New England Plant Conservation Program

Conservation and Research Plan

Hydrophyllum canadense L.
Maple-Leaved Waterleaf

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SUMMARY

Hydrophyllum canadense L. (Hydrophyllaceae), Maple-leaved waterleaf, is a Division 2 plant species in New England (Brumback and Mehrhoff et al. 1996). There is one extant occurrence in Vermont and four extant occurrences in Massachusetts; the species has not been reported from any other New England states. Three of the five occurrences consist of approximately 500-2000 clumps, and two occurrences consist of approximately 50-100 clumps. *Hydrophyllum canadense* is an S1 species in both New England states and receives some protection as a threatened species in Vermont and as an endangered species in Massachusetts. Outside of New England, *H. canadense* occurs in 18 states, in the District of Columbia, and in Quebec and Ontario. It is reported, but unconfirmed, in one additional state. It is an S1 or S2 species in two of these states, as well as the District of Columbia and Quebec.

In New England, *Hydrophyllum canadense* grows in fertile, moist hardwood forests in areas of calcareous bedrock. Adequate shade and a moist, porous, nutrient-rich substrate are likely requirements for the species. Threats such as development, habitat alteration, invasion by exotic plant species, inadvertent disturbance to plants and their habitat, and stochastic events can compromise the few remaining New England occurrences of *H. canadense* and are addressed in this Conservation and Research Plan.

The conservation objectives of this Plan are to:

1. Ensure the persistence of all extant *H. canadense* populations and the habitat necessary to support them in New England;

2. Search for and protect previously unknown occurrences;

3. Explore the desirability and feasibility of expanding the extent and number of occurrences via augmentation, reintroduction, or introduction of the taxon.

The initial focus for such efforts would be augmentation. The result of achieving these conservation objectives would be the continued existence and protection of five extant populations and protection of at least one additional occurrence.

In order to meet these conservation objectives, numerous conservation actions must be taken. These actions include: land acquisition or other forms of protection; regular surveys of occurrences; *de novo* searches for new populations; species biology research; habitat management; *ex-situ* activities (continued seed collection, seed germination and propagation research); possible augmentation or reintroduction; and education.

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) 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

Hydrophyllum canadense L. (Hydrophyllaceae), Maple-leaved waterleaf, is a shade-tolerant perennial herb of fertile, moist hardwood forest habitats. When growing under optimal conditions, the plant forms dense swards and can be one of the dominant herbaceous plants present.

Hydrophyllum canadense blooms in June and is pollinated by a variety of Dipteran and Hymenopteran species. Seeds are dense and rounded and are likely dispersed by gravity and water in the immediate environment of the plant. The species can also reproduce vegetatively via its well-developed rhizomes, and this is likely an important means of reproduction.

Hydrophyllum canadense occurs in Quebec and Ontario, Canada, southern Vermont and western Massachusetts, to the south in Maryland and chiefly in the mountains to Georgia, and west to Wisconsin and Illinois. The species occurs in 20 states, the District of Columbia, two Canadian provinces, and has been reported, but not verified, in one additional state. The taxon is an S1 (typically fewer than 5 occurrences or very few individuals) or S2 (typically 6-20 occurrences or few remaining individuals) species in four states, the District of Columbia, and in Quebec. There are no states in which *H. canadense* is reported as extirpated. *Hydrophyllum canadense* receives protection as a threatened or endangered species in three states. In New England, *H. canadense* is a Division 2 species (a regionally rare taxon with fewer than 20 occurrences in New England) (Brumback and Mehrhoff et al. 1996). The plant is represented by a single current population in Vermont and four current populations in Massachusetts; it is listed as a threatened species in Vermont and as an endangered species in Massachusetts. Conservation of *H. canadense* in New England will preserve an important part of this region's natural heritage and will contribute to the conservation of the species throughout its range.

Threats to *Hydrophyllum canadense* include: impacts from invasive exotic plant species; habitat disruption; development; inadvertent disturbance to plants; herbivory; stochastic events; and the potential for low genetic diversity. Several of these threats may have played a role in the extirpation of known historic occurrences and continue to affect current occurrences.

A conservation and research plan for *Hydrophyllum canadense* is necessary to encourage the immediate and long-term persistence of the taxon in New England. The extremely small number of occurrences is cause for great concern. Although the plant forms dense stands at three of the five New England occurrences, the plant is still vulnerable to extirpation due to a number of threats confronting the species. The species' limited presence in New England, threats to the taxon and its habitat, and its conservation

importance serve as rationales for developing this New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. The goals of this plan are to compile existing information on the taxon and to provide a framework for the long-term conservation of *H. canadense* in New England. The plan consists of two sections, with the first section providing background information on the taxonomy, biology, ecology, distribution, and status of *H. canadense*. The second section uses this information to develop conservation objectives, general conservation actions for the taxon, recommended conservation actions for each occurrence, and a prioritized implementation schedule for the completion of actions.

DESCRIPTION

Hydrophyllum canadense (Hydrophyllaceae) is a mesophytic fibrous-rooted perennial arising from long, well-developed rhizomes. The stems are from 20-70 cm in height, and the upper portions, including the inflorescence, are generally glabrous or with scattered hairs. As is typical of the family, much of the remainder of the plant is hairy. The cauline leaves are 10-20 cm wide and nearly as long, palmately 5-9 lobed, and coarsely, but unevenly toothed. The alternate leaves attach to the stem with petioles, and there may be 2-3 small lateral leaflets present. Newly emergent leaves and seedlings exhibit spotting. The plant overwinters as a rosette of leaves attached to the rhizome. The white to pink-purple flowers occur on short pedicels in cymose inflorescences and are 8-12 mm in length, with lobes shorter than the tube. Flowers have a 5-parted calyx and a campanulate 5-cleft corolla. Stamens extend beyond the corolla by 3-6 mm, and the shortly bifid style extends beyond the corolla by 4-5 mm. There are four ovules in a unilocular, superior ovary; typically from 1-4 seeds develop in a capsule. The distinctive maple-shaped leaves, the largely glabrous stems, and the degree to which the stamens extend beyond the corolla distinguish *H. canadense* from other species of *Hydrophyllum*. Description of *H. canadense* is based on information from (Fernald 1950, Beckmann 1979, Westmoreland 1981, and Gleason and Cronquist 1991).

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Hydrophyllum canadense is one of eight species of *Hydrophyllum* in North America. The genus occupies two disjunct regions, with four species found in eastern North America (*H. appendiculatum*, *H. canadense*, *H. macrophyllum*, and *H. virginianum*) and four species in western North America (*H. capitatum*, *H. fendleri*, *H. occidentale*, and *H. tenuipes*) (Beckmann 1979, Westmoreland 1981). The center of distribution for the eastern species assemblage is at the southern edge of the maximum extent of the Pleistocene glaciation in southern Illinois, Indiana, Ohio, and northern Kentucky (Constance 1942). The first citation for the genus *Hydrophyllum* is by Linnaeus in his 1735 *Systema Naturae*. The original description of *H. virginianum* encompassed both *H. virginianum* and *H. canadense*; *H. canadense* was named in 1739 (Beckmann 1980). Kartesz and Kartesz (1980) list no synonyms for *H. canadense*, but (Constance 1942) lists *H. acerifolium* Salisb. (1796) and *H. lobatum* Stokes (1812) in his

discussion of *H. canadense.* All species of *Hydrophyllum,* including *Hydrophyllum canadense,* have a diploid chromosome number of 2*n*=18 (Gleason and Cronquist 1991). *Hydrophyllum* appears to be a genus of closely related, but distinct, species; the integrity of the species is likely maintained by strong internal reproductive barriers to hybridization (Beckmann 1979).

The genus probably had a single progenitor that was likely to have been a mesophytic perennial herb from a horizontal rhizome, with large, pinnate or pinnately divided leaves, a lax, cymose inflorescence, exserted stamens and styles, and possibly an appendaged calyx (Constance 1942). *Hydrophyllum canadense* appears to be most closely related to the biennial *H. appendiculatum* (Beckmann 1979). *Hydrophyllum canadense* and *H. appendiculatum* resemble one another morphologically in several leaf and calyx characters. Also, the first-year plants of the biennial *H. appendiculatum* are similar to perennial *H. canadense* plants at the same life stage (Beckmann 1979). Examination of similarities in gel banding patterns for seed proteins among the *Hydrophyllum* species reveals a higher coefficient of similarity for the two species than for *H. canadense* and any of the other species. Chung and Constance (1992) discuss relationships of several *Hydrophyllum* species based on seed characteristics. Despite morphological and biochemical similarities, however, interspecific crosses between *H. canadense* and *H. appendiculatum* (and all other members of the genus) failed (Beckmann 1979). Crosses between *H. canadense* as the pistillate parent and either *H. appendiculatum* or *H. tenuipes* as the pollen parent produced swollen ovaries, but no seeds. Furthermore, no examples of interspecific hybridization among *Hydrophyllum* species are known in nature even though there are numerous sets of sympatric species (Beckmann 1979).

Analysis of data on morphology, hybridization, and biochemistry (flavonoids and seed proteins) indicate that the most closely allied species of *Hydrophyllum* are not always those within the current eastern and western geographic groupings (Beckmann 1979). One possible explanation is that the genus *Hydrophyllum* may have exhibited continuous distribution across North America in the warm deciduous temperate forests of the Cenozoic. The development of large regions of aridity may then have isolated representatives in the more humid regions of eastern and western North America. Modern affinities among the species suggest that prior to range disruption, two species complexes possibly existed that do not correspond to the current geographic species complexes (Beckmann 1979).

SPECIES BIOLOGY

Hydrophyllum canadense is a mesophytic perennial herb that grows from a well-developed, branching rhizome. The plant blooms from May through July throughout North America (June in New England). Pollinators include a variety of Dipteran species that forage for nectar only and Hymenopteran species that forage primarily for pollen (Beckmann 1979). Pollinators are active in the morning and other times during the day; the most frequent pollinators observed by Beckman (1979) were *Apis mellifera, Bombus pennsylvanicus, B. vagans, B. grisecollis, B. nevadensis, Osmia* spp., *Hoplitis* spp., and

Anthophora spp. Floral attractants include corolla pigmentation, pollen masses on exserted anthers, and nectar accumulated in corolla folds; the flowers are odorless. Individual flowers remain open for approximately 72-84 hours. Flower anthesis occurs around dawn, and insects usually remove pollen within six to eight hours. Flowers produce nectar throughout their duration. In a comparative pollination study of all North American *Hydrophyllum* species, *H. canadense* was the only species described as having low pollinator activity. Overtopping leaves can obscure the inflorescences and may cause this low pollinator activity. Unlike other species of *Hydrophyllum* observed, pollen often remains in anthers until the flowers senesce. The consequences of low pollinator activity for the species are unknown. Although *H. canadense* is self-compatible, there are no apparent self-pollination strategies present within the species (*e.g.*, anther dehiscence prior to anthesis or stigma receptivity prior to anthesis) (Beckmann 1979). Extensive studies of the reproductive biology of *H. appendiculatum* (Wolfe 1992; Wolfe 1993a; Wolfe 1993b; Wolfe 1995) may provide some insights applicable to *H. canadense* as well. Diggle (1997) discusses floral morphology and resource limitation for several taxa including species of *Hydrophyllum.*

When seeds mature, they are subglobose and exhibit a high density. They fall from the capsule to the ground, and the primary mechanism of seed dispersal is via surface water present in the immediate environment of the plants. Evidence of seed dispersal by ants was observed in some species of *Hydrophyllum*, but not in *H. canadense* (Beckmann 1979).

Based on a study of flavonoids and seed proteins, *Hydrophyllum canadense* exhibits little intra- and inter-populational variability; this is true of the other *Hydrophyllum* species as well (Beckmann 1979). Differences among individuals within a population and across populations were quantitative only.

No known detailed studies exist on such aspects of the biology of *Hydrophyllum canadense* as herbivory, seed germination and seedling establishment, or vegetative reproduction. Extensive herbivory on leaves was observed in New England populations (J. Ramstetter and R. Popp, personal observation). Transplantation from natural populations to greenhouse settings and to garden plots is possible Beckmann (1979), and plants grown in a research garden setting reseed themselves (Chris Mattrick, New England Wild Flower Society, personal communication).

HABITAT/ECOLOGY

In New England, *Hydrophyllum canadense* grows in fertile, moist hardwoods in areas of calcareous bedrock. Adequate shade and a moist, porous substrate appear to be requirements for the species (Beckmann 1979). All four *Hydrophyllum* species in eastern North America occur in rich, moist woods (Wilson 1960). Especially in the eastern United States, the distribution of *Hydrophyllum* species is associated with major river drainages. Vermont's only population of *H. canadense* grows along the perimeter of a second-growth floodplain forest with thick, silty accumulations. Dominant canopy

species include *Populus deltoides* and *Acer saccharum,* and *Matteuccia struthiopteris* is the dominant herbaceous plant. The invasive exotics *Alliaria petiolata, Polygonum cuspidatum,* and *Hesperis matronalis* are dense at this site. In Massachusetts, the plant grows in fertile, mesic hardwood forests. Dominant canopy species include *A. saccharum* and *Fraxinus americana*; species found in the herb layer at multiple sites include *Allium tricoccum, Caulophyllum thalictroides, Dryopteris marginalis,* and *D. goldiana*. Elevations for the *Hydrophyllum* occurrences in New England range from approximately 540 to 1490 feet (165 to 454 meters).

A study of herb-soil relationships at a site in Georgia suggests that the occurrence and abundance of *Hydrophyllum canadense* is related in part to soil nutrient and moisture characteristics (Graves and Monk 1982). *Hydrophyllum canadense* occurs at relatively high pH levels (up to pH 6.6) with low available soil aluminum and iron concentrations and high soil moisture contents. Relatively high soil nitrogen and calcium levels are correlated with the occurrence of *H. canadense.* *Hydrophyllum canadense* and co-occurring species may be limited in their distribution by high requirements for several basic cations, nitrogen, and moisture, and low requirements for iron, aluminum, and molybdenum. At this Georgia site, *H. canadense* forms dense swards and can limit growth of other species on the most base rich soils. Of 15 species present, *H. canadense* exhibits the second highest maximum percent cover in plots; only *Impatiens* sp. exhibits a higher maximum percent cover.

Leaves of *Hydrophyllum canadense* appear to be well-adapted to shade conditions, both as a result of light-scattering within the palisade and spongy mesophyll layers of the leaf and because of horizontal leaf orientation (DeLucia et al. 1991, DeLucia et al. 1996). Experimental work altering the ability of leaves to absorb light suggests that intercellular reflectance within the leaves increases light absorption by nearly 30%. These characteristics may allow *H. canadense* to increase light absorption and photosynthesis under shaded conditions (DeLucia et al. 1996). *Hydrophyllum canadense* exhibits a number of cellular characteristics in its leaves that may increase the light harvesting efficiency of such shade leaves at intermediate irradiance levels (DeLucia et al. 1991).

Little is known about the relationship between root morphology and patterns of nutrient uptake and allocation in most plant species, but a study by Pregitzer et al. (1997) provides basic information for *Hydrophyllum canadense*. As a perennial herb, *H. canadense* may lose all roots except rhizomes at the end of each growing season. The root systems of *H. canadense* include up to five branching orders of roots (positions along the root system). The first two orders of roots have the largest number of branches, and root diameter diminishes from the first order to the fifth order roots. Root length is greatest in second-order roots. Carbon concentration within the root orders increases gradually from first- through fifth-order roots, but nitrogen concentration remains relatively constant. Specific root length increases with increasing root order. The relationships between the functional architecture of root systems such as that of *H. canadense* and mycorrhizal associations, root mortality, and below-ground carbon and nitrogen cycling need to be investigated (Pregitzer *et al.* 1997). The physiological and

ecological significance of root architecture and patterns of root nutrient concentration remain to be determined for *H. canadense*. Any new knowledge may contribute to an understanding of the feasibility of transplantation.

A study of a river floodplain system in Maryland revealed complex relationships between light levels, disturbance levels, percent cover of exotics, and percent cover of native species including *H. canadense* (Pyle 1995). As at New England sites, *H. canadense* co-occurs with a number of invasive exotic plant species in the Potomac River floodplain, and these invasive species may outcompete native herbaceous species such as *H. canadense*. No information on the effects of light levels or disturbance levels on *H. canadense* are available in the literature searched. Disturbances such as periodic flooding, as well as other important ecological processes, could be potentially important features in the long-term maintenance of populations of *H. canadense*. However, certain types of disturbance could be detrimental to populations and lead to reductions in population size or extirpation of a population.

THREATS TO TAXON

There are several potential threats confronting *Hydrophyllum canadense* in New England. Potential threats to the taxon identified in element occurrence records from Natural Heritage Program data bases include: invasive exotic plant species; herbivory; inadvertent disturbance to plants and habitat; alteration of appropriate light and moisture regimes with timber harvest or succession; stochastic events that could eliminate the few remaining populations; low genetic diversity (as a result of small populations and vegetative reproduction); and development. Some of these threats are largely self-explanatory, while others require further explanation. Additionally, while adverse impacts of a number of threats have been suggested, lack of biological information about the taxon and lack of experimental data make it difficult to establish several of these potential threats as confirmed threats.

There are at least two considerations that would be useful in assessing the relative degree of threat posed by various events and activities. The first consideration is the relative impact that a threat would have on the population and its habitat if it were to occur; the second consideration is the likelihood of the threat actually occurring. In terms of relative impacts, large-scale alterations of the population or its habitat (invasive exotic plant species; alteration of appropriate light and moisture regimes; stochastic events; and development) are likely to be the most serious if they were to occur. Unfortunately, for most of the threats, there is little information available that would allow accurate predictions on the likelihood of the threats actually occurring. In the absence of additional information, it is not possible to speculate meaningfully on the relative degree of threat posed by these threats. The following section elaborates further on each of the potential threats.

- **Invasive exotic plant species** are present at all five New England sites and are especially prevalent at one of them (VT .001 [Pownal]). The most problematic

invasive exotic plant species include *Alliaria petiolata, Polygonum cuspidatum, Hesperis matronalis, Berberis thunbergii,* and *Rosa multiflora*; they may outcompete *H. canadense* and other natives and alter the habitat substantially.

- **Herbivory** on leaves was substantial at two New England occurrences observed in 2000. The particular agents of herbivory are unknown, but the damage to leaves appears to be caused by insects or perhaps slugs or rodents. It is unknown if this herbivory has a measurable negative impact on individuals or the populations. Herbivory damage is common in the Great Smokies National Park late in the season (Paul Somers, Massachusetts Natural Heritage and Endangered Species Program, personal communication).

- **Inadvertent disturbance** to plants and their habitat may occur during maintenance, recreation, timber harvest, and monitoring activities.

- **Alteration of appropriate light and moisture regimes** may occur as the result of timber harvest, succession, or alteration of the streams, seeps, or surface runoff upon which the species depends.

- **Stochastic events** may eliminate the low number of extant populations of the taxon. There are only five known extant populations in New England, leaving the taxon vulnerable to extirpation. For example, the Vermont population is in the floodplain of a major river and could be impacted by flooding. In Massachusetts, one population is below a dam and is subject to riparian disturbances; another occurs on and at the base of a steep outcrop susceptible to sloughing.

- **Low genetic diversity** is indicated by the results of Beckmann's (1979) chemotaxonomic study. Although three populations are of a reasonable size, many of the stems observed may be the result of vegetative propagation creating genetically homogeneous populations. Consequences of low genetic diversity can include inbreeding depression and reduced ability to respond to environmental changes in evolutionary time. If *H. canadense* primarily reproduces vegetatively, then reduced evolutionary potential will be a greater concern than inbreeding depression.

- **Development** that results in deforestation or adverse hydrological changes in the taxon's habitat would negatively affect the species. There are no specific development threats known, but three of the sites are privately owned, and there are no specific conservation measures in place at any of the sites.

DISTRIBUTION AND STATUS

General Status

Hydrophyllum canadense occurs in 20 states, the District of Columbia, and Quebec and Ontario, Canada. The species occurs in southern Vermont and western Massachusetts in New England, New Jersey, the District of Columbia, south to Georgia, and west to Illinois. *Hydrophyllum canadense* is considered an S1 species in four states and in Quebec and an S2 species in the District of Columbia. *Hydrophyllum canadense* has been reported, but not verified (SR) in Alabama. Constance (1942) cited three herbarium records for the taxon in Alabama prior to 1942. In New England, *H. canadense* is an S1 species in Vermont (T) and in Massachusetts (E), and it is listed as a Division 2 species in New England (Brumback and Mehrhoff et al.1996). There are no reported states in which *H. canadense* has been extirpated. See Table 1 for details of ranks and status of *H. canadense* in the United States and Canada. Information in the table represents the best available information from a variety of sources (Fernald 1950, Gleason and Cronquist 1991, Association for Biodiversity Information 2000, Association for Biodiversity Information 2001, and personal communications with Natural Heritage Program botanists and data managers).

Table 1. Occurrence and status of *Hydrophyllum canadense* 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)
District of Columbia (S2?)	Arkansas (S?)	Alabama (SR)	Not applicable.
Massachusetts (S1; E)	Georgia (S3)		
New Jersey (S1; E)	Illinois (S?)		
Quebec, Canada (S1)	Indiana (S?)		
South Carolina (S1; SC)	Kentucky (S?)		
Vermont (S1; E)	Maryland (S?)		
	Michigan (S?)		
	Missouri (S?)		
	New York (S4)		
	North Carolina (S4)		
	Ohio (S?)		
	Ontario, Canada (S4)		
	Pennsylvania (S4)		
	Tennessee (S?)		
	Virginia (S4)		
	West Virginia (S?)		
	Wisconsin (S?)		

Figure 1. Occurrences of *Hydrophyllum canadense* in North America. States and provinces shaded in gray have confirmed, extant occurrences of the taxon. The state with stippling, Alabama, is ranked "SR," with reported but unverified occurrences (see Appendix for explanation of ranks).

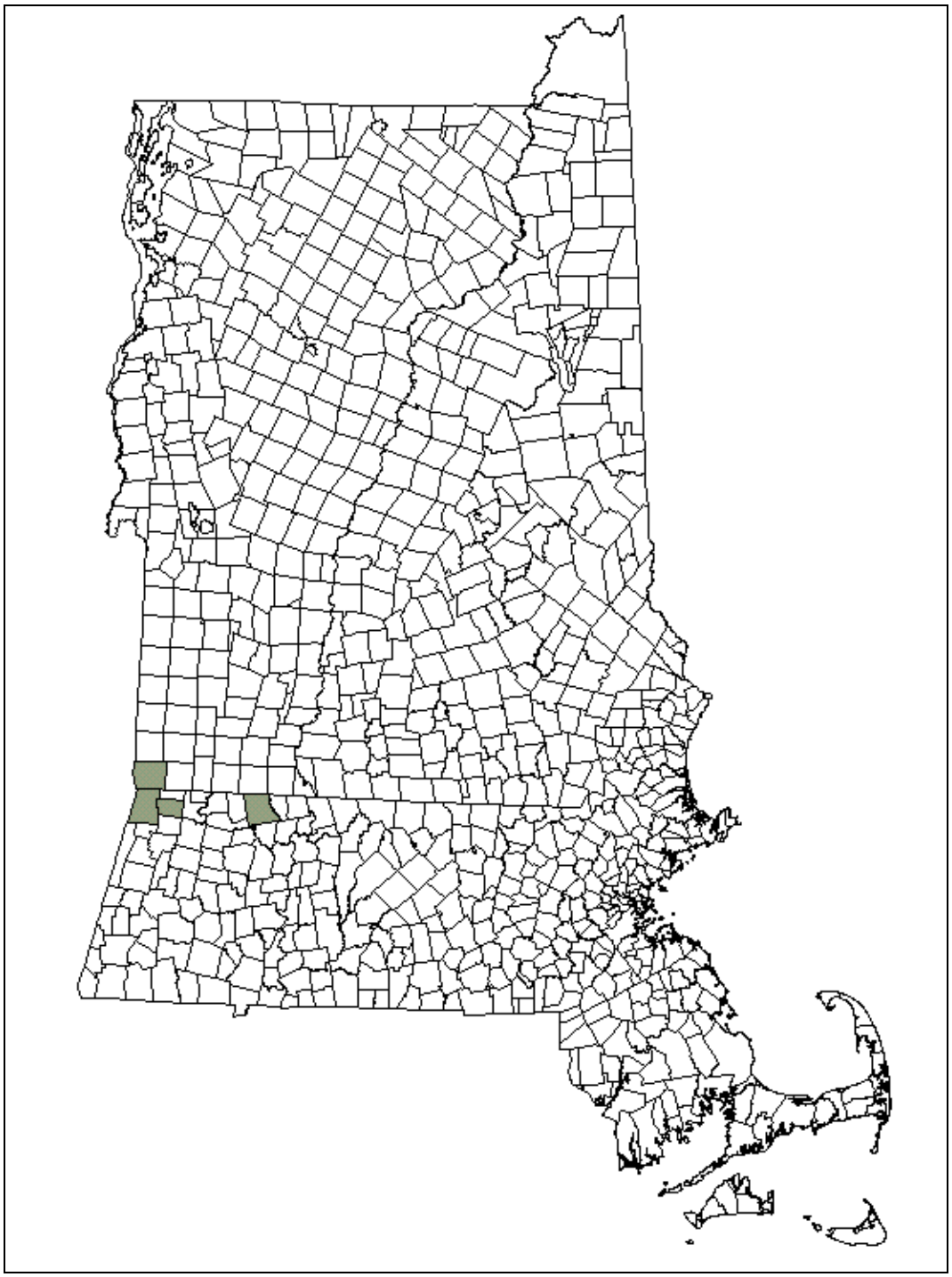

Figure 2. Current occurrences of *Hydrophyllum canadense* in New England. Town boundaries for Vermont, New Hampshire, and Massachusetts are shown. Towns with shading have 1-5 current occurrences.

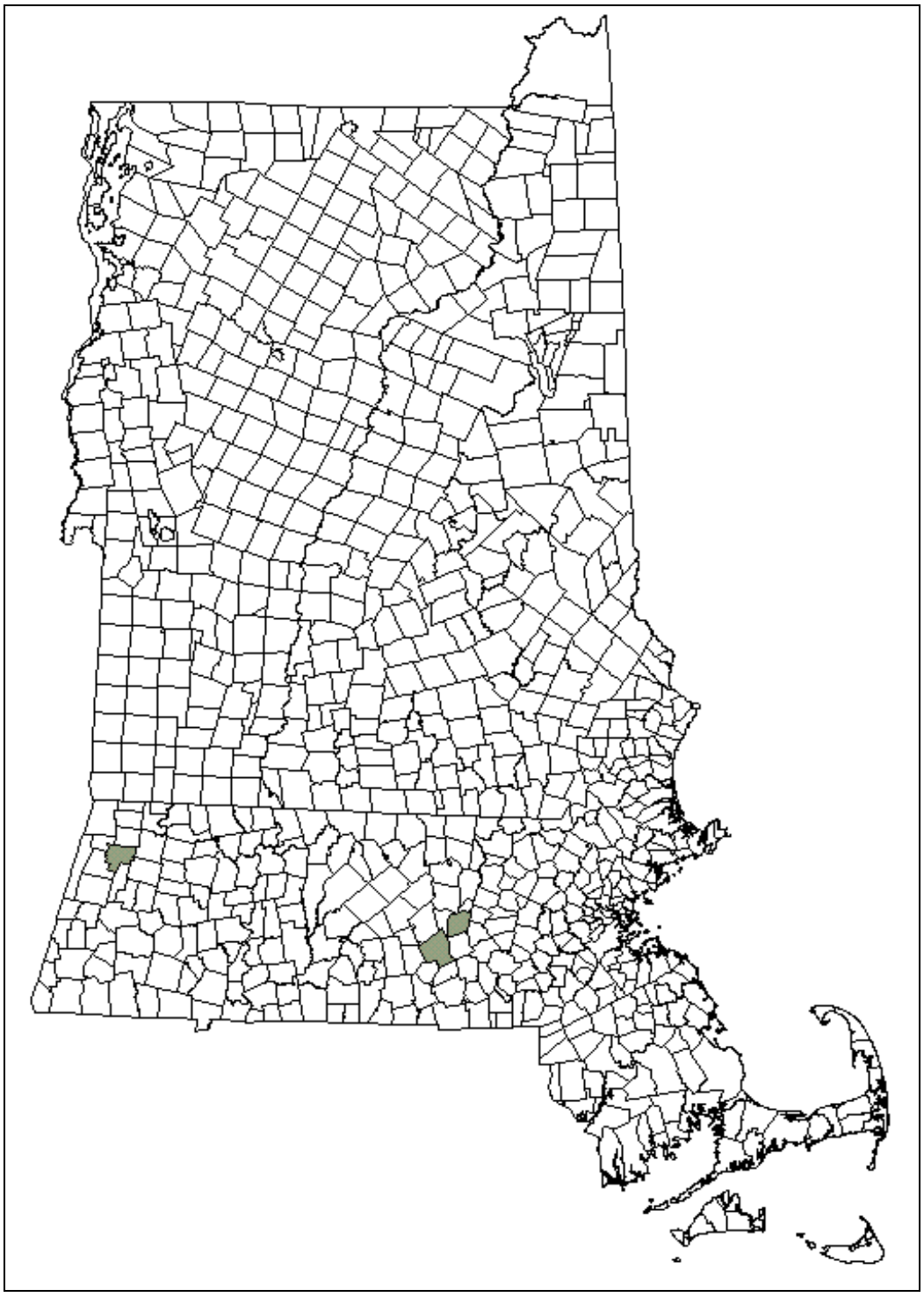

Figure 3. Historic occurrences of *Hydrophyllum canadense* in New England. Town boundaries for Vermont, New Hampshire, and Massachusetts are shown. Towns with shading have 1-5 historic records of the taxon.

Table 2. New England Occurrence Records for *Hydrophyllum canadense*. Shaded occurrences are considered extant.

State	EO #	County	Town
VT	**.001**	**Bennington**	**Pownal**
MA	**.001**	**Berkshire**	**North Adams**
MA	.002	Berkshire	Cheshire
MA	.003	Worcester	Boylston
MA	.004	Worcester	Worcester
MA	**.005**	**Berkshire**	**Williamstown**
MA	**.006**	**Franklin**	**Colrain**
MA	**.007**	**Franklin**	**Colrain**

Status of All New England Occurrences--Current and Historic

There are five known extant occurrences of *Hydrophyllum canadense* in New England (Table 2). One of these populations occurs in southwestern Vermont and four occur in northwestern Massachusetts. There are no known historic occurrences in Vermont and three in Massachusetts. The extant Vermont occurrence consists of approximately 1000 stems in a 1/4-1/3 acre area (1012-1349 m^2); the population is likely stable. One of the extant Massachusetts occurrences consists of 1000-2000 clumps in a 1-2 acre area (0.4-0.8 ha), and another consists of 50-100 clumps in less than 1/4 acre (0.1 ha); the two populations appear to be stable. Two additional Massachusetts populations were discovered in 2000 by Jesse Bellemare and Glenn Motzkin. One consists of approximately 65 mature plants in a 25 m^2 area and the other contains 1000-2500 mature plants concentrated in three small patches (each 25 m^2 or less).

The Vermont occurrence is in a second-growth floodplain forest dominated by *Populus deltoides* and *Acer saccharum* with *Matteuccia struthiopteris* and high densities of invasive exotics at the base of a steep slope and on either side of an intermittent stream. The Massachusetts occurrences are in hardwood forests dominated by sugar maple. Light is filtered and conditions are mesic. Elevation is 540 feet (165 m) at the Vermont occurrence, and from 700 feet (213 m) to 1490 feet (454 m) in Massachusetts. Soils are calcareous. Potential threats include invasive exotics, proximity to woods roads, canopy closure, natural soil erosion and sloughing, maintenance activities, development, and timber harvest.

CURRENT CONSERVATION MEASURES IN NEW ENGLAND

Current conservation measures that potentially protect *Hydrophyllum canadense* in New England include protection under state endangered species and wetland protection legislation, site ownership by entities that may protect or manage the species, seed collection and seed germination studies by the New England Wild Flower Society (NEWFS), and monitoring.

State Endangered Species Legislation and Other Regulations

In Vermont, *Hydrophyllum canadense* is listed as a Threatened species and is protected under the 1981 Vermont Endangered Species Law 10 V.S.A. Chapter 123. This law prohibits the taking of plants without a permit from the Vermont Agency of Natural Resources, but does allow for exclusions for agricultural and silvicultural activities. In Massachusetts, *H. canadense* is listed as an Endangered species and is protected under the 1992 Massachusetts Endangered Species Act, MGL c.131A and its regulations, 321 CMR 10.00. Additionally, *H. canadense* would receive protection under the Wetlands Protection Act at the MA .001 (North Adams) site where plants are within 200 feet of a perennial stream. Also, the taxon could receive some protection in Massachusetts if a proposed project requires Natural Heritage Review (for example, a timber plan review).

While *Hydrophyllum canadense* receives legal protection in both Vermont and Massachusetts, the scope of protection provided by these endangered species acts and other legislation is limited. For example, in Vermont, the legislation does not address threats such as land use considered incompatible with the well being of the species unless the plant itself is taken. Habitat, therefore, remains unprotected in Vermont. Also, a permitting process exists in both states that can allow for the taking of individuals of any listed taxon under certain conditions.

Site Ownership

Conservation of *Hydrophyllum canadense* occurrences may result from site ownership by private or public entities that act to protect the plant. Two extant Massachusetts occurrences are owned publicly. MA .001 (North Adams) is owned jointly by the Department of Environmental Management and a municipal water company. The town water company is aware of the plant and requests that any new findings be submitted to it. MA .005 (Williamstown) is owned by the Division of Fisheries and Wildlife and was purchased specifically to protect the plant. Although no management plans are currently in place for either site, ownership by these entities should enhance conservation possibilities for *H. canadense* in Massachusetts. MA .006 (Colrain) and MA .007 (Colrain) are owned privately; development of a conservation strategy is currently underway at MA .007. The sole Vermont occurrence, VT .001 (Pownal), is owned privately, and no known conservation measures are in place for the taxon.

Seed Collection and Seed Germination Studies

The New England Wild Flower Society collected seeds from the Vermont population in 1998 and has been storing seeds and conducting germination trials since that time. 689 seeds were collected from 55 individuals (all of the fruiting plants that could be found). 489 seeds were placed in the seed bank. 100 seeds were sown fresh and another 100 were placed in a drier. Of the 100 dried seeds, half were sown without further treatment and half were sown cold in refrigerated conditions for three months and then placed in a greenhouse. Three seedlings emerged from the dried and untreated seeds, one seedling emerged from the fresh and untreated seeds, and nine seedlings emerged from the fresh, cold-treated seeds. Seedling establishment is prolific in a cultivated garden setting (Chris Mattrick, New England Wild Flower Society, personal communication).

Monitoring

Although monitoring of populations is not a conservation measure in itself, it is an essential prerequisite for any management activities that may be carried out. Regular and consistent monitoring to establish the current status of populations and to assess population trends is necessary prior to and during completion of any conservation measures. Monitoring reported to state Natural Heritage Programs has taken place at irregular intervals for the taxon to this point. Also, a consistent sampling method has not been used; population counts have been based on stems, clumps, and plants.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR TAXON IN NEW ENGLAND

Three conservation objectives are proposed for *Hydrophyllum canadense* to ensure its persistence in New England during the next 20 years. The first objective is to maintain, at a minimum, the five existing occurrences at their current population levels: VT .001 (Pownal): about 1000 stems; MA .001 (North Adams): 1000-2000 clumps; MA .005 (Williamstown): 50-100 clumps; MA .006 (Colrain): 1000-2500 plants; MA .007 (Colrain): 65 plants. This will require protecting critical habitat for the taxon, as well as protecting the plants themselves. The second objective is to search for and protect previously unknown occurrences. The third objective is to explore the desirability and feasibility of reintroduction of the taxon. Reintroduction could include augmentation of some populations, expanding the number of occurrences by restoring the species to a portion of its historic range, and possible introduction into suitable, previously unoccupied habitat. Augmentation should be the initial focus of such efforts if they were to occur. Specifically, the result of achieving the above objectives would be the presence of a minimum of five protected occurrences, with at least three consisting of 1000s of clumps (plants), and the protection of at least one additional occurrence.

The rationale for developing the three conservation objectives stated above are as follows. First, *Hydrophyllum canadense* has only five known occurrences in New England, and protection of these apparently healthy existing populations is vital to the conservation of the species in New England. Currently, there are no occurrences that are both owned by conservation-oriented entities and have management plans in place. It is also important to protect habitat affecting the plants (e.g., upstream portions of the stream at MA .001 that may impact plants and downstream portions that may serve as areas for seed dispersal and seedling establishment). Second, to increase the likelihood that the taxon will persist in New England, the number of known occurrences should be increased and newly-found populations should be protected. From a biological viewpoint, discovering previously unknown populations and protecting them is likely to be the most successful strategy for increasing the number of known populations in New England. The discovery of two previously unknown populations in Massachusetts in 2000 points to the potential for this strategy. Third, because there are only five currently known occurrences, it is prudent to conduct preliminary a investigation of reintroduction of the species in New England. At some point in the next 20 years it may become necessary to augment populations, to reintroduce the species at or near historic locations, or to introduce the species to suitable, but previously unoccupied habitat. Reintroduction would only become a viable conservation objective once a number of ethical and biological issues are resolved; specific reintroduction issues are outlined in the General Conservation Actions section.

If the goal of the existence and protection of a minimum of six occurrences of *Hydrophyllum canadense* is achieved, this would return the number of known extant sites to the total number of current and historic occurrences originally reported from New England. The goal of six protected occurrences should initially be met by securing protection for all five currently known populations and locating and protecting one additional population. If it becomes necessary and if it is determined that reintroduction is desirable and feasible, then reintroduction may also become a conservation objective. Although a goal of a higher number of protected occurrences would be desirable to ensure the conservation of *H. canadense*, it is likely that the taxon has always been rare in New England. The species is at the edge of its range and is represented by few populations in New England (Constance 1942). Although two new populations were discovered in 2000, the taxon is a unique and conspicuous member of the flora that grows in relatively well-botanized habitat; it is unlikely that botanists have overlooked numerous additional populations.

III. LITERATURE CITED

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Appendix 1. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information

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 **C** that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnational jurisdiction **C** 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 **C** 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 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.