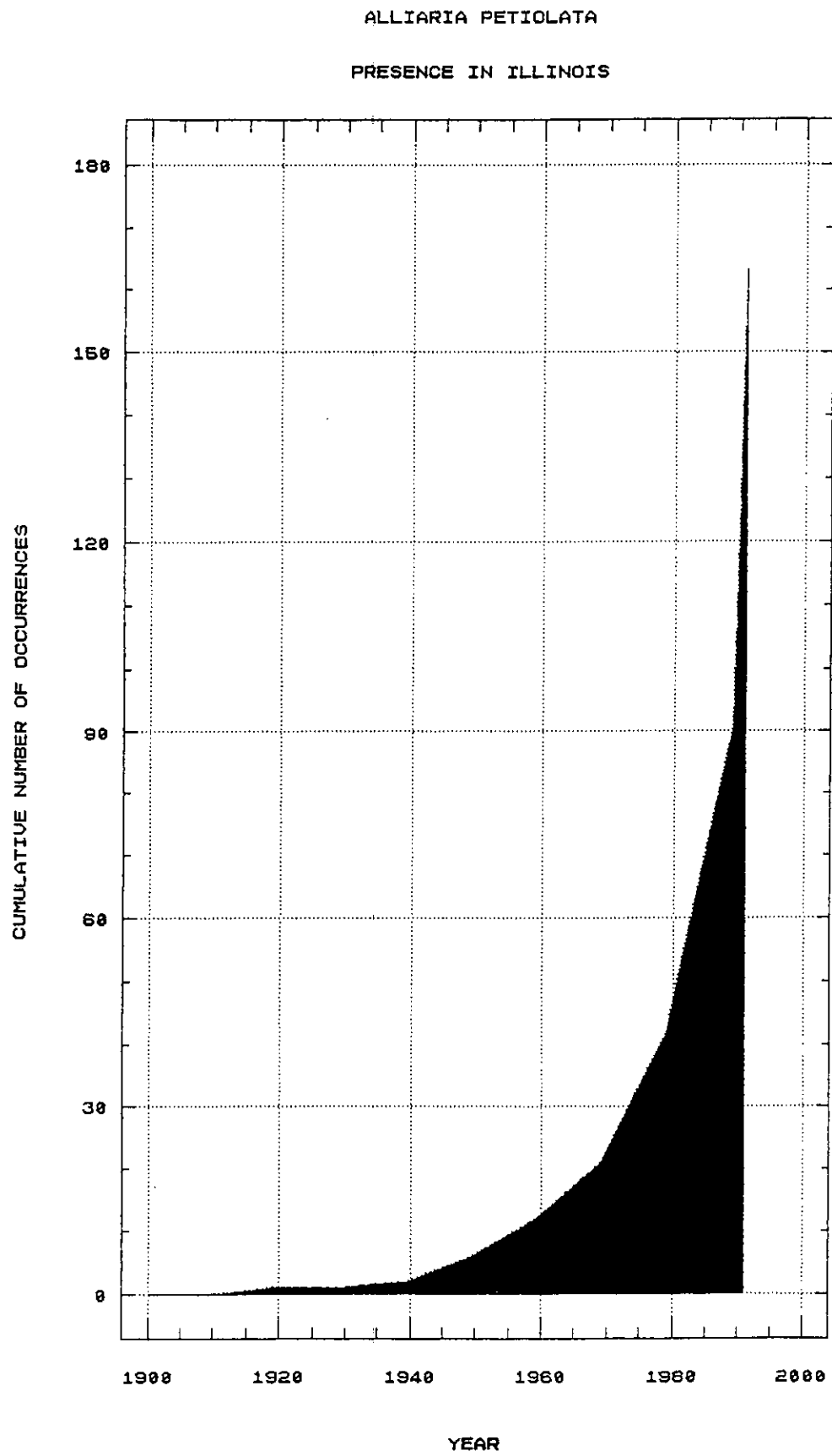


Figure 3:



Extent of Infestation

In five counties virtually all available habitat supports populations of *Alliaria*: Winnebago, Ogle, Cook, Du Page, and Kane. The plant is present along roadsides, in urban areas, and in the majority of forested communities within each county. The eastern half of Lake County is similarly infested, while the western half, and adjacent McHenry County, have low to moderate levels of infestation.

Alliaria was recorded in 18 state parks and 57 nature preserves in June 1991 (Table 2). Fifty percent of state parks, and 40% of nature preserves, within the known range of *Alliaria* have been invaded by this species.

TABLE 2: *Alliaria petiolata* presence in state parks and nature preserves (based on herbarium records and sight observations; many nature preserves field checked 1988-1991).

	Number of Sites		Number of sites with <i>Alliaria</i>	Percent with <i>Alliaria</i>	
	in state	in infested counties		in state	in infested counties
STATE PARKS	59	36	18	31%	50%
NATURE PRESERVES	194	141	57	29%	40%

Alliaria is present in the majority of county forest preserves and conservation districts in northeast Illinois (Table 3). Recently invaded counties, counties with little available habitat, and counties with few natural area visitors, tend to have low to moderate levels of infestation.

TABLE 3: *Alliaria petiolata* presence in northern Illinois County Forest Preserve and Conservation Districts.

County Agency	Number of Sites	Number with <i>Alliaria</i>	% with <i>Alliaria</i>
Boone CCD	1	1	100%
Cook FPD	185 ¹	17 ²	9%
DuPage FPD	58	49	85%
Kane FPD	26	15	58%
Lake FPD	62	15 ²	24%
McHenry CCD	22	7	32%
Ogle (Byron FPD)	1	1	100%
Will FPD	31	14 ²	45%
Winnebago FPD	31	26	84%

¹ = Includes boatramps, picnic areas, fishing lakes; excludes golfcourses.

² = Many sites not inspected for *Alliaria* presence.

DISCUSSION

Entry

Alliaria was first recorded in North America in 1868, and spread to Illinois by 1918, where it was collected north of Chicago. Mode of entry into the state is unknown, but is presumed to be related to anthropogenic activity. *Alliaria* was historically used as a potherb in Europe, and may have been similarly utilized by early settlers in the eastern states (Brooks 1983, Fernald et al. 1958), although there is no evidence that *Alliaria* was imported into the midwest as a food plant.

The species was not mentioned in state or local floras until 1945 (Jones). Early botanists (Mead 1846, Lapham 1857, Bebb 1859, Brendel 1859, Vasey 1861, Patterson 1876, Schneck 1876, Brendel 1887, Higley and Radin 1891, Hill 1899, Peppoon 1927, Buhl 1934) did not mention *Alliaria*, indicating that the species either was not observed, or was observed but not considered established.

Rate of Spread

Alliaria exhibits two modes of regional spread; establishment of multiple satellite populations (*sensu* Auld et al. 1978, Auld and Coote 1980), often separated by great distances (see Figures 1B and 1C), and spread as an advancing front from population centers (see Figures 1D-1F). Eventually the satellite populations coalesce, as seen in Figure 1G.

The rate at which new populations were established approximately doubled every ten years (Table 1). From 1918 to 1939 the rate-of-spread was one latilong block per decade. This increased to one block every 2.5 years between 1940 and 1949, every 1.7 years between 1950 to 1959, and every 1.25 years between 1960 and 1969. In the next decade, the rate of spread increased to 2.1 latilong blocks each year, and by 1980 to 1989, *Alliaria* spread at the rate of 4.9 blocks per year. The increase in the last decade reflects the contribution of sight observations; 11 of the 49 records are herbarium or literature records, and 38 occurrences are sight observations made between 1985 and 1989. Without these sight records, the rate of spread curve would flatten, implying that the majority of potential habitat was occupied. This does not appear to be the case with *Alliaria* in Illinois, and may reflect the tendency for invasive weeds to be well collected in the early stages of invasion, and undercollected in the later stages. Sight observations in 1990 and the first half of 1991 documented an additional 72 latilong blocks with *Alliaria*. Although there are inherent biases in combining herbarium and sight observations, the overall results indicate that *Alliaria* has spread and is continuing to spread at a rapid, exponential rate through available habitat in Illinois. On the basis of the 1990/91 locations, *Alliaria* is now spreading, or being detected, at the rate of some 7,000 km²/year.

Graphing occurrences cumulatively by decade produces a classic J curve (Figure 2), indicating the exponential spread of the plant. The curve began to rise in the 1940's, steepened in the 1980's, and became nearly vertical by 1991. This pattern is similar to, and in some cases more severe than, the exponential spread documented for other invasive weed species (Auld and Coote 1980, Mack 1981, Lacey 1957, Stuckey 1980, Thompson et al. 1987). *Alliaria*'s spread is moderate in comparison to the annual grass *Bromus tectorum*, which occupied all available habitat in the northwestern United States in less than 30 years (Mack 1981).

The rapid increase in *Alliaria* spread is consistent with increases

recorded for other alien species, beginning approximately 40 to 50 years after initial invasion (Stuckey et al. 1987, Lacey 1957).

In contrast to many problem herbaceous species that have been present in the state since the mid 1800's (Darlington 1922), *Alliaria* is a relatively recent invader, and increaser, in Illinois, occupying habitat unused by other alien forbs. *Alliaria*'s rapid transition from uncommon alien to invasive problem species corroborates Forcella and Harvey's (1983) findings that 'problem weed species' change over time.

Within Illinois, a combination of natural and anthropogenic disturbance factors appear associated with the dramatic increase in number of sites invaded by *Alliaria*. Disturbances create habitat suitable for initial entry, and continued disturbances maintain habitat suitable for expansion. Once established in a locale, additional disturbance may not necessary for continued spread of *Alliaria* (*sensu* Mack 1985). Anthropogenically disturbed habitats such as roadsides, heavily used preserves, and urban areas, and naturally disturbed habitats such as floodplains and riverbanks provide dispersal corridors. Exponential expansion of weed species has been correlated with road construction (Forcella and Harvey 1983), railroad construction (Mack 1981), bombing (Lacey 1957), canal construction (Stuckey et al. 1987), and conversion of the natural landscape to agricultural uses (Mack 1981).

Distribution

Alliaria is an obligate biennial that spreads exclusively by seed. Seeds typically fall within a few meters radius of the plant (Nuzzo personal observation). Wind dispersal of seeds is limited and seeds do not float well, although seeds readily attach to moist surfaces (Cavers et al. 1979).

Natural long distance dispersal mechanism is unknown. Anthropogenic distribution is the major factor in long-distance dispersal of this plant (Lhotska 1975), a trait common to many weed species (Noble 1989).

In Illinois *Alliaria* frequently enters natural areas along roads or trails. Hikers carry seeds on muddy boots, in pant cuffs, pockets and hair, and disperse these seeds in the same and different natural areas. In McLean County, *Alliaria* is known only from the woods in Funk's Grove Nature Preserve, a prairie grove surrounded by agricultural land, while in Alexander County *Alliaria* grows along a road in Horseshoe Lake State Park. Both sites are isolated from other forested areas containing *Alliaria*, and *Alliaria* was apparently imported by natural area visitors or workers. Similar modes of entry are believed responsible for populations in other sites, including Allerton Park in Sangamon County, the SIU campus in Jackson County, and Kickapoo State Park in Vermillion County. The frequency of *Alliaria* in parks and preserves may be more closely related to visitors dispersing seeds among isolated sites, than to worker bias in selecting locations for collecting or observing plants. M. DeMauro-Roth (personal communication 1991) observed that *Alliaria* is present in Will County Forest Preserves that are readily accessible to the public, and is absent from similar, but less accessible, sites.

Roadside mowing facilitates distribution of *Alliaria* between isolated shaded areas, such as woodlots, shrubrows, and individual trees. Twenty percent of herbarium collections with habitat data were made near roads (Table 4). This distribution mode is noticeable along

uous distribution, and Highway 72 in Ogle and Carroll Counties, where *Alliaria* occurs under isolated trees and fencerows. Cars pick up seeds in mud-encrusted tires, and both cars and trains may propel seeds along the travel route. *Alliaria* is frequently observed in woods adjacent to railroad tracks (5% of the herbarium records; Nuzzo personal observation), and railroads are listed as habitat by Brooks (1983).

Seeds are also dispersed long distances by natural means. Riverbanks are frequent habitats (7% of herbarium records were from riverine habitat), and rivers function as dispersal corridors for seeds. The upper stretches of the Rock, Fox, and DesPlaines Rivers are heavily infested with *Alliaria*, while the lower areas have fewer occurrences. Riverbanks and associated floodplains have a high frequency of natural disturbance (Rejmanek 1989), and provide shaded moist habitat readily invaded by *Alliaria*. Although seeds reportedly do not float well (Cavers et al. 1979), the distribution pattern in Illinois indicates that *Alliaria* disperses along rivers.

TABLE 4: *Alliaria petiolata* habitat recorded on herbarium specimen labels. One habitat type recorded for each specimen; trail and park recorded in addition to habitat type. When multiple collections were made from the same location (as at Allerton Park), the first record in each decade was used to represent habitat type (1= Habitat separately recorded. 2 = Park, nature preserve, forest preserve).

HABITAT TYPE	# HERBARIUM SPECIMENS
Woods	41
River	1
Road	8
Woods and Road	8
Woods and River	5
Urban	7
Railroad	4
Waste Ground	2
Campus, Arboretum	2
Open Area	3
Trail ¹	4
Park ^{1,2}	24

Alliaria has also been observed in a number of localities as a single small colony growing in bare soil at the base of a large tree, several hundred meters distant from the closest known seedsource. Seeds are rarely wind dispersed, and transport to this microhabitat is likely associated with animal activities. Seed herbivory by birds or mammals has not been directly observed, and dispersal agent is unknown.

Alliaria may be distributed directly or indirectly by white-tailed deer (*Odocoileus virginianus*). High deer populations alter community structure and create habitat suitable for *Alliaria* establishment, including reduced litter layer, decreased herbaceous cover, and increased soil disturbance (Nuzzo personal observation). Deer preferentially browse native vegetation and avoid *Alliaria* (Nuzzo personal observation), which indirectly favors growth of *Alliaria*. Seeds may lodge in deer fur, and then be transported within and between individual sites.

Habitat

Alliaria occupies a variety of habitats, as indicated on herbarium records (Table 4). *Alliaria* was most frequently collected from wooded communities, in particular dry-mesic upland forest, wet-mesic floodplain forests, and shaded roadsides. The majority of occurrences were in shaded disturbed locations, often in association with some form of anthropogenic disturbance, such as a trail, road or railroad. This affinity for disturbed shaded habitat is typical of *Alliaria*'s presence elsewhere in North America where it is frequently reported from floodplains (Cavers et al. 1979, Trimbur 1973), roadsides, 'waste places' and developed areas (Brooks 1983, Fernald 1970, Jones 1971). Less frequent habitats include farm fields, sunny roadsides, abandoned roadbeds, and gardens.

Alliaria was frequently recorded from parks and nature preserves; 30% of the herbarium records with habitat information were collected from protected natural areas. The frequency with which *Alliaria* occurs in protected, often high quality, communities indicates in part the extent of invasion in the state, and in part reflects anthropogenic distribution of seeds. Twentynine percent of dedicated nature preserves within the state are infested with *Alliaria*, as are 31% of state parks (Table 2). This percentage increases when sites outside the area of infestation are omitted from consideration. *Alliaria* occurs in 42 counties, which contain 141 nature preserves (40% with *Alliaria*) and 36 state parks (50% with *Alliaria*) (Table 2).

Alliaria is most common in northeast Illinois, and is rare in the southern third of the state. The distribution pattern in Illinois is closely aligned with the Shelbyville Moraine; south of this landform, *Alliaria* is virtually absent. This distribution pattern may reflect an affinity for calcareous soils, as reported by Clapham et al. (1962) and Cavers et al. (1979). However, the May 1991 observation of *Alliaria* in Alexander County indicates that the species may invade the southern third of the state, if seed is transported to suitable habitat and appropriate growing conditions are present.

Potential Future Spread

In five counties *Alliaria* occupies virtually all available habitat (Winnebago, Will, Kane, Cook, DuPage). It is likely that *Alliaria* will continue to spread through occupied counties, particularly in the northern third of the state, and will invade additional areas. Spread will be faster in counties with large forested areas or numerous wooded roadsides and woodlots, than in counties with isolated woodlots and grassy roadsides. However, unglaciated Jo Daviess County, which is 17% wooded (Iverson et al. 1989) may be less susceptible to invasion than the adjacent glaciated counties, due to soil and substrate differences.

Continued spread is predicted throughout the northern two thirds of the state, particularly in areas that have high disturbance rates. The total area suitable for *Alliaria* invasion and growth will increase with increasing human development and disturbance of the natural landscape.

Control

Active management to eliminate *Alliaria* from natural areas (see Nuzzo 1991), and to limit invasion into new locales will slow the spread of this plant. Such management is feasible in isolated forested communities and in regions where *Alliaria* has very low presence. In particular, *Alliaria* should be removed from southern Illinois and from

counties with few or small populations. Annual monitoring for and immediate removal of *Alliaria* prior to seed production will limit establishment in high quality natural areas. In the densely infested northeast part of the state, the frequency and abundance of *Alliaria* in unmanaged habitats limits the effectiveness of single-site management.

Long-term effective control will require significant reduction or elimination of *Alliaria* populations on public and private lands throughout the infested region. Auld et al. (1978/79) theorize that 20% of a weed's populations must be eliminated annually over a 20 year period in order to eradicate the species; elimination of 5% of the populations will not slow the rate of spread, and at least 15% of all infested sites must be managed to effect an immediate decrease in the total numbers of a weed species. Successful control at this level is unlikely with current management techniques. Development and implementation of biological control agents provide the most likely means to effectively reduce presence of *Alliaria* in the midwest.

ACKNOWLEDGEMENTS

I would like to thank the curatorial staffs of herbaria in Illinois and other states for making collection information available. Several curators provided additional reference materials for which I am most grateful. I especially appreciate the considerable effort expended by state and county field biologists who actively searched for *Alliaria* throughout the state, in particular John Alesandrini, Alan Branhagan, Dan Brouillard, Marcella deMauro-Roth, Michael Jones, Wayne Lampa, Bob Lindsey, Mike Martinez, Randy Nyboer, Jody Shimp, Rob Shook, Mary Kay Solecki, and Todd Strole. I thank the Illinois Chapter of The Nature Conservancy for distributing observation forms through the Volunteer Stewardship Network, and the numerous individuals who provided information about *Alliaria*'s presence in specific locations. I also thank Matt Paulson for assistance in preparing the distribution maps.

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Contributing herbaria are the Carnegie Museum (CM), Northern Illinois University (DEK), Eastern Illinois University (EIU), Field Museum (F), Indiana University (IND), University of Illinois (ILL), Illinois Natural History Survey (ILLS), Illinois State Museum (ISM), Kansas State College of Pittsburg (KSP), University of Minnesota (MIN), Morton Arboretum (MOR), Western Illinois University (MWI), New York State Museum (NYS), Oregon State University (OSC), Vanderbilt University (VDB), University of Wisconsin-Madison (WIS), and University of Washington (WTU).

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APPENDIX:

Alliaria petiolata herbarium specimens collected from Illinois and held by the Carnegie Museum (CM), Northern Illinois University (DEK), Eastern Illinois University (EIU), Field Museum (F), Indiana University (IND), University of Illinois (ILL), Illinois Natural History Survey (ILLS), Illinois State Museum (ISM), Kansas State College of Pittsburg (KSP), University of Minnesota (MIN), Morton Arboretum (MOR), Western Illinois University (MWI), New York State Museum (NYS), Oregon State University (OSC), Vanderbilt University (VDB), University of Wisconsin-Madison (WIS), and University of Washington (WTU).

BOONE

1964 Evers 79913 ILLS
1976 Schulenberg 76-068 MOR

CARROLL

1954 Ahles H.E. 8027 ILL ISM
1954 Buser F.B. 5027 IND
1962 Wunderlin s.n. MWI
1965 Wunderlin s.n. MWI

CHAMPAIGN

1966 Jones G.N. 42658 ILL
1974 Evers 110046 ILLS
1974 Evers 112599 ILLS

CLARK

1976 Ebinger 15778 EIU

COLES

1964 Ebinger 4405 OSC EIU
1973 Ebinger 12573 EIU

COOK

1918 Colton 6 F
1954 Evers 42275 ILLS
1954 Winterringer 11499 ISM
1956 Winterringer 12700 ISM
1959 Capek s.n. DEK
1960 Oemick 10 DEK
1964 Evers 81052 ILLS
1967 Del Carlo s.n. DEK
1973 Kral 50356 VDB
1979 Rowlatt 431 MOR
1979 Rowlatt 399 MOR
1980 Evert 2467 MOR
1986 Sperry 28836 KSP

DEKALB

1974 Schulenberg 74-038 MOR

DEWITT

1980 Shildneck C-11810 ILL
1978 Shildneck 10462 ISM MWI

DUPAGE

1947 Swink s.n. MOR
1970 Ciolcac s.n. MOR
1971 Braham s.n. MOR
1979 McPherson 10 F
1971 Braham s.n. DEK
1972 Evers 107861 ILLS
1974 Angelo s.n. F

FULTON

1984 Henry & Scott s.n. MWI
1984 Henry & Scott s.n. MWI

GRUNDY

1960 Evers 63884 ILLS
1975 Schulenberg 75-006 MOR

HANCOCK

1988 Henry & Scott s.n. MWI

KANE

1952 Swink 959 F
1960 Winterringer 17535 ISM
1975 Apfelbaum s.n. ILL
1976 Schulenberg 76-058 MOR
1989 Shimp & Shimp 371 MOR

KANKAKEE

1987 Swink & Shimp 7552 MOR

KENDALL

1975 Schulenberg 75-072 MOR

LAKE

1952 Lane 682 ISM
1976 Schulenberg 76-753 MOR
1977 Moran 113 MOR
1977 Robertson 1040 ILLS
1977 Robertson 1080 ILLS
1977 Robertson 1322 ILLS

LASALLE

1975 Evers 114506 ILLS
1975 Evers 114796 ILLS

MACON
1972 Shildneck C-3502 ILLS ILL ISM

MASON
1974 Maier s.n. ILL
1980 Riegel s.n. EIU
1989 Ebinger 24299 EIU

MCHEERY
1971 Schulenberg s.n. MOR

OGLE
1975 Muller 97 DEK

PEORIA
1963 Chase 17226 ILL ILLS ISM WTU MU
1977 Runde s.n. MOR DEK

PIATT
1949 Ahles 1048 ILL
1951 Jones 18985 ISM ILL
1952 Jones 19536 ILL
1954 Jones 20259 ILL
1956 Jones 20653 ILL
1956 Jones 20682 ILL DAO
1957 Jones 21282 ILL
1957 Jones 21356 ILL WTU
1957 Jones 21418 ILL
1958 Jones 21819 ILL
1960 Jones 30136 ILL
1960 Jones 30289 ILL
1960 Jones 30556 ILL
1961 Jones 31796 ILL
1961 Jones 31805 ILL
1961 Jones 32115 ILL
1963 Jones 35448 ILL
1965 Jones 40156 ILL
1965 Jones 41857 ILL
1966 Jones 42708 ILL
1966 Jones 42891 ILL
1967 Jones 43979 ILL
1967 Jones 44226 ILL
1967 Jones 44445 ILL
1958 Evers 56045 ILLS
1961 Runde 16436 ISM MOR ILLS ILL MIN
1965 Evers 82602 ILLS
1971 Ebinger 10459 EIU
1971 Seigler DS-3909 ILL
1972 Jones 952 ILL
1975 Evers 114179 ILLS
1978 Warnock 454 ILL

PUTNAM
1981 Ebinger 20557 EIU

SANGANON
1945 Eifert 10207 ISM
1974 Ebinger 14362 EIU

SHELBY
1987 Horton 25 EIU
1989 Ebinger 24253 EIU

TAZEWELL
1957 Chase 14371 ILL
1959 Heitmann 789 ISM
1972 Koelling 4575 ISM
1981 Koelling 6595 ISM

WILL
1976 Schulenberg 76-314 MOR

WINNEBAGO
1939 Fuller 156f ISM
1940 Fuller 1695H ILL ISM
1940 Fuller 1166H ILL ISM
1978 Nuzzo 53 --
1979 Akerman s.n. MWI



NATIVE LANDSCAPES

124 DAWSON AVENUE
ROCKFORD, ILLINOIS 61107
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MEMO

TO: John Schwegman
FROM: Victoria Nuzzo *VN*
DATE: July 31 1991
SUBJECT: *Alliaria petiolata* report

Enclosed please find 20 copies of the report **Current and Historic Distribution of Garlic Mustard (*Alliaria petiolata*) in Illinois** as per my contract with the Illinois Department of Conservation (Nongame Wildlife Conservation Fund). Final billing for the report will follow. Please contact me with your comments after reading the report.



PROGRESS REPORT #1

November 6, 1990

*Garlic mustard (Alliaria petiolata) (Bieb). Cavara & Grande-
rate of spread and potential impact on groundlayer species.
(Nongame Wildlife Conservation Fund Contract)*

PROGRESS REPORT #1

November 6, 1990

Garlic mustard (Alliaria petiolata) (Bieb). Cavara & Grande
rate of spread and potential impact on groundlayer species.
(Nongame Wildlife Conservation Fund Contract)

PROGRESS

Site Selection and Location

Research plots were established in August 1989 in four natural communities in eight natural areas in northern Illinois. Site selection criteria consisted of: 1) moderate to high garlic mustard density within a defined area; 2) garlic mustard population with an apparent 'front'; 3) Grade A to Grade C natural quality with a diverse groundlayer; 4) protected natural area with owner commitment to protect the study site for at least three years.

Eleven plots were established in six natural areas where garlic mustard had a wide-spread distribution:

Bliss Woods is a Grade C dry-mesic and mesic upland forest, located in Kane County and owned by the Kane County Forest Preserve District. Three plots were located on and adjacent to an esker; one plot paralleling the sideslope of the esker, one north of and adjacent to the base of the esker, and one bisecting the sideslope and base of the esker.

Mississippi Palisades State Park is a Grade C dry-mesic upland forest located in Carroll County, owned and managed by the Illinois Department of Conservation. Two plots were established on slopes in different watersheds of the park.

Atwood Park is a Grade C dry-mesic upland forest located in Winnebago County and owned by the Rockford Park District. One plot was located in the forest.

Captain Daniel Wright Woods is a Grade C mesic upland forest, located in Lake County and owned and managed by the Lake County Forest Preserve District. One plot was located in the forest.

Pilcher Park is a Grade B mesic floodplain forest, located in Will County and owned by the Joliet Park District. Three plots were

located on both sides of a small creek.

Pecatonica Bottoms Nature Preserve is a Grade B wet-mesic floodplain forest, located in Winnebago County and owned and managed by the Winnebago County Forest Preserve District. One plot was established in the forest.

Two transects were established in sites where garlic mustard had a linear distribution:

MacArthur Woods Nature Preserve is a grade B dry-mesic upland forest located in Lake County and owned and managed by the Lake County Forest Preserve District. A 140 meter long baseline was established along an intermittent stream channel.

Sheridan Ravine is a Grade A dry-mesic upland forest located in Lake County near Lake Michigan. A 600 meter long baseline was established along a narrow hiking trail.

Methods

Plots were located to bisect the apparent front of the garlic mustard population, with endpoints located in the dense garlic mustard and in the non-invaded adjacent area. Each plot measured 25m wide and 50m long, and contained six parallel, evenly spaced, 50m long x 2m wide belt transects. Data were collected by 1m² quadrats along the transects. Presence/absence data by size class (adult and seedling) was recorded for each 1m² along each transect, for a total of 600 quadrats/plot. Density of adult garlic mustard plants, and percent cover by cover class of adult garlic mustard, seedling garlic mustard, all herbaceous species, all woody species <1m, and soil, leaves and wood, were collected at 10m intervals along each transect, for a total of 36 quadrats/plot.

Similar data were collected by 1m² quadrats parallel to the baselines for all quadrats that contained garlic mustard, recorded by position relative to the baseline. Quadrats were located from 0-5m from the baseline at Sheridan Ravine, and 0-16 meters from the baseline at MacArthur Woods.

Data were collected in August 1989, and in May and August 1990, in all plots. Data were collected in August of both years

along the two baselines.

Garlic mustard seed production was recorded in August 1990 in the six sites with permanent plots. Data were collected for 98-100 plants at each site, in two replicates, and consisted of: number of plants/m², number of siliques/plant, and number of seeds in one silique/plant in a silique located along the lower third of the primary axis. Quadrats were arbitrarily located in different densities of garlic mustard plants, in patches that appeared representative of the population as a whole, to determine average seed production/plant and /m² at each site within patches. Counts were also made of selected very large plants to determine the high end of seed production/plant.

Data summarization for statistical analysis was partially completed.

MODIFICATIONS TO THE WORK PLAN

The research program was expanded in 1990 to include seed production counts at six sites. Investigation of seed production rates was added to the study to permit correlation between mean seed production and potential increase in garlic mustard presence and frequency within the plots.

Midsummer flooding covered the plot in the Pecatonica Bottoms Nature Preserve to a depth of up to 0.5 meter for a period exceeding one week. This flood event was very atypical for the site. In August, some 3-4 weeks after floodwaters receded, data were collected. All garlic mustard plants were killed by the flooding. Seedstalks produced prior to flooding showed minimal damage and it is assumed that seed production and dissemination occurred in a normal fashion. Impact of midsummer flooding on seedbank contribution will be monitored in 1991, and impact on survival of seeds produced in 1990 will be detectable in 1992.

FOCUS OF NEXT YEAR

All 1989 and 1990 data will be summarized, and preliminary data analysis will be conducted winter 1990/1. Seed production

data will be analyzed winter 1990/1. Additional data will be collected in May and August 1991 and 1992. Change in garlic mustard frequency, density and percent cover will be analyzed through time at each site. Rate-of-spread from seeds produced in 1989 will be apparent in 1991, and rate-of-spread from seeds produced in 1990 will be apparent in 1992. Collected data will be compared within and among quadrats at each site to determine if native herbaceous species richness and/or percent cover changes in relation to garlic mustard abundance, or length of time that garlic mustard occupies a quadrat.

SUBMITTED BY: Victoria A. Nuzzo
Native Landscapes
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