

New England Plant Conservation Program

Doellingeria infirma (Michx.) Greene
(*Aster infirmus* Michx.)
Cornel-leaved flat-topped aster

Conservation and Research Plan
for New England

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SUMMARY

Doellingeria infirma (Michx.) Greene (Asteraceae), commonly named cornel-leaved flat-topped aster or Appalachian flat-topped aster, is ranked G5 or globally secure, but is considered imperiled in three of the nineteen states in its distribution. *Flora Conservanda*: New England has ranked the species as Division 2 or Regionally Rare. Historical specimens of the taxon are present in Connecticut and Massachusetts herbaria. The only three extant populations in New England are found in Massachusetts, where the state rank is S1. The species reaches its northern range limit in Massachusetts. The species occurs in the mountains and adjacent plateaus from Alabama to central New York, along the Appalachian Mountain range, hence its common name.

Doellingeria infirma is a slender, erect, herbaceous perennial forb. Often called “weak aster,” the plant has a flexuous stem, growing three to six meters in height with inflorescences in an open corymbiform panicle with scattered heads. The leaves are few in number and alternately arranged. The flowers appear in late July through early September. The inflorescences set seed throughout September. The achenes are wind-dispersed.

The New England occurrences of *Doellingeria infirma* are threatened by invasive species, shading, natural and human disturbances, habitat loss, and are characterized by small population sizes and low reproductive rates.

The conservation objectives for *Doellingeria infirma* are to maintain eight occurrences in Massachusetts with an average of 60 individuals at each site with 10-25% of the mature plants flowering each year if the population is growing substantially. This conservation objective will be met in part by performing *de novo* searches in northeastern and central Rhode Island and central and southwestern Connecticut in dry, rich woods with circumneutral bedrock. Auxiliary conservation actions will include habitat management involving periodic canopy thinning and possible use of fire, as well as removal of invasive species. Other priority actions for protecting the taxon include land acquisition, education and scientific research.

PREFACE

This document is an excerpt of a New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. Full plans with complete and sensitive information are made available to conservation organizations, government agencies, and individuals with responsibility for rare plant conservation. This excerpt contains general information on the species biology, ecology, and distribution of rare plant species in New England.

The New England Plant Conservation Program (NEPCoP) of the New England Wild Flower Society is a voluntary association of private organizations and government agencies in each of the six states of New England, interested in working together to protect from extirpation, and promote the recovery of the endangered flora of the region.

In 1996, NEPCoP published “*Flora Conservanda: New England.*” which listed the plants in need of conservation in the region. NEPCoP regional plant Conservation Plans recommend actions that should lead to the conservation of *Flora Conservanda* species. These recommendations derive from a voluntary collaboration of planning partners, and their implementation is contingent on the commitment of federal, state, local, and private conservation organizations.

NEPCoP Conservation Plans do not necessarily represent the official position or approval of all state task forces or NEPCoP member organizations; they do, however, represent a consensus of NEPCoP’s Regional Advisory Council. NEPCoP Conservation Plans are subject to modification as dictated by new findings, changes in species status, and the accomplishment of conservation actions.

Completion of the NEPCoP Conservation and Research Plans was made possible by generous funding from an anonymous source, and data were provided by state Natural Heritage Programs. NEPCoP gratefully acknowledges the permission and cooperation of many private and public landowners who granted access to their land for plant monitoring and data collection.

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I. BACKGROUND

INTRODUCTION

Doellingeria infirma (Michx.) Greene, a flat-topped white aster (Asteraceae), is native to eastern North America. It is known by various common names such as corn-leaved flat-topped white aster, Appalachian flat-topped white aster, or “weak aster.” This taxon is ranked G5 or globally secure, but is considered imperiled in three of the nineteen states in its distribution (NatureServe Explorer 2001). *Flora Conservanda: New England*, a listing of rare and endangered plant species in New England, ranks the species as Regionally Rare or Division 2, “with fewer than 20 current occurrences (seen since 1970) within New England” (Brumback and Mehrhoff et al. 1996). It reaches the northern edge of its range in northeastern Massachusetts. The taxon has never been reported in Maine, New Hampshire, or Vermont. Rhode Island and Connecticut list the species as historical and SR (reported), respectively. Specimens of the taxon are represented in Connecticut and Massachusetts herbariums. The only three extant populations in New England are found in Massachusetts, where the state rank is S1 (NatureServe Explorer 2001). The largest population, in western Massachusetts, had a total of 250+ individuals in 1998, of which more than half were flowering at that time. Another population in Woburn is at the northernmost point at which the taxon has ever been observed in New England. A small population, west of Boston, is adjacent to a busy highway (according to Massachusetts Natural Heritage Program [MANHESP] Element Occurrence Records [EORs]).

The taxon is one of four species within *Doellingeria* sect. *Doellingeria* that are native to eastern portions of the United States. The other three species (*D. umbellata*, *D. sericocarpoides*, and *D. reticulata*) are found along the coastal plains of the southeast. *Doellingeria infirma* is the only species within the genus native to the Appalachian Mountain region and New England (Semple et al. 1996).

Doellingeria infirma is a slender, erect, herbaceous, perennial forb (MANHESP 1985m Connecticut Botanical Society 2002). The flowers appear in late July through early September. This species is known to be insect-pollinated, but details of its pollination biology are unknown (Semple et al. 1996). The fruit is a glabrous achene with bristles. The achenes are wind-dispersed. The best time to observe the plant is in mid-August when it is in full bloom (MANHESP 1985).

The three extant occurrences in Massachusetts are threatened by small population size and isolation, which may result in a lack of genetic variation. Shading, invasive species competition, herbivory and anthropogenic factors also threaten the Massachusetts populations of *Doellingeria infirma*. The taxon warrants conservation to preserve potential habitat and existing populations, and this Conservation and Research Plan describes specific actions to achieve an overall objective of maintaining eight

occurrences in Massachusetts with an average of 60 individuals at each site with 10-25% of the mature plants flowering each year if the population is growing substantially.

DESCRIPTION

Doellingeria infirma is a non-stoloniferous, herbaceous plant that grows from a low basal rosette of leaves (MANHESP 1985). It produces an erect, sinuous, glabrous to sparsely strigose stem approximately one meter or less in height (Fernald 1950, Semple et al. 1996, Semple 2002d). The leaves are arranged alternately on the stem and are all the same size. Leaves are lanceolate to elliptic and sessile, but not clasping. The leaves are entire and smooth except for hairy veins beneath (Fernald 1950). The inflorescence growth form is open corymbiform (flat-topped) with few to many heads. Heads are 2.5 cm across with 5-9 broad white petals (Semple et al. 1996). Within the genus *Doellingeria*, the involucre is 5-7 mm long. Involucral bracts or phyllaries are light green to yellow-green throughout and strongly graduated, with a blunt or rounded apex and a raised and resinous midvein and lateral nerves (Nesom 1993). The subrigid pappus in *Doellingeria* is comprised of one or two inner series of long bristles and an outer series of whorled slender bristles or setae much shorter than the inner (Nesom 1993, Haines 2001). *Doellingeria* is also distinguished by large, glabrous achenes (fruit) with 5-9 broad, often resinous ribs (Nesom 1993).

Doellingeria umbellata is a related species that overlaps the habitat range of *Doellingeria infirma*. *Doellingeria umbellata* is a larger, leafier plant with a densely pubescent stem and elliptic, sparsely strigose leaves on top and pubescent leaves below. The plant has a capitulescent, corymbiform inflorescence with 20-100 heads, with small white rays, on few to many branches (Semple et al. 1991, Semple et al. 1996, Semple 2002d). The lower stem leaves are deciduous before flowering in the fall. *Doellingeria umbellata* is stoloniferous with short to long rhizomes, whereas *Doellingeria infirma* is non-stoloniferous (Semple et al. 1991). Diagnostic differences between *Doellingeria infirma* and *Doellingeria umbellata* are shown in Table 1, below. Semple et al. (1991) describe the range of *Doellingeria umbellata* as "limited to northeastern deciduous and boreal forests around Canada and Newfoundland to Minnesota and becoming rare in "south and central southern states of the eastern United States." Gleason and Cronquist (1991) label its habitat as moist thickets and lowland woods. *Doellingeria infirma*, however, predominates in the mountains and adjacent plateaus from Alabama to central New York and southern New England (Semple et al. 1991). Semple et al. (1991) recognize another species, *Doellingeria sericocarpoides*, as "very similar" to *D. infirma* and *D. umbellata*. This species has more obovate and coarse leaves with broader and less deltoid-like phyllaries. *Doellingeria sericocarpoides* has more leaves, more heads and a more congested leafy capitulescence than *D. infirma*. However, this species occurs in bogs and wet thickets and woods from eastern Texas to New Jersey and is unlikely to occur in New England (Semple et al. 1991). Misidentification of *Doellingeria infirma* may confound our understanding of its distribution in New England.

Table 1. Differences between *Doellingeria infirma* and *Doellingeria umbellata* from Semple et al. (1991) and Gleason and Cronquist (1991)

Character	<i>D. infirma</i>	<i>D. umbellata</i>
Flower heads	few to 45+	20-100+
Rhizomes	Not stoloniferous	Stoloniferous with short to long rhizomes
Leaves	Subsessile or short-petiolar, 15-50 mm wide	Sessile, 7-35 mm wide
Achenes	Glabrous	Sparsely strigose to puberulent
Plant height	40-100 cm	40-200 cm
Habitat	Dry to mesic woods	Moist, low places

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Doellingeria infirma is a member of the North American clade of the tribe Astereae in the Sunflower family (Asteraceae) (Semple 2002c). Nees first established *Doellingeria* in 1832. The genus was accepted for a period in the late 1800s until in 1873 Bentham and Hooker included it within the larger genus *Aster* with the publication of *Genera Planetarum* (Nesom 1993, Haines 2001). Asa Gray maintained *Doellingeria* in various treatments, but finally submerged it with *Aster* in his *Synoptical Flora* in 1884 (Nesom 1993). Most North American botanists subscribed to the idea of a conglomerated *Aster* advocated by Bentham and Hooker and by Gray. However, some botanists continued to recognize *Doellingeria* as a distinct genus: e.g., Greene (1896), Rydberg (1954), Small (1933) and Correll and Johnson (1970) in Nesom 1993 and Semple et al. 1991. Semple et al. (1991) treated the eastern North American species as *Aster* sect. *Triplopappus* after Jones (1980), Semple and Brouillet (1980), and Jones and Young (1983). Nesom (1993) reviewed the taxonomy of the genus and split it into two sections, South American and Old World Astereae and Asters of the North American clade (Semple 2002a). The revisional study of *Aster* subg. *Doellingeria* (Semple et al. 1991) corroborated Nesom's studies and understanding of the variation patterns of the North American taxa and their corresponding taxonomy. Analyses of morphology, chloroplast DNA, and karyotype studies have demonstrated that *Aster* is polyphyletic and that New World species are distinctly separate from Old World and South American species (Semple 2002a).

Currently, the entire family Asteraceae is under revision to reflect the true evolutionary history of the group (Haines 2001, Semple 2002a). The genus *Doellingeria* has been accepted for quite some time, although sometimes subsumed within *Aster sensu lato* (Semple 2002b). *Doellingeria infirma* was first presented as *Aster infirmus* Michx. in *Flora Borealis Americana* in 1803 (Nesom 1993, Reveal 1991). Greene researched the taxon's taxonomy and distribution and renamed it *Doellingeria infirma* in 1896 (Nesom 1993). However, *Aster infirmus* was the accepted name through the late 1990s.

One of the main factors that divided *Doellingeria* from the *Aster* genus was the shared number of chromosomes ($n=9$) between species within *Doellingeria* (Hill 1983). After years of research, taxonomists eliminated the *Aster* genus and replaced *Aster infirmus* with the current taxon, *Doellingeria infirma*.

Synonyms for *Doellingeria infirma* (Michx.) E.L. Greene 1896 are *Aster infirmus* Michx. 1803, *Aster cornifolius* Muhl. ex Willd. 1803 (J. Semple, University of Waterloo, personal communication), *Doellingeria humilis* (Willd.) Britt 1898, *Aster umbellatus* P. Mill. var. *brevisquamis* Fern. (USDA, NRCS 2002). Semple (personal communication) found the following synonyms through nomenclature research: *Aster humilis* Willd 1803, *Doellingeria cornifolia* (Muhl. ex Willd) Nees 1832, *Diplostephium cornifolium* (Muhl. ex Willd) DC 1836, *Diploppaus cornifolius* (Muhl ex. Willd) Darl ex B.S.P 1888, and *Doellingeria umbellata humilis* (Willd) W. Stone 1912. There are numerous scientific articles that list other taxa of *Doellingeria* or *Aster* as synonyms for *Doellingeria infirma*; however these were the dominant synonyms amongst the many.

SPECIES BIOLOGY

Asters are highly variable morphologically due to diverse growing conditions and intraspecific genetic variation (Semple et al. 1996). The success of the family may be due to highly efficient pollination specializations, versatile reproductive capabilities, and wind dispersal of small, dry fruits. The evolution of high floral density has attracted effective pollinators that have in turn influenced the development and structure of flower parts, fruits and dispersal organs (Mani and Saravanan 1999). There is no evidence to infer that *Doellingeria infirma* is rhizomatous or spreads vegetatively (Semple et al. 1991).

Naturally-occurring interspecific hybrids of asters have been found in Ontario. Although crosses between closely-related species within the genus *Doellingeria* are rare and have not been documented for *D. infirma*, they have produced viable hybrid progeny (Semple et al. 1996).

In general, various insects pollinate asters. Bees, wasps, moths, butterflies, and beetles have been seen foraging for either pollen or nectar on native species, but it is not certain which of these kinds of insects are effective pollinators (Semple et al. 1996). The composite head forms essentially a single, simple blossom to attract pollinators more effectively than single flowers scattered in a loose panicle. Ironically, the highly specialized flower head is inefficient for bees because the compressed head makes the bee work harder for its reward. However, butterflies find the nectar supply of the composite adequate. The weak scent in composite heads also works well with the poor olfactory senses of butterflies (Mani and Saravanan 1999). Synchronization between nectar secretion and foraging by butterflies renders butterfly pollination effective (Mani and Saravanan 1999). The role of butterfly pollination in the Asteraceae has not been researched thoroughly.

There is no current evidence to suggest a symbiotic relationship between *Doellingeria infirma* and any other related plant species, macroinvertebrates, fungi or animals. Data do indicate that herbivory, possible by rabbits or small rodents threaten the taxon (MANHESP, unpublished Element Occurrence Records).

Information on the specific breeding system of *Doellingeria infirma* does not exist. A study of *Aster furcatus*, another rare species, determined that low seed set was limited by a low diversity of S-alleles, which is associated with self-incompatibility. However, the study found a relationship between self-compatibility and the number of ovules per inflorescence in this species, indicating that self-compatibility can evolve from self-incompatible progenitors under strong selection (Reinartz 1994). Self-compatible species can have a selective advantage over populations lacking a sufficient number of S-alleles to produce compatible crosses. Genetic models have found predominant selfing and predominant outcrossing to be alternating states (e.g., Schemske and Lande 1985, Waller 1986, cited in Reinartz 1994). In regards to the effects of pollination on small populations of related species, one study attributed insufficient pollen quantity and quality (S-allele diversity) to lower seed set in a small population of *Eupatorium resinsum* (Asteraceae) (Byers 1995). Further studies are needed to determine whether *Doellingeria infirma* exhibits inbreeding depression, self-incompatibility, or pollen limitation.

HABITAT/ECOLOGY

The general habitat that supports *Doellingeria infirma* is typically dry, or dry-mesic deciduous woodlands, thickets, and slopes, with dappled sunlight. In the southeastern United States, it may be found in moister woods with oaks (*Quercus* spp.) and American hazelnut (*Corylus americana*).

Each of the occurrences in Massachusetts represents a slightly different habitat type. The Woburn (MA .003) site is a low-slope community. The site is on a flat aspect with dappled light and an open understory. The bedrock in this part of eastern Massachusetts is acidic, but the community has ample soil moisture that may balance soil acidity and provide suitable conditions for the taxon (Jorgensen 1978). The Lincoln (MA .001) population is located in a fairly undisturbed oak-hickory forest, with dry thin, acidic soils. This specific habitat could be considered a hilltop to mid-slope community (Jorgensen 1978). The plants at the ridgetop receive the most sunlight and tend to mature and dehisce earliest. In western Massachusetts, the Holyoke (MA .010) population is located within a mid/low-slope community. The site is the most species-rich, with a number of dominant mid-slope and low-slope canopy trees and shrubs (MANHESP EORs and Jorgensen 1978). The trap rock bedrock at this site is less acidic than eastern Massachusetts; the soils at this location are richer in minerals and more circumneutral in pH (Jorgensen 1978). In summary, the taxon is most often located in dry to mesic woods with an open shrub layer and a moderately open tree canopy.

Associated vegetation found within the natural plant communities of this species include: American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), black oak (*Quercus velutina*), white oak (*Quercus alba*), black cherry (*Prunus serotina*), Pignut hickory (*Carya glabra*), shagbark hickory (*Carya ovata*), sugar maple (*Acer saccharum*), ironwood (*Ostrya virginiana*), sweet birch (*Betula lenta*), striped wintergreen (*Chimaphila umbellata*), blueberry (*Vaccinium angustifolium*), brome-grass (*Bromus pubescens*), blue-stemmed goldenrod (*Solidago caesia*), early goldenrod (*Solidago juncea*), naked flowered tick-trefoil (*Desmodium nudiflorum*), prostrate tick-trefoil (*Desmodium rotundifolium*), late purple aster (*Symphyotrichum patens*), smooth aster (*Symphyotrichum laevis*), wavy-leaved aster (*Symphyotrichum undulatum*), Pennsylvania sedge (*Carex pensylvanica*), and poison ivy (*Toxicodendron radicans*) (MANHESP EORs).

The potential role of fire in helping to maintain populations of *Doellingeria infirma* is poorly understood. Evidence from a recent burn at MA .003 (Woburn) suggests that fire may promote transient increases in population size, either directly by facilitating seed germination or indirectly by reducing cover of competing plant species. Oak woodlands have been prone to fire throughout their range and certain rare herbaceous species found in this forest type may benefit from fire. Further studies are needed to determine if *Doellingeria infirma* is among the species that may benefit from fire.

THREATS TO TAXON

The New England populations of *Doellingeria infirma* face numerous threats that affect population sizes and viability. Specific threats vary at each site and include: shading; invasive species; low reproductive rates; natural and human disturbances; and habitat loss. Invasive species have become dense at the Lincoln (MA .001) population. The ridgetop site previously held numerous individuals until a moderately invasive shrub, common barberry (*Berberis vulgaris*) began to dominate the open sunny knoll (Nancy Webb, New England Wild Flower Society Plant Conservation Volunteer, personal communication). Native plants cannot compete with invasive species that emerge earlier in the spring, grow faster, set seed early, and maintain foliage longer.

The Woburn (MA .003) and Holyoke (MA .010) populations have been disturbed in the past by fire and logging, respectively (MANHESP EORs). Such disturbances have not completely hindered the growth of *Doellingeria infirma* (and, in fact, a transient population increase was seen at MA .003 [Woburn] following a 2001 fire), but they may have promoted the growth of additional herbaceous vegetation, which compete for light and other resources. As indicated by the lengthy list of associated species in the EORs, competition between the taxon and other herbaceous plants may be affecting the population size of these occurrences. Trampling by users of nearby recreational trails at MA .003 (Woburn) is a potential threat to plants at that site.

Specific genetic studies of the Massachusetts populations have not been conducted; however, the EORs clearly document a decrease, in certain years, in the number of mature individuals that produce seed. Such low reproduction may be exacerbated by small population sizes and isolation of populations from one another. The species also reaches its northern range limit in New England. The colder climate and slightly more acidic soils are two factors that may limit the increase in population sizes in this region. There is no definitive evidence in the historic herbarium records that suggest why this species has declined. Consistent monitoring during the optimal time between the last bloom and the last budding achene would create a better understanding of the taxon's reproductive cycle, seed dispersal, and threats to population viability.

The Massachusetts populations are also threatened by habitat loss. The encroachment of surrounding neighborhoods has narrowed the size of habitats that would otherwise support this species. Many of the extant sites and possible habitats within New England are in danger of being developed for residential or commercial use. The fragmentation of populations of suitable combined habitats may increase the risk of extirpation that small populations face. The loss of potential habitats is an even greater threat since we are not yet aware of all the possible sites that may support this species.

It is possible that climatic and especially soil conditions in New England are inimical to supporting large populations of *Doellingeria infirma*. In the Appalachian Plateau and Ohio River Valley where the taxon is more commonly found, the community type is one of a mixed mesophytic forest with characteristic limestone bedrock and richer, only slightly acidic soils (Jorgensen 1978). There are portions of southern New England that maintain this type of habitat. Sites in western Connecticut are "intermediate between the mixed mesophytic and low slope communities" (Jorgensen 1978). The Connecticut Valley Lowland has numerous historic records of *Doellingeria infirma*. Rick Enser, Rhode Island Natural Heritage Program, has also suggested *de novo* surveys of the circumneutral areas of northeastern and central Rhode Island (personal communication). A detailed study of the ecological and biological conditions that generate suitable habitats for this species is highly recommended.

DISTRIBUTION AND STATUS

General Status

Doellingeria infirma is ranked G5, globally secure (NatureServe 2001). The taxon is found throughout the southeastern United States as far south as Georgia and as far west as Mississippi, Tennessee, Kentucky and Ohio (see Figure 1, Table 1). The occurrences in the states outside of New England are labeled SR (reported), SU/S? (unranked or unknown), S2 in New Jersey, S3 in Maryland, and S5 in North Carolina. Delaware, the District of Columbia (S1/S3) and Massachusetts rank the taxon as state imperiled (S1) (NatureServe 2001, see Table 1). The District of Columbia has broadly ranked *Doellingeria infirma* so it would be comparable to rankings from surrounding

states that have more natural habitat (Chris Lea, National Park Service, personal communication).

The species varies from common to infrequent in the Piedmont and Coastal Plains of southern states. It has been referenced as a common plant in: New Jersey (D. Snyder, New Jersey Natural Heritage Program, personal communication); Delaware (McAvoy and Bennett 2001); Maryland (Brown and Brown 1984); Virginia (Harvill et al. 1986); West Virginia (P. J. Harmon, West Virginia Wildlife Diversity Program, personal communication) and the Carolinas (Radford et al. 1965). It is also found in the Blue Ridge Mountains of Georgia (Jones and Coile 1988). The species also occurs in the Mississippi Embayment and Bluegrass provinces of Mississippi (R. Wieland, Mississippi Department of Wildlife, Fisheries and Parks, personal communication). It occurs in Kentucky (D. White, Kentucky Nature Preserves Commission, personal communication), and the Cumberland and Allegheny Mountains of Tennessee (Tennessee Vascular Plants Database 2002). *Doellingeria infirma* is the only species within the genus that is found predominantly inland of the coastal plain region of the southeastern United States (Semple et al. 1996).

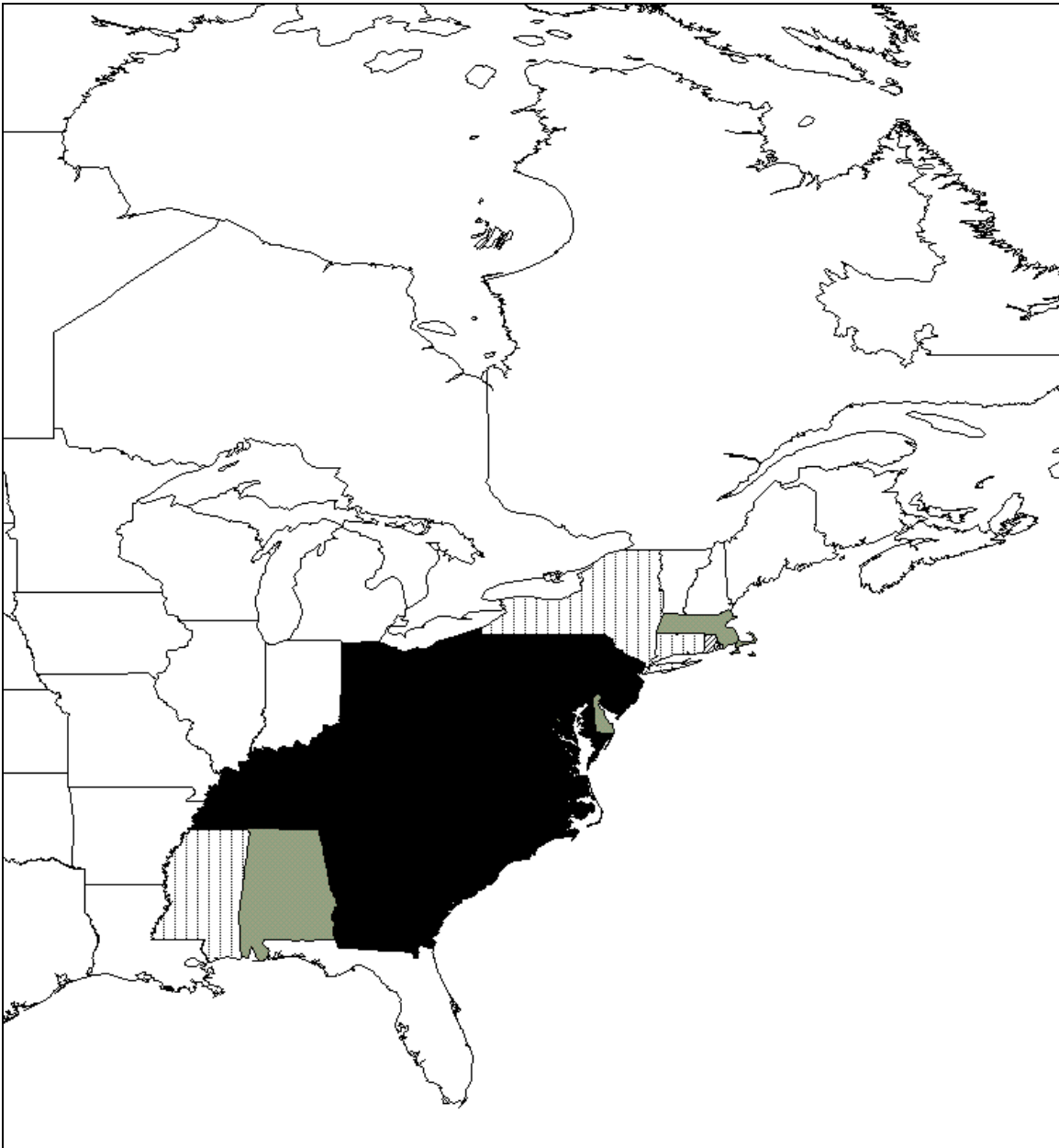


Figure 1. Occurrences of *Doellingeria infirma* in North America. States shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. States shaded in black have more than five confirmed occurrences. The state (Rhode Island) with diagonal hatching is designated "historic," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported" but without additional documentation). See Appendix for explanation of state ranks.

Table 1. Occurrence and status of <i>Doellingeria infirma</i> in the United States and Canada based on information from Natural Heritage Programs.			
OCCURS & LISTED (AS S1, S2, OR T & E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE REPORTED OR UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
Massachusetts (S1/E): 3 extant and 8 historic occurrences.	Maryland (S3): infrequent in Piedmont and Coastal Plain (Brown and Brown 1984).	Alabama (SR): 1 county listed (Cullman County) (Mohr 1969), not currently tracked (M. Barbour, Alabama Natural Heritage Program, personal communication).	Rhode Island (SH): Heritage records indicate a 1965 occurrence in Providence County, not currently tracked; Enser (Rhode Island Natural Heritage Program) suggests status should be changed to SU.
Delaware (S1): infrequent, 2 extant populations within the coastal plain, historical from Piedmont, south to Kent County (McAvoy and Bennett 2001).	North Carolina (S5): found in 44 counties (Radford, et al. 1965). Additional counties may have occurrences, fairly common in the piedmont and Mtns. of North Carolina (A. Weakley, University of North Carolina herbarium, personal communication).	Connecticut (SR): historical records from 5 counties (Graves et al. 1910), not tracked, no EORs (K. Zyko, Connecticut Natural Diversity Database, personal communication).	
District of Columbia (S1/S3): 1995 Annotated checklist from Rock Creek Park, National Park Service, Washington, D.C. (M. Koenen, National Park Service, personal communication).	Kentucky (S?): found in 3 geographic regions in eastern third of state (Browne and Athey 1992); infrequent, identification in question (White, personal communication).	Georgia (SR): Distributed in 23 counties (Duncan and Kartesz 1981, Mellinger 1984, Jones and Coile 1988.); no current information on tracking status.	
New Jersey (S2): 9 extant populations in 4 counties, 27 historical occurrences in approx. 15 counties (Snyder, personal communication).	Pennsylvania (S?): Found historically in approx. 90 counties (Rhoads and Klein 1993); infrequent (J. Kunsman, The Nature Conservancy-Pennsylvania, personal communication).	Mississippi (SR): currently the species is not tracked (Wieland, personal communication).	

Table 1. Occurrence and status of <i>Doellingeria infirma</i> in the United States and Canada based on information from Natural Heritage Programs.			
OCCURS & LISTED (AS S1, S2, OR T &E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE REPORTED OR UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
	West Virginia (S?): 23 counties with possible extant occurrences; “not common, but not in a unique habitat to warrant tracking” (Harmon, personal communication).	New York (SR): collected in Franklin, Columbia, and Greene Counties prior to 1990, collected in Rensselaer between 1990 and present (Weldy et al. 2000); not currently tracked (S. Young, New York Natural Heritage Program, personal communication).	
		Ohio (SR): 8 counties, eastern and southeastern Ohio with 60 populations before being delisted from watch list in 1989, currently not tracked (J. McCormac, Ohio Dept. of Natural Resources, personal communication).	
		South Carolina (SR): 13 counties (Radford et al. 1968); 17 counties all in Piedmont province, not currently tracked (J. Holling, South Carolina Department of Natural Resources, personal communication).	
		Tennessee (SR): 29 counties with possible extant occurrences (Tennessee Vascular Plants Database 2002).	
		Virginia (SR): 63 counties (Harvill et al. 1986); not tracked, considered frequent, species needs to be re-ranked as S5 (J. Townsend, Virginia Dept. of Conservation and Recreation, personal communication).	

Status of all New England Occurrences — Current and Historical

Figures 2 and 3 show the distributions of extant and historical localities for *Doellingeria infirma*, respectively. The species has not been found in Maine (Don Cameron, Maine Natural Areas Program, personal communication), Vermont (Anne Turner, Vermont Nongame and Natural Heritage Program, personal communication) or New Hampshire (Sara Cairns, New Hampshire Natural Heritage Inventory, personal communication).

Massachusetts has listed *Doellingeria infirma* as Endangered with a rank of S1. There are three known extant occurrences and one potential occurrence, in West Springfield, that may eventually be merged with the Holyoke site. The first known occurrence was reported in 1882 in Winchester, Massachusetts. The Massachusetts Natural Heritage Program has ten element occurrence records, four of which are currently tracked (MANHESP EORs). Arthur Haines, Research Botanist for the New England Wild Flower Society (NEWFS), has reverified historic herbarium specimen records for each of the ten element occurrences in Massachusetts (Table 2).

The Connecticut Natural Diversity Database ranks the taxon as SR, State Reported, and does not currently survey for the species (Zyko, personal communication). Connecticut specimen records indicate its occurrence in central and southwestern Connecticut.

The Rhode Island Natural Heritage Program ranks *Doellingeria infirma* as state historic. Herbarium research has not uncovered historical or current records for this species (Enser, personal communication).

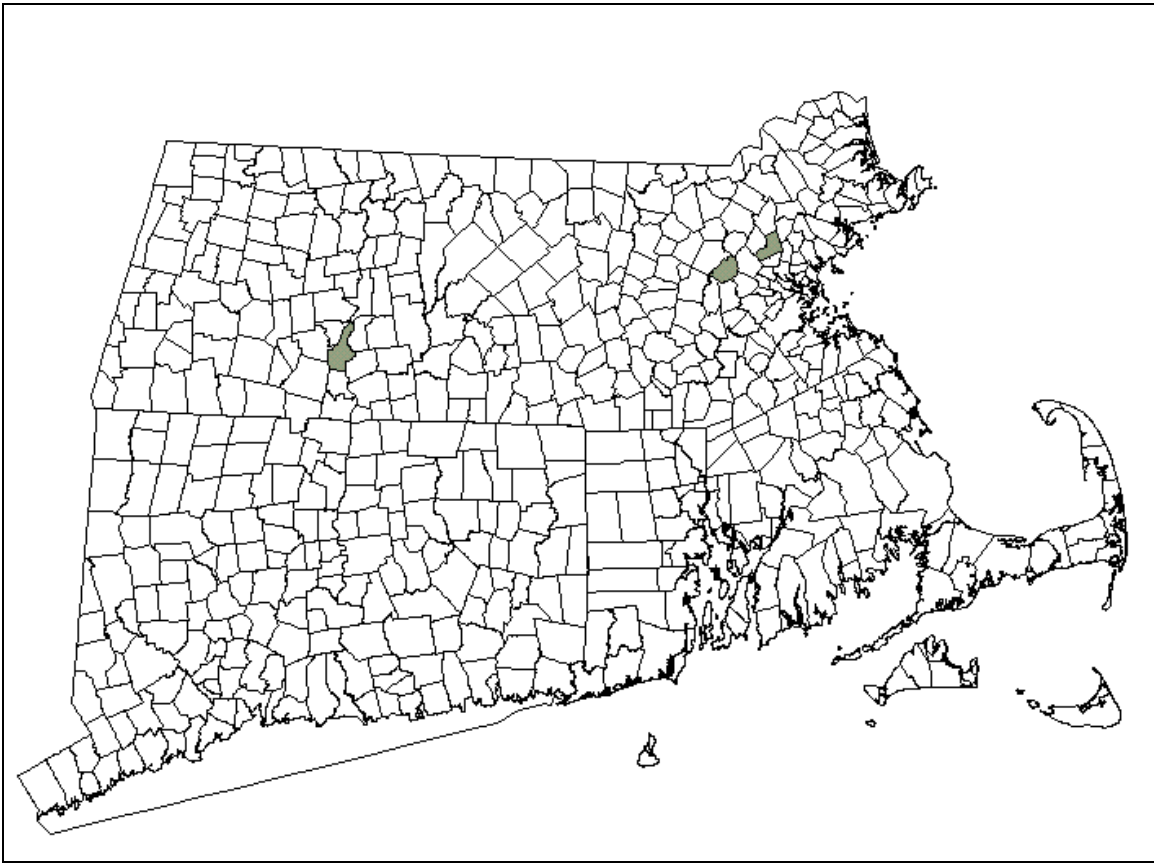


Figure 2. Extant occurrences of *Doellingeria infirma* in New England. Town boundaries for southern New England states are shown. Towns shaded in gray have one to five extant occurrences of the taxon. The putative West Springfield occurrence is not shown.

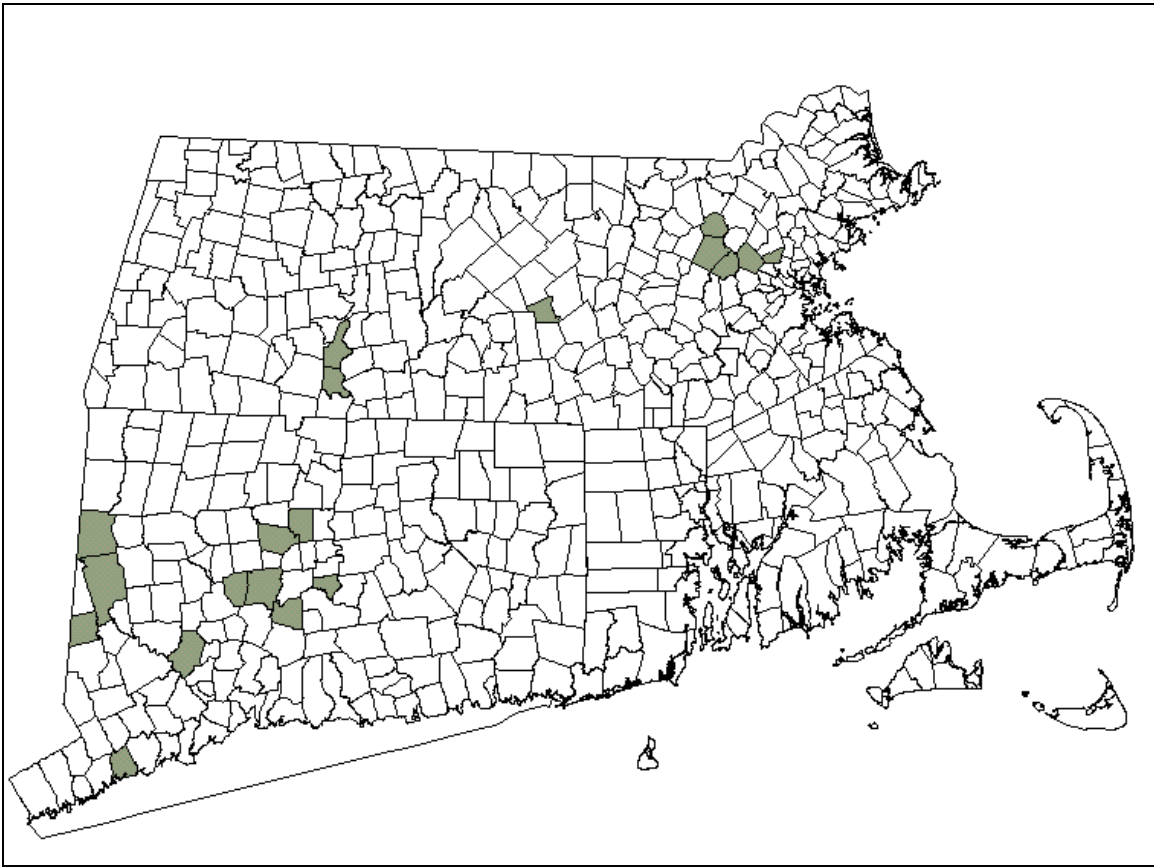


Figure 3. Historical occurrences of *Doellingeria infirma* in New England. Towns shaded in gray have one to five historical records of the taxon.

Table 2. New England Occurrence Records for <i>Doellingeria infirma</i>. Shaded occurrences are considered extant.			
State	EO Number	County	Town
MA	.001	Middlesex	Lincoln
MA	.002	Middlesex	Concord
MA	.003	Middlesex	Woburn
MA	.004	Middlesex	Lexington
MA	.005	Worcester	Paxton
MA	.006	Middlesex	Lincoln
MA	.007	Middlesex	Carlisle
MA	.008	Middlesex	Winchester
MA	.009	Hampden	Holyoke
MA	.010	Hampden	Holyoke
MA	.011	Hampden	West Springfield
RI	.001	Providence	N/A
CT	.001	Fairfield	Westport
CT	.002	Hartford	Southington
CT	.003	Hartford	Farmington
CT	.004	Hartford	West Hartford
CT	.005	Hartford	Farmington
CT	.006	Middlesex	Cromwell
CT	.007	New Haven	Oxford

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

After careful review of Massachusetts Natural Heritage Program EORs, visits to the extant occurrences, and discussions with numerous Natural Heritage program staff, I have projected the following conservation objective for *Doellingeria infirma* as eight occurrences in Massachusetts. Each population should maintain an average of 60 individuals, with 10-25% of the mature plants setting seed each year if the population is growing substantially.

I focus on Massachusetts initially, as the status of *Doellingeria infirma* in Connecticut and Rhode Island is poorly understood. If *de novo* surveys uncover additional populations elsewhere in New England, these conservation objectives should be revised to encompass these states.

The total number of populations is empirically based on the number of extant and historical populations recorded from Massachusetts, including the West Springfield occurrence. The taxon occupies a relatively common habitat in the state. Intensive surveys have not occurred for this taxon, and given it can be potentially missed or misidentified, it is conceivable that several more populations of the taxon exist in Massachusetts. While the focus for immediate conservation objectives is on Massachusetts (with the only extant occurrences in New England), based on suggestions from Rick Enser and research on the habitat ecology of this taxon, I also recommend surveying potential habitat for the taxon within Connecticut and Rhode Island.

The average population size is also based on empirical observations of the three extant populations over the years they have been surveyed. Population sizes at the current sites have ranged from 3 to 100+ plants (MA .001 [Lincoln]), 5 to 125 plants (MA .002 [Woburn]), and 1 to 365+ plants (MA .010 [Holyoke]), with numbers varying over an order of magnitude from year to year. Thus, an "average" population size over time allows for some year-to-year variability in population size, while maintaining a minimum number of plants that reflects the mean population size among all the occurrences. A population size of less than 60 plants seen for five consecutive years would indicate the need for conservation action. A proportion of these plants should be setting seed; therefore, I call for 10-25% reproduction as an average over time. We know little about the viability of seed from extant populations or what precise proportion of plants are needed to reproduce in order to contribute to population growth. Future quantitative monitoring, particularly of seedling recruitment and actual demographic growth, is needed to refine this estimate.

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IV. APPENDICES

1. An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe

1. An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe

The conservation rank of an element known or assumed to exist within a jurisdiction is designated by a whole number from 1 to 5, preceded by a G (Global), N (National), or S (Subnational) as appropriate. The numbers have the following meaning:

- 1 = critically imperiled
- 2 = imperiled
- 3 = vulnerable to extirpation or extinction
- 4 = apparently secure
- 5 = demonstrably widespread, abundant, and secure.

G1, for example, indicates critical imperilment on a range-wide basis -- that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnational jurisdiction -- i.e., a great risk of extirpation of the element from that subnation, regardless of its status elsewhere. Species known in an area only from historical records are ranked as either H (possibly extirpated/possibly extinct) or X (presumed extirpated/presumed extinct). Certain other codes, rank variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty.

Elements that are imperiled or vulnerable everywhere they occur will have a global rank of G1, G2, or G3 and equally high or higher national and subnational ranks (the lower the number, the "higher" the rank, and therefore the conservation priority). On the other hand, it is possible for an element to be rarer or more vulnerable in a given nation or subnation than it is range-wide. In that case, it might be ranked N1, N2, or N3, or S1, S2, or S3 even though its global rank is G4 or G5. The three levels of the ranking system give a more complete picture of the conservation status of a species or community than either a range-wide or local rank by itself. They also make it easier to set appropriate conservation priorities in different places and at different geographic levels. In an effort to balance global and local conservation concerns, global as well as national and subnational (provincial or state) ranks are used to select the elements that should receive priority for research and conservation in a jurisdiction.

Use of standard ranking criteria and definitions makes Natural Heritage ranks comparable across element groups; thus, G1 has the same basic meaning whether applied to a salamander, a moss, or a forest community. Standardization also makes ranks comparable across jurisdictions, which in turn allows scientists to use the national and subnational ranks assigned by local data centers to determine and refine or reaffirm global ranks.

Ranking is a qualitative process: it takes into account several factors, including total number, range, and condition of element occurrences, population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, environmental specificity, and fragility. These factors function as guidelines rather than arithmetic rules, and the relative weight given to the factors may differ among taxa. In some states, the taxon may receive a rank of SR (where the element is reported but has not yet been reviewed locally) or SRF (where a false, erroneous report exists and persists in the literature). A rank of S? denotes an uncertain or inexact numeric rank for the taxon at the state level.

Within states, individual occurrences of a taxon are sometimes assigned element occurrence ranks. Element occurrence (EO) ranks, which are an average of four separate evaluations of quality (size and productivity), condition, viability, and defensibility, are included in site descriptions to provide a general indication of site quality. Ranks range from: A (excellent) to D (poor); a rank of E is provided for element occurrences that are extant, but for which information is inadequate to provide a qualitative score. An EO rank of H is provided for sites for which no observations have been made for more than 20 years. An X rank is utilized for sites that are known to be extirpated. Not all EOs have received such ranks in all states, and ranks are not necessarily consistent among states as yet.