New England Plant Conservation Program

Conservation and Research Plan

Rotala ramosior (L.) Koehne
Toothcup

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United States Fish and Wildlife Service
Silvio O. Conte National Fish and Wildlife Refuge

Approved, Regional Advisory Council, May 2001

SUMMARY

Rotala ramosior (L.) Koehne, or Toothcup is a small, often inconspicuous annual amphibious or terrestrial herb in the Lythraceae family. *Rotala* is represented in North America by three species, two natives and one introduced. *Rotala indica* is an adventive species thought to have been brought into North America through the rice trade. The two native species are *Rotala mexicana* and the focus species, *Rotala ramosior*. The taxon is secure globally and nationally in the United States, having ranks of G5 (globally secure) and N5 (nationally secure) respectively. It is considered imperiled in Canada with a Canadian National Rank of N1 or critically imperiled. In each of the New England States where it occurs, it is listed as S1 or critically imperiled (The Nature Conservancy 1999).

Little is known about the life history or species biology of *R. ramosior*. Typical of an annual species, it appears to undergo wide fluctuations in population numbers from year to year. In this case, fluctuations appear to be dependent on the timing and amount of seasonal rainfall and the water levels at population sites. The flowering period is described variously as June or July through September or October. All New England occurrences, both current and historic, occur on pond, lake, and reservoir shores. When observed, the species always occurs on the newly exposed shores following a natural or unnatural water drawdown.

Historically, *Rotala ramosior* was represented in New England by 25 occurrences ranging throughout the three southern New England states: Massachusetts, Rhode Island, and Connecticut. The species is currently listed as SR (reported but unverified) in New Hampshire. A specimen recently discovered for New Hampshire elevates the total number of occurrences historically known from New England to 26. Currently, only nine extant occurrences are known from the region: two in Massachusetts, two in Rhode Island, and five in Connecticut.

Threats to *R. ramosior* are limited but significant, and include: invasive species and efforts to control them; alterations in hydrological regime; habitat succession; biological controls released for *Lythrum salicaria*, and sedimentation.

The primary conservation objective for the taxon is to maintain all current occurrences at present levels or higher. Other objectives include: increasing the number of total populations in Massachusetts, Rhode Island, and Connecticut to twelve, which would restore the taxon to approximately 50% of its former site distribution in the region; protecting and managing all current and future extant sites in a manner compatible with *R. ramosior* maintenance; and conducting species biology research on the species to determine insect pollinators, seed dispersal mechanisms and success, and seed viability.

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.

This document should be cited as follows:

Mattrick, Christopher. 2001. *Rotala ramosior* (L.) Koehne (Toothcup) Conservation and Research Plan. New England Wild Flower Society, Framingham, Massachusetts, USA.

I. BACKGROUND

INTRODUCTION

Rotala ramosior (L.) Koehne (Lythraceae) is a small inconspicuous, amphibious to terrestrial, annual herb. Although common throughout most of its range, the taxon is considered regionally rare in New England (Brumback and Mehrhoff et al. 1996). In New England, its historic distribution is limited to New Hampshire, Massachusetts, Rhode Island, and Connecticut, with current stations restricted to the latter three. Historically, 26 occurrences have been documented from the New England region, although there is no evidence to suggest that all of these populations existed concurrently. Today, only nine are considered extant, and of these, only five have been observed since 1990. In New England, the taxon is restricted to the exposed gravelly or cobbley shores of ponds, lakes, and reservoirs that experience wide fluctuations in water levels. Occupying this ephemeral zone between the annual high and low water marks, the species is relatively intolerant of competition with other vegetation. Few associated species occur directly with *R. ramosior* in most situations. Maintenance of this type of hydrologic regime is critical to the protection of the taxon in the region.

The taxon occurs at the northern edge of its range in New England, and this is partially responsible for its rarity in the region. Other reasons for rarity and threats to the taxon include: invasive species, sedimentation, and habitat succession.

The intent of the conservation plan is to summarize existing information on the habitat and biology of the species, assess threats to the taxon and to each occurrence, evaluate current conservation measures, and set forth actions designed to protect and maintain the taxon in New England.

DESCRIPTION

The following description is based on information from the following sources Jepson 1925, Merriman 1930, Fernald 1950, Kearney 1951, Gleason 1952, Peck 1961, Eisendrath 1978, Gleason and Cronquist 1991, Magee and Ahles 1999. *Rotala ramosior* (L.) Koehne, or Toothcup is a small, often inconspicuous annual amphibious or terrestrial herb in the Lythraceae family. Its stems, often much branched, but sometimes simple, can reach two to four dm in height. Plants are glabrous or nearly so, with stems prostrate or erect, and sometimes four-angled. The opposite, lance-shaped leaves taper gradually to the base, sometimes resulting in short petiole, but most often appear sessile. The leaves are one-nerved, somewhat rigid, and blunt-tipped, ranging from 15 to 30 mm in length. The leaves are uniform in size, not reduced upward along the stem.

The flowers are sessile, inconspicuous, four- (six) merous, and very small, four to 1.5 mm in length; appearing singly, rarely to three, in the axils of most leaves. Each flower is subtended by a pair of subulate bracts, less than half the length of the floral tube. The petals are obovate, translucent, ranging from white to pink to purple; each petal is four-lobed at the summit. The petals surpass the four slightly shorter stamens, but are quickly deciduous. The tips of the anthers are barely exserted. The stigma is sub-sessile. The style is short. The calyx is conspicuous, shallowly 4-lobed and cup-shaped, giving the inflorescence a greenish appearance, aging to red. In flower, the calyx is 1-3 mm long, but may reach up to 4 mm when in fruit. The four sepals alternate with four triangular-shaped appendages, each opposite a flower petal. The ovary is sub-globose to globose, and four-loculed. The capsule is sub-globose to globose, and approximately 3 mm wide and may appear one-loculed at maturity. The capsule wall is thin, typically yellow in color with many minute transverse striations on the surface. The fruit capsule is dry, three- to four- valved and septicidally dehiscent. At maturity, the calyx tube encloses the capsule. Each capsule produces many tiny (0.3 x 0.3 mm) red-brown, ovoid, plano-convex seeds

For most of the season, the plant is inconspicuous, but can easily be recognized later in the season by the bright red coloration of its stems, leaves, and fruit (Torrey 1843, Cook 1979, Mattrick personal observation).

TAXONOMIC RELATIONSHIPS, HISTORY AND SYNONOMY

Rotala is a member of the Lythraceae Family, a group of approximately 600 species placed in 31 genera worldwide, most commonly found in the tropics (Shirley Graham, Kent State University, personal communication). *Rotala* is a cosmopolitan genus with anywhere from 44 to 50 species accepted worldwide (Correll and Correll 1972, Cook 1979). Most of these species are located in tropical or sub-tropical regions (Correll and Correll 1972). Cook (1979) identifies Africa as the center of *Rotala* species diversity, but it appears that Asia is the origin of the genus. Linneaus described the type specimen for this genus, *Rotala verticillaris*, in 1771.

Rotala is represented in North America by three species, two native and one introduced. *Rotala indica* is an adventive species thought to have been brought into North America through the rice trade. The two native species are *Rotala mexicana*, which occurs in Mexico and sporadically around the world, and the focus species, *Rotala ramosior*. The distribution of *R. ramosior* is given below. What is now accepted as *Rotala ramosior* was first described by Linneaus in 1753 in his *Species Plantarum* 1: 120 under the synonym *Ammannia ramosior* (Missouri Botanic Garden 2001). There have been numerous taxonomic changes to this species and the genus *Rotala* since its original description. A partial list of synonyms include *Ammannia humulis* Michx (1803)., *A. catholica* Cham. & Schtdl, *A. dentifera* A Gray, *A. occidentalis* DC. Prodr., *A. ramosa* Hill., and *A. monoflora* Blanco, Spreng.

In 1877, Koehne in the Flora Brasiliensis 13(2), annotated what was at that time known as *Ammannia ramosior* (L.) to *Rotala ramosior* (L.) Koehne (Missouri Botanic Garden 2000). This taxonomy was widely accepted until 1935, when M. L. Fernald and Ludlow Griscom split *Rotala ramosior* into two varieties, *interior* and *typica*. This split was based on differences in fruits and bracts. One variety, var. *typica*, with small fruits and small subulate bractlets was found chiefly on the sandy soils of the eastern coastal plain, shores of Great Lakes, and on the pacific slope. A second, more robust variety was found in rich bottomland soils from the Hudson Valley to Iowa and south. This variety, var. *interior*, was noted to have conspicuously larger fruits with linear-lanceolate, elongate bracts. The type specimen for variety *interior* was collected by Albert Ruth in 1890 (no. 224) from low wet ground in Knox County, Tennessee. This specimen resides in the Gray Herbarium at Harvard University. The variety *typica*, is based on the Clayton (Gronovius) specimen collected in Virginia, specimen (no.774), on which Linneaus first based *Ammannia ramosior*. Under this variety were the synonyms *Ammannia ramosior* L, *A. humulis* Michx, and *Rotala ramosior* (L.) Koehne. Clayton collected the type specimen for this species under the synonym *Ammannia ramosior* in Virginia in 1753 (Fernald and Griscom 1935).

The usage of the two varieties appears to have been controversial since they were first described by Fernald in 1935. Several floras indicate a hesitancy or refusal to use the varietal status. Smith (1978) in *An Atlas and Annotated List of the Vascular Plants of Arkansas* states that "the variety *interior* is weak, being based on the more robust inland plants that differ only slightly from the 'typical' material". Cooperrider (1995) in *The Dicotyledoneae of Ohio* notes that Fernald (1950) and Gleason (1952) both assign Ohio plants to the var. *interior*, but states he follows Blackwell (1970) in recognizing no varieties. Further, Graham (1975) does not recognize either variety. Finally, Cook (1979) annotated all previous incarnations of *Rotala ramosior* into a single species. He considers *Rotala ramosior* as endemic to the Western Hemisphere.

The epitaph *rota* means 'little wheel' in Latin, in reference to the whorled leaves found in some species. The species epitaph *ramosior* means 'very branching'. The common name, Toothcup, is most likely a reference to the shape of the calyx (Gleason 1952, Eisendrath 1978).

Confusion with other taxa is uncommon, but several species are cited in the literature as potential look-a-like species. *Rotala ramosior* can be confused with some species of *Ammannia*, but with a hand lens they can be easily separated. Seed capsules in *R. ramosior* are covered with many transverse striations, whereas the capsules of *Ammannia* are smooth. *Ludwigia palustris* can also cause confusion in some locations; longer calyx lobes lacking interlobular appendages separate *Rotala ramosior* from this species (Voss 1985).

SPECIES BIOLOGY

Little is known about the life history or species biology of *R. ramosior*. Typical of an annual species, it appears to undergo wide fluctuations in population numbers from year to year. In the case of *R. ramosior*, fluctuations appear to be dependent on the timing and amount of seasonal rainfall and water levels at population sites. The flowering period is described variously as June or July through September or October (Fernald 1950, Radford et al. 1968, Cook 1979). Stone (1973) noted flowering from early July to September, and fruiting from late July through autumn in southern New Jersey. In New England, fruiting typically occurs from mid-August (18) to mid-September (20) (Seymour 1969). Flowering has been observed at one site in New England at the end of July (Mattrick, personal observation). In lower latitudes, plants probably flower nearly year-round (Cook 1979, Graham personal communication).

As with most species in the Lythraceae, the flowers are entomophilous or insect-pollinated. No published studies indicating the specific insect pollinators of *R. ramosior* or any member of the genus exists. However, other members of the Lythraceae family including *Lythrum salicaria* and *Cuphea* sp., are known to be bee-pollinated (Parker and Tepedino 1990). Shirley Graham at Kent State University notes that although the species is insect-pollinated, it is primarily self-pollinated. This self-compatibility eliminates threats due to loss of pollinators to other more showy species such as *Lythrum salicaria*, and ensures an adequate supply of seed from year to year regardless of insect pollinator activity. The plants are monoecious and hermaphroditic, containing both male and female flowers on the same plant. The flowers are also homostylous (Shirley Graham, Kent State University, personal communication).

A large number of seeds are produced from a single plant (Cook 1979). The small size and weight of the seeds makes them easily dispersed by wind, gravity, and water. The exact dispersal mechanisms utilized are unknown, but the species demonstrates an ability to regularly colonize new, sometimes distant locations. The seeds of this species have inverted epidermal hairs that may allow them to attach to the feet of waterfowl (Graham, personal communication). Similarly, seeds may be transported from site to site in mud stuck to the feet of waterfowl (Carol Baskin, University of Kentucky, personal communication, Margaret Ardwin, consulting botanist, personal communication). Shirley Graham feels that the primary dispersal mechanism is wind. The tiny, virtually weightless seeds could be easily caught by the wind and transported to a new location (Graham, personal communication).

Attempts to germinate the seeds at the New England Wild Flower Society (NEWFS) have been unsuccessful. However, Carol Baskin at the University of Kentucky has succeeded in establishing a germination protocol for the species. Seeds require light and high temperatures to germinate. Darkness appears to be a limiting factor in the germination of this species. Those sown at a depth of greater than 1 mm rarely germinate. Higher daytime and evening temperatures seem to increase germination. Under controlled conditions in the lab, daytime temperatures of 15ºC combined with nighttime temperatures of 6ºC produced no germination.

Daytime temperatures of 25ºC combined with nighttime temperatures of 15ºC resulted in a germination percentage of 32%. The best germination percentage, 99%, resulted from daytime temperatures of 35ºC and nighttime temperatures of 20ºC (Baskin, personal communication). This apparent affinity for high temperatures may explain the rarity of this species in New England, where daytime temperatures reach 35ºC only a few weeks each year.

A recent germination study conducted by graduate students at the Brown University on seeds of *R. ramosior* found that although all treatments (fertilization, gibberellic acid, inundation, control, and stratification) resulted in some germination, cold, moist stratification for 21 days followed by long warm day length yielded the highest germination percentages. All other treatments, when combined with stratification showed an increase in the germination percentages (Fite-Wassilak et al. 2001).

As with many tiny seeds, particularly those of the Lythraceae family, *Rotala ramosior* seeds are long-lived in the soil seed bank. In tests conducted over 10 years in Kentucky, soil sods removed from *Rotala ramosior* locations and placed in flats contained plants each year (Baskin, personal communication). Although some seeds may survive for extended periods of time in the soil seedbank, Graham (personal communication) indicates that seeds of *R. ramosior* quickly lose viability with perhaps as much as 50% of the seed produced becoming non-viable in a single year. This low survivorship in the soil seed bank may have implications for restoration activities at recently historic (within 15 years) sites in New England.

There has been little genetic work on the genus. It is known that the base chromosome number in *R. ramosior* is n=8. *Rotala ramosior* is endemic to, and exists as two races in the Western Hemisphere. A diploid race ranging from Mexico and sporadically southward through Central and South America, has a chromosome count of n=16. The plants of this species found in the United States and Canada are a tetraploid race with a chromosome count of n=32. (Cook 1979; Graham, personal communication). Further research on the chromosome numbers of *R. ramosior* throughout its western hemispheric range is needed. Tetraploid individuals have been identified from Texas and North Carolina. Diploids are found solely from Mexico southward, indicating that the species originated in a more southerly area and is expanding northward.

No symbiotic or parasitic relationships are known.

HABITAT AND ECOLOGY

Throughout its North American range, *R. ramosior* is described as occurring in a wide variety of habitats. The common thread among them all is an association with moisture. The taxon is considered an obligate wetland species in eight of thirteen national USDA defined regions. It does not occur in three regions (Alaska, Hawaii, and Intermountain – NV and UT). In two other regions (north plains and central plains), it is considered NI, indicating that insufficient information was available to determine an indicator status (USDA 2001). Habitats for the species are variously described as wet areas; wet soil around ponds and lakes; low woods; ditches; fallow fields; irrigated fields; along streams; mucky or sandy shores; wet depressions (Merriman 1930, Correll and Correll 1972, Beal 1977, Eisendrath 1978). In Pennsylvania, a small colony of plants was observed at the edge of a cultivated field near a tributary to the Susquehanna River (Don Cameron, Maine Natural Areas Program, personal communication). The lower Susquehanna River in Pennsylvania contains a number of populations of this taxon, but it is not as common as the amount of seemingly suitable habitat would lead one to believe. The populations along the Susquehanna are inundated part of the year, occurring in ephemeral sites just below the permanent vegetation line, often mixed *with Eragrostis hypnoides* and *Cyperus* species (Cameron, personal communication). In Ontario, at the northern edge of its range, the taxon is a component of the tall grass prairie community (Tallgrass Ontario 2001). In California, the taxon is considered by the California Vernal Pool Assessment to be a vernal pool associate in some regions of the state (Keeler-Wolf et al. 1998).

The habitat types occupied by *Rotala ramosior* in New England are greatly limited in comparison to those throughout most of its range. All sites with occurrences throughout the North American range of this species do share a common feature – fluctuating water levels and seasonal inundation (Voss 1985, Keeler-Wolf et al. 1998). All New England occurrences, both current and historic, occur on pond, lake, and reservoir shores. There are no references to populations on river or stream shores, ditches, irrigated fields, etc. in New England. The species always occurs on the newly exposed shores following a natural or unnatural water drawdown. These observations, combined with the species' apparent absence from these same sites in years of heavy rainfall and high water levels, indicate that *R. ramosior* is adapted to sites that are inundated in the spring and drawn down naturally or artificially over the course of the summer (Mattrick, personal observation; MANHESP, unpublished data; CTNDDB, unpublished data).

Given this habitat preference, it is a mystery why the plant is not found on the margins and shores of the numerous coastal plain pond shores of southeastern New England. This absence may relate to water pH (Beal 1977). A series of habitat studies of marsh and aquatic plants in North Carolina revealed *R. ramosior* to prefer sites with a water pH of 6.3 to 7.6, with a median pH of 6.8. No measurements of soil pH at any sites were made (Beal 1977). This affinity for sites with somewhat circumneutral water pH may in part explain its absence from apparently suitable habitat on coastal plain pond shores in southeastern Massachusetts and Rhode Island. Yet in New York, four of the seven known populations occur on the margins of coastal plain ponds in Suffolk County, New York. Additional occurrences are found in dug sumps in pine barren habitats on Long Island (Steven Young, New York Natural Heritage Program, personal communication). Coastal plain pond shores and pine barren habitats are typically acidic in nature. This information seems to contradict the assumption of *Rotala ramosior*'s preference for circumneutral sites revealed in Beal's (1977) studies in North Carolina.

The dense vegetation that develops along the shores of coastal plain ponds in mid-summer may preclude the colonization of these sites by *R. ramosior* (Juliana Barrett, consulting botanist, personal communication). Another limitation to the dispersal of this species are its tiny seeds, which may not be well adapted to frequent, long distance geographic dispersal, relying on chance dispersal by wind or birds to establish itself at new, distant locations (Leslie Mehrhoff, University of Connecticut, personal communication).

Gleason and Cronquist (1991) list the taxon as occurring near the coast. A reference to the taxon occurring on the coastal plain or near the coast appears in several state and regional floras (Deam 1940, Gleason 1952, Gleason and Cronquist 1991). Although the species does occur -- sometimes abundantly -- in coastal regions, it is inaccurate to describe it as a "coastal plain" species, given its distribution in Arkansas, Missouri and other inland regions.

A study of the tallgrass prairie community in Ontario by Tallgrass Ontario found the species to be fire-tolerant. An indication of fire tolerance also occurs in Kalamazoo County in Michigan, where the preferred habitat is noted as burned or dried marshes (Voss 1985). These are the only two references to fire in the species' ecology, and although *R. ramosior* may be fire-tolerant, there is nothing to suggest it is fire-dependent.

The study by Tallgrass Ontario also reveals that the species most often occurs on sands, loams, silts, and clays. In New England, populations occur on sands, gravels, cobbles, and peats (CT NDDB, unpublished data; MANHESP, unpublished data; RI NHP, unpublished data; Mattrick, personal observation).

Rotala ramosior is listed as a species that requires high light intensity (Tallgrass Ontario 2001). This affinity for full sun situations was also noted in Pennsylvania, where some of the largest populations of the species along the shores of the Susquehanna River are located under high-tension electric line crossings (Cameron, personal communication). Most New England stations occur in full sun, and shading seems to reduce both density and vigor of individuals (Mattrick, personal observation).

Associated species in the immediate vicinity of *R. ramosior* in our region are limited; the plant tends to occupy a sparsely vegetated microhabitat. The species is intolerant of competing vegetation and quickly disappears from sites where water fluctuations or other vegetation limiting factors cease to exist (Mehrhoff, personal communication). However, several species seem to be associated with the taxon at multiple sites, including *Gratiola aurea, Fimbristylis autumnalis, Ludwigia palustris*, and *Lythrum salicaria*. Other associates listed include: *Agalinus tenuifolia, Agrostis hymenalis var. scabra, Alisma subcordatum, Bidens frondosa, Chamaesyce maculata, Cyperus aristatus, Cyperus strigosus, Drosera intermedia, Eleocharis obstusa, E. smallii, Eriophorum virginicum, Hemicarpa micrantha, Hypericum boreale, Juncus pelocarpus, J. acuminatus, Leersia oryzoides,* *Lindernia dubia, Lycopus americanus, Lycopus uniflora, Panicum dichotomiflorum, P. philadelphicum, P. rigidulum,* and *Polygala sanguinea.*

DISTRIBUTION AND STATUS

Rotala ramosior is considered in most floras as widely distributed in the Western Hemisphere. Although *R. ramosior* is endemic to the Western Hemisphere, it is found sporadically in other locations including Italy and the Philippines. Its spread from North and South America to these and other cosmopolitan locations is likely due to accidental introductions via to rice cultivation (Graham, personal communication). The species appears to reach the northern edge of its range in New England and similar latitudes worldwide. It is listed as occurring in North, Central, and South America. In eastern North America, *R. ramosior* ranges from Massachusetts west through Ontario to Minnesota and south to Florida, Arkansas, Texas and Mexico. It is absent from most of the Rocky Mountain region and much of the inter-mountain west, but has a western North American distribution as well, ranging from Washington to northwest Montana south to California through Central to South America. Its full range in Central and South America is largely unknown, although its global distribution as given by the W3-Tropicos database includes Mexico, Belize, El Salvador, Guatemala, Panama, Costa Rica, Venezuela, Peru, Brazil, Bolivia, and Ecuador (Missouri Botanic Garden 2001). Cook (1979) considers *Rotala ramosior* endemic, to the Western Hemisphere, but distinguishes within the species two distinct races based on ploidy levels. The first is a diploid race with two sets of chromosomes, occurring from Mexico southward, and the second is a tetraploid race with four sets of chromosomes in the United States and Canada. The North American distribution of *R. ramosior* is shown in Figure 1.

The taxon is secure globally and nationally in the United States, having ranks of G5 (globally secure) and N5 (nationally secure) respectively. It is considered imperiled in Canada with a Canadian National Rank of N1 (critically imperiled). In each of the New England States where it occurs, it is listed as S1 (critically imperiled) by The Nature Conservancy and ABI (1999).

The species is ranked by Natureserve as SR, or "state reported," in many states throughout its North American range, including New Hampshire. However, a survey of Heritage Program web sites, local and state floras, state checklists, and personal communications with state Natural Heritage programs indicate it is extant, in fact common, in many of those states. The rankings given in Table 1 for each state are based on The Nature Conservancy's element stewardship abstract (TNC/ABI 1999). Following these rankings, a species ranked "SR" would be placed in the 'occurrence unverified' column. If through the research for this document, the taxon was found to be extant, the SR rank is maintained but placed in the 'occurs and not listed column' of Table 1.

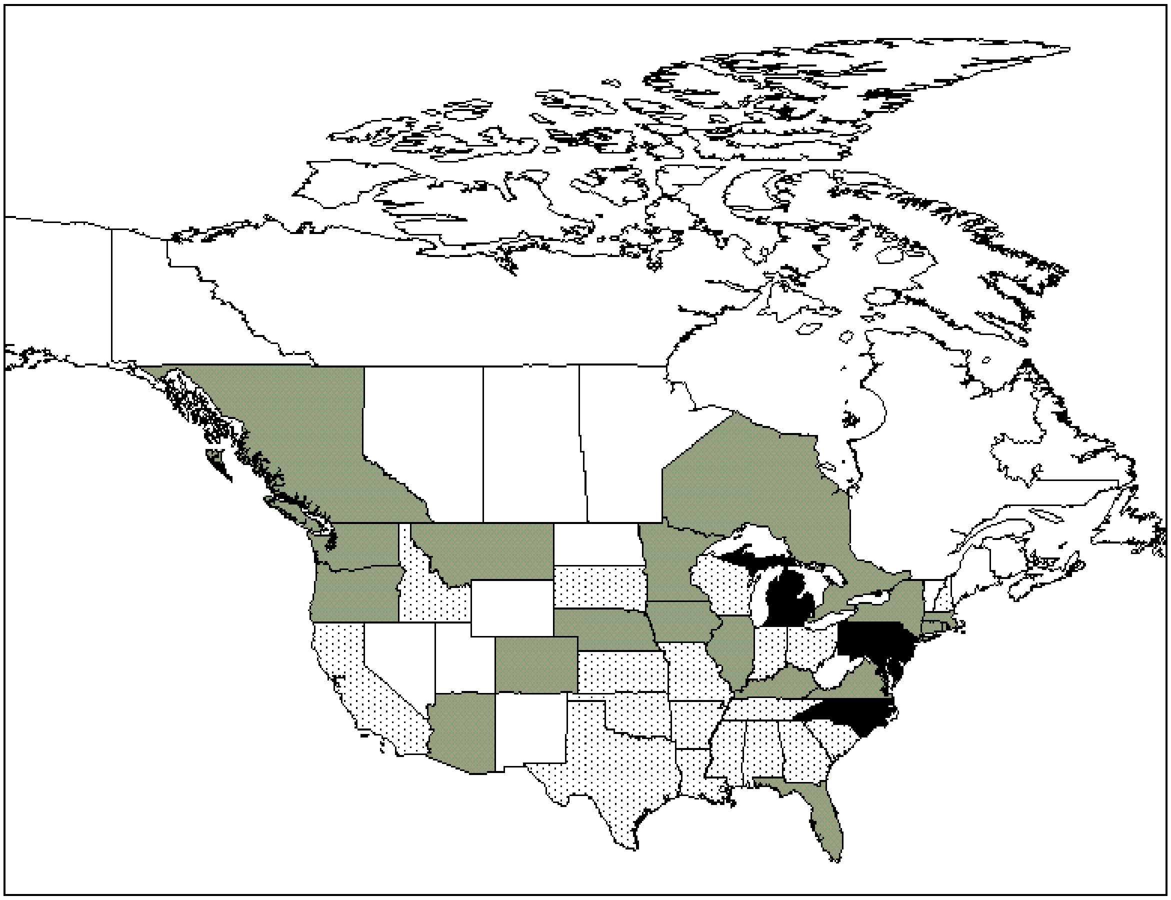

Figure 1. Occurrences of *Rotala ramosior* in North America. States and provinces shaded in gray have one to five (or an unspecified number of) current occurrences. Areas shaded in black have more than five confirmed, extant occurrences of the taxon. Stippling indicates states where the taxon is ranked "SR" (status reported; see Appendix for explanation of Natureserve ranks).

Table 1. Occurrence and status of *Rotala ramosior* 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 UNVERIFIED**	**HISTORIC (LIKELY EXTIRPATED)**
Arizona S1	Arkansas SR	Alabama SR	New Hampshire SR
British Columbia S1	California SR	Georgia SR	
Colorado S1	Delaware S3	Idaho SR	
Connecticut S1	District of Columbia S?	Oklahoma SR	
Massachusetts S1	Florida S?	Wisconsin SR	
Minnesota S2	Illinois S?		
Montana S1	Indiana SR		
Nebraska S2	Iowa S3		
New York S2	Kansas SR		
Ontario S1	Kentucky S?		
Rhode Island S1	Louisiana SR		
West Virginia S2	Maryland S4/S5		
	Michigan S3		
	Mississippi SR		
	Missouri SR		
	New Jersey S3		
	North Carolina S5		
	Ohio SR		
	Oregon S?		
	Pennsylvania S3		
	South Carolina SR		
	South Dakota SR		
	Tennessee SR		
	Virginia SR		
	Texas SR		
	Washington S?		

In each of the New England states where *Rotala ramosior* occurs, its state status is endangered. *Flora Conservanda*: The New England Plant Conservation Program (NEPCoP) list of plants in need of conservation lists the taxon as division 2, or regionally rare (Brumback and Mehrhoff et al. 1996). *Flora Conservanda* only lists seven occurrences of the taxon in

New England: one in Massachusetts, one in Rhode Island, and five in Connecticut. Since the publication of this document in 1996, one new population has been discovered in Massachusetts, and for the purpose of this document, one extant Rhode Island population of questionable origin is considered. Thus there are a total of nine extant occurrences in New England.

Locally outside of New England, *R. ramosior* is tracked by the New York Natural Heritage Program, where it is listed as S2 or state imperiled, and has a state status of threatened. Seven current occurrences are known, most of the populations last observed in the 1980's. Two populations are large consisting of over 100 individuals, the remainder are small containing less than 50 plants each. It is confirmed from two counties (Suffolk and Putnam), and listed as historic in four counties (Queens, Nassau, Ulster, and Richmond), and possible in two others (Kings and Albany) (Young, personal communication).

The taxon is considered S3 or vulnerable in New Jersey, and has a state status of special concern. It is a tracked element but not of high conservation concern, existing in approximately 20 populations on the coastal plain of southern New Jersey. It is commonly found in abandoned sandpits in Cape May county, where several large populations are known (David Snyder, New Jersey Natural Heritage Program, personal communication).

Status of New England Occurrences

Historically, *Rotala ramosior* was represented in New England by 25 occurrences ranging throughout the three southern New England states: Massachusetts, Rhode Island, and Connecticut. A specimen recently discovered for New Hampshire elevates the total number of occurrences historically known from New England to 26 (see Figure 2). Currently, only nine extant occurrences are known from the region: two in Massachusetts, two in Rhode Island, and five in Connecticut. Additionally, all but two of these (CT .001, RI .002) have been discovered since 1983. It is unclear whether any of these sites was extant for long prior to their discovery. However, it is known that at least two sites, MA .012 and the East Greenwich, Rhode Island location, were not suitable habitat as recently as twenty years ago. Also, several of the extant sites are significant natural areas and have been heavily botanized for many years without noting the presence of *R. ramosior*. The recent discovery of so many occurrences may reveal a tendency of populations to be short-lived. In New England, the loss of occurrences may be equally tied to site alterations and other ecological changes. This may also indicate ability for the species to migrate from site to site over long periods of time. Graham (personal communication) believes the species may not be long-lived at a single site. The long-term survival of this species may depend on its ability to colonize suitable habitat at new locations.

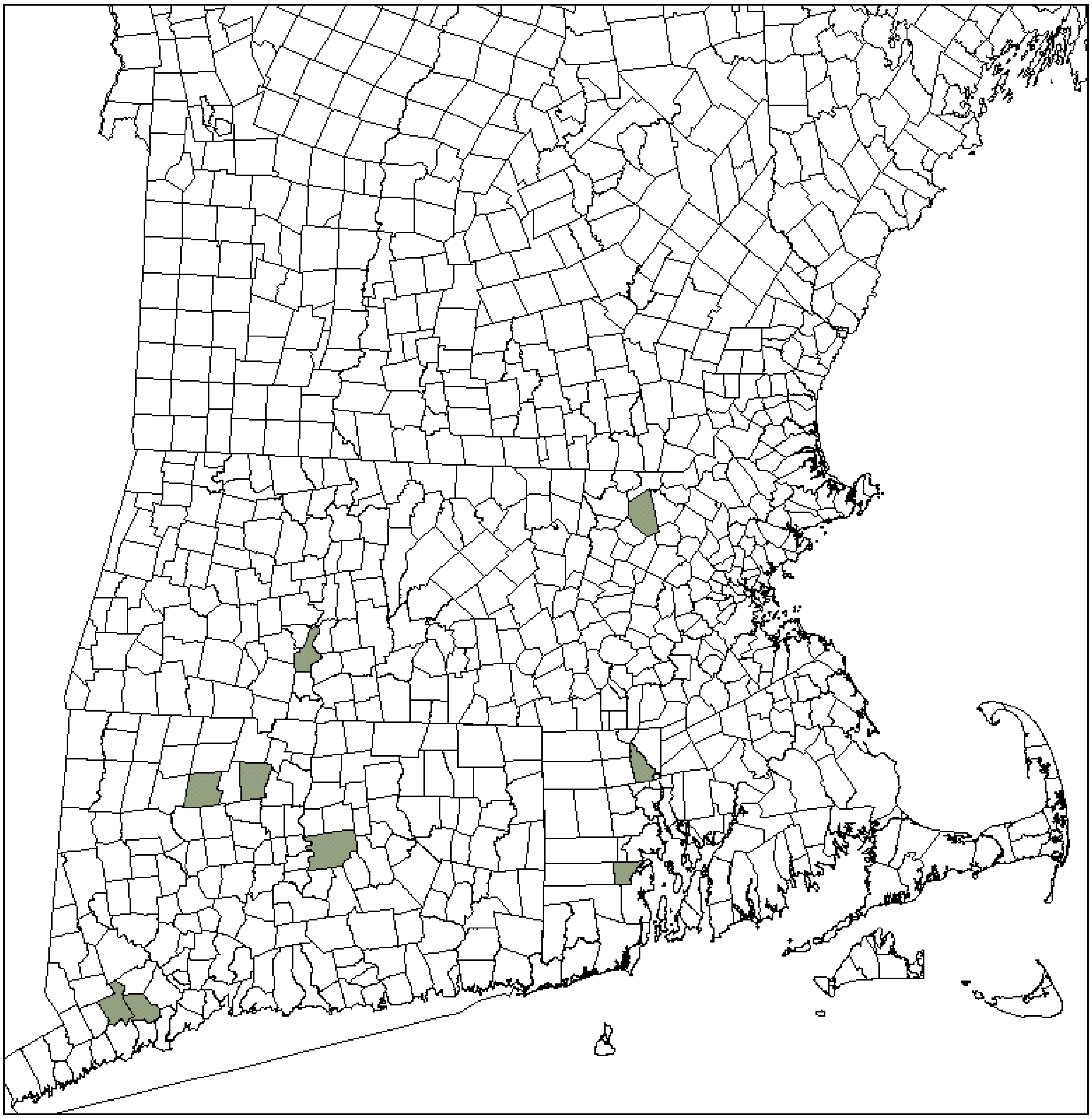

Figure 2. Extant occurrences of *Rotala ramosior* in New England. Town boundaries for southern New England states are shown. Towns shaded in gray have one to five confirmed, current occurrences of the taxon.

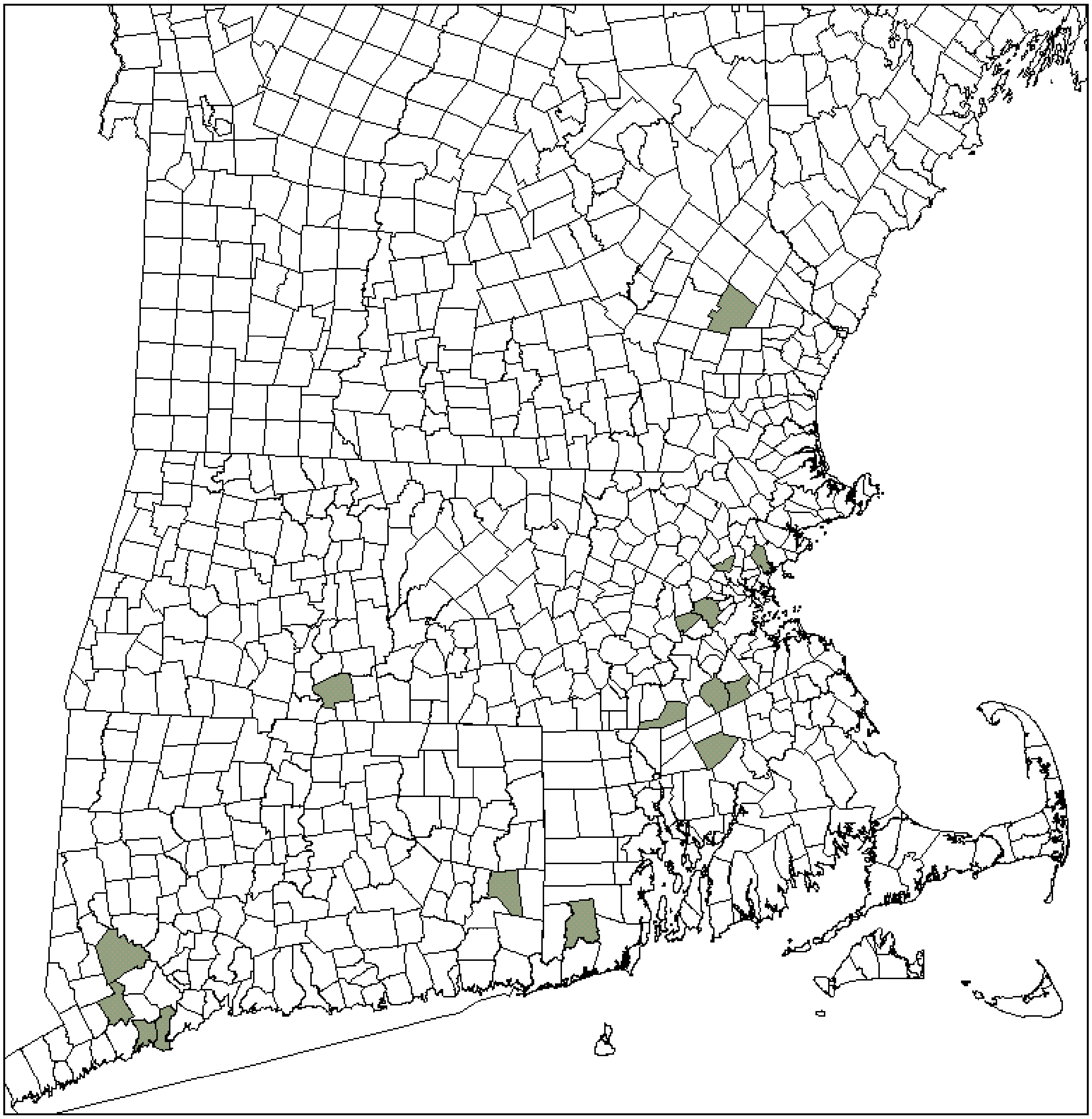

Figure 3. Historic occurrences of *Rotala ramosior* in New England. Towns shaded in gray have one to five historic records of the taxon.

Table 2. New England Occurrence Records for *Rotala ramosior*. Shaded occurrences are considered extant.

State	EO #	County	Town
NH	None	Rockingham	Nottingham
MA	.001	Essex	Saugus
MA	.002	Middlesex	Winchester
MA	.003	Norfolk	Sharon
MA	.004	Bristol	Norton
MA	.005	Hampden	Springfield
MA	.006	Middlesex	Newton
MA	.007	Norfolk	Wellesley
MA	.008	Hampden	Springfield
MA	.009	Norfolk	Stoughton
MA	.010	Norfolk	Wrentham
MA	**.011**	**Hampden**	**Holyoke**
MA	**.012**	**Middlesex**	**Westford**
RI	.001	Washington	Richmond
RI	**.002**	**Providence**	**Lincoln**
RI	**No EO #**	**Kent**	**East Greenwich**
CT	**.001**	**Hartford**	**Simsbury**
CT	.002	Fairfield	Newtown
CT	.003	Fairfield	Easton
CT	.004	Fairfield	Bridgeport
CT	**.005**	**Fairfield**	**Trumbull**
CT	.006	New London	Griswold
CT	**.007**	**Hartford**	**Glastonbury**
CT	**.008**	**Fairfield**	**Easton**
CT	.009	Fairfield	Stratford
CT	**.010**	**Litchfield**	**New Hartford**

THREATS TO THE TAXON

Threats to *R. ramosior* are limited but significant. Although many populations occur on protected or quasi-protected lands, both anthropogenic and naturally-occurring threats are of concern at many sites. Some sites are currently under direct threat; at other stations the threats should be considered potential.

Invasive Species and their Biological Control

At several of the extant occurrences (MA .011 [Holyoke], MA .012 [Westford], CT .007 [Glastonbury]), invasive species, particularly *Lythrum salicaria*, are present and pose a significant threat to the continued existence of this species at the location. Although not a direct threat at any site, the habitat occupied by *R. ramosior* at most locations could also sustain *Polygonum cuspidatum* and *Phragmites australis*. Further, efforts to eradicate these and other invasive species through mechanical or chemical means may inadvertently harm both extant and currently unknown populations or individuals of *R. ramosior*.

Lythrum salicaria and *Rotala ramosior* are closely related, both members of the Lythraceae family. Prior to the North American release of *Lythrum salicaria* biological control agents, extensive host specificity tests were carried out. This testing included *R. ramosior*. The introduced insects, two leaf-feeding beetles (*Galerucella calmariensis* and *G. pusilla*), and the weevil (*Hylobious transversovittatus*), neither oviposited nor developed larvae on *R. ramosior* during these tests (Bernd Blossey, Cornell University, personal communication). However, a study conducted by Michigan State University found that when *Galerucella calmariensis* was given no other food choice significant feeding by the beetle on *R. ramosior* occurred (Landis and Klepinger 1998). Blossey et al. (2001) also reported transient attacks by *Galerucella* spp. on neighboring non-target plant species.

This is an important potential threat to *R. ramosior*, especially in portions of its range, such as New England, where the species is considered endangered. If *G. calmeriensis* were to exhaust its food supply of *Lythrum salicaria*, it may shift feeding to *R. ramosior* in that and subsequent seasons, reducing or even eliminating flower and fruit production. As an annual species, the taxon relies on seed production alone for its survival; any interruption in the flowering and fruiting cycle is potentially devastating. Seeds of *Lythrum salicaria* remain viable in the soil seedbank for more than ten years (Malecki et al. 1994), and those of *R. ramosior* appear to be equally persistent (Baskin, personal communication). It should be noted that there are no known observations of *G. calmariensis* feeding on *R. ramosior* in the wild. Further field studies and observations are needed.

Changes in Hydrology

Changes in the hydrology at any of the extant sites would be detrimental to populations. In New England, the taxon appears to be adapted to pond, lake, or reservoir shores that experience fluctuations in water levels throughout the season: high levels in the spring, and being drawn down over the course of the summer and autumn. *Rotala ramosior* appears on the edges of these water bodies in June or July as water levels recede. Large-scale hydrological changes producing either a permanent lowering or a permanent raising of water levels will result in a significant alteration in (decline) or extirpation of some populations. Several sites (e.g., CT .002 [Newtown], CT .007 [Glastonbury], MA .012 [Westford]) are, or act like, kettle hole ponds: the level of water in the pond is directly related to groundwater levels. At these sites, significant development adjacent to or in the area of these ponds may irreversibly alter pond hydrology, and impact *R. ramosior* populations. Other locations (MA .011 [Holyoke], CT .008 [Easton], CT.010 [New Hartford], RI .002 [Lincoln]) are public water supply or flood retention reservoirs, with the water levels dependent on the influx of stream or rainwater. At most of these locations, if waters were to remain high over many years, requests to draw down the reservoirs could be made. However, the design of at least one of these reservoirs (MA .011 [Holyoke]) makes this impossible.

Anthropogenic Threats

Human uses at several sites pose significant threats to populations at those locations (MA. 012 [Westford], CT .007 [Glastonbury], RI .002 [Lincoln], and East Greenwich, RI). Incompatible activities noted include off-road vehicle or all-terrain vehicle use, hiking, horseback riding, dirt and mountain bike riding, swimming, gravel extraction and development. In most situations, the perpetrators of these activities are unaware of the impact their actions are having on this rare species. Even such relatively benign activities as swimming, could have a dramatic effect on a population by trampling or dislodging plants colonizing sandy or gravelly shores at authorized and unauthorized swimming areas.

Habitat Succession

Rotala ramosior occupies a zone along shorelines that few other species colonize. The taxon appears ill-adapted to competition with other species for light and space (Mehrhoff, personal communication; Ardwin, personal communication). The shoreline at many sites is kept free of competing vegetation by the natural fluctuations in water levels. If this natural fluctuation were to cease, other larger, potentially more aggressive herbaceous and woody species would begin to colonize the habitat currently occupied by *R. ramosior*.

Sedimentation

At least one site (CT .007 [Glastonbury]) is being impacted by sedimentation. The over-washing of sediment onto pond shores from adjacent roadways, agricultural lands, or sediment deposited by stream flow is a distinct threat to this species. The species requires high light intensity to germinate. In tests conducted at the University of Kentucky by Carol Baskin, seeds buried at a depth of 1 mm or more did not germinate. The taxon requires exposed soil, sand or gravels to germinate, even the presence of leaf litter at a site will inhibit germination.

CURRENT CONSERVATION MEASURES IN NEW ENGLAND

Few conservation measures for *R. ramosior* are in place. Monitoring at most sites has been erratic or non-existent. Only eight sites have been visited once since 1991 (MA .002 [Winchester], MA .011 [Holyoke], MA .012 [Westford], RI. 002 [Lincoln], East Greenwich, RI, CT .001 [Simsbury], CT .007 [Glastonbury], and CT .010 [New Hartford]), and of those, only five have been visited more than once. Of extant sites, three have not been re-visited since they were first discovered in the 1980's and early 1990's. However, several sites (MA .011 [Holyoke], in particular) have received significant attention in recent years.

Of the nine current sites, public or quasi-public agencies and private conservation groups own five: two are located within the boundaries of state parks, two are owned by town conservation commissions, and one is a former landfill now managed as a town park. Aside from the one occurrence owned by a town and co-managed by The Nature Conservancy and the two occurrences on state parkland in Connecticut, ownership does not necessarily convey protection. Even on these protected lands, current management practices are not specifically designed to protect the occurrences of *R. ramosior*. The remaining four sites are located on the shores of water bodies managed as reservoirs.

Only one site has received intensive study and management work (MA .011 [Holyoke]). The New England Wild Flower Society, Silvio O. Conte National Fish and Wildlife Refuge, and the City of Holyoke are working together to control the spread of *Lythrum salicaria* at the site through mechanical means. In an attempt to protect *R. ramosior* at this site in the future, a long term management plan for this site will be developed in autumn 2001 by the New England Wild Flower Society and the City of Holyoke.

The New England Plant Conservation Program has collected seed from only one population in the region (East Greenwich, Rhode Island). Germination trials at NEWFS have been unsuccessful in establishing a germination protocol for this species. Graduate students at Brown University have succeeded in establishing a germination protocol for New England gene-type seeds provided by NEWFS. The final report of this study indicates that although all treatments (fertilization, gibberellic acid, inundation, control, and stratification) resulted in some germination, cold moist stratification followed by long warm day length yielded the highest germination percentages. All other treatments, when combined with stratification, showed an increase in the germination percentages (Fite-Wassilak et al. 2001). These findings concur with those of Carol Baskin in her studies of *Rotala ramosior* germination in the southern United States. Approximately 500 seeds remain in the NEPCoP seedbank at NEWFS. The seeds were collected in 1995.

Due to its specialized habitats, the species is protected somewhat by the various states wetland protection acts, which require the filing of applications for any work taking place in or adjacent to wetland habitats. Although not specifically an act designed to protect plant species, the presence and state status of the species should come to the attention of the permitting body through this process. The specific regulations vary from state to state, but all provide some degree of protection. Additionally, the state endangered species acts provide a degree of protection to the taxon. As the species is considered SR/SH in New Hampshire, it receives no protection under the 1987 Native Plant Protection Act RSA 217-A:3, III. If the plant were to be rediscovered in that state, it would be considered under this law, but this would not provide any specific protection measures for the taxon. In Massachusetts, the species is protected under the 1992 Endangered Species Act, MGL c. 131A and its regulations, 321 CMR 10.00. In Rhode Island, the species receives protection under the Rhode Island Endangered Species Act, Title 20 of the General Laws of the State of Rhode Island 20-37-3. This law only protects the species from digging and transport for the purposes of sale of the plants. In Connecticut, it is protected under Public Act 89-224. This act protects the species from collection or destruction on publicly (i.e. state) owned properties. It also prevents state agencies from knowingly destroying or adversely impacting populations. It also prohibits the collection of the species for sale or transport across state lines. The only state with a law or statute with any "teeth" to it, providing for penalty, is Massachusetts.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

Although widespread and thought to be common throughout much of its North American range, *Rotala ramosior* is endangered in New England (Brumback and Mehrhoff et al. 1996). Whether the species has actually declined over the last century or simply migrated from location to location is unclear. There are 26 records of the taxon in New England since 1886. Between 1886 and 1944, seventeen occurrences were documented. Most of these populations were documented only once. The only sites at which the species was observed in multiple years during this period are MA .003 [Sharon], MA.007 [Wellesley], CT .001 [Simsbury], CT .002 [Newtown], CT .003 [Easton], and CT.006 [Griswold]. Only nine of these sites have been searched for since the time of their last observation, and only one (CT .001 [Simsbury]) has been verified since 1944. Seymour (1969) lists one site in Smithfield, Rhode Island , but there is no indication of a first observation date, and it is not considered in the above numbers.

Since 1980, nine occurrences have been documented. Of these, only two (RI .002 [Lincoln], CT .001 [Simsbury]) were known to exist prior to 1980; the other seven are new discoveries. It is difficult to pinpoint how many populations may have existed simultaneously at any time in New England. The apparent transience of this species at many locations and its identification in periods of heavy botanical activity, (1886-1944 [World War II began shortly after this period, field botany declined] and 1980-present [the Heritage Programs established in the late-1970s/early 1980s]), make it difficult to establish a target number of populations, not to mention propose population levels at each site.

Given this information, several conservation objectives are set forth. The first, and primary conservation objective for the taxon is to maintain all current occurrences at present levels or higher. This action should ensure the species' maintenance as part of the flora of the New England region. The second objective is to increase the number of total populations in Massachusetts, Rhode Island, and Connecticut to thirteen. This objective would restore the taxon to approximately 50% of its former distribution in the region. This is a reasonable objective given the current number of stations, and the historical data suggesting no more than 17 populations occurred simultaneously on the New England landscape. This can be accomplished by relocating historic populations, discovering new populations, or by introducing plants into suitable habitat on protected lands. Specific proposed population levels for each occurrence, where appropriate, are given later. The third objective is to protect and manage all current and future extant sites in a manner compatible with *R. ramosior* maintenance. The fourth objective is to conduct species biology research on the species to determine pollinators, seed dispersal mechanisms and success, and seed viability and longevity in the soil seed bank in New England.

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IV. APPENDICES

1. Plan addendum

2. An explanation of conservation ranks used by The Nature Conservancy and Natureserve

1. Addendum to Conservation Plan for *Rotala ramosior*

In the time between the completion of this plan in its final draft form and the completion of revisions, two new sites for this taxon were reported to the author. Neither of these locations is yet documented by the state Natural Heritage programs, nor have either of these sites been completely surveyed. At a future date, this plan should be updated to include these two locations, but it is proposed that the inclusion of these two sites not alter the conservation objectives or goals of this plan. That is to say, we are still seeking to locate or restore four additional populations throughout its range in New England, bringing the total target number of occurrences to 15, as opposed to the 13 set forth in the plan as it exists currently.

The two new populations should be visited and thoroughly inventoried within the next year. Both populations are briefly discussed below.

West Greenwich, Rhode Island -- This population appears to have been known prior to the creation of this plan, although it is not known to the Rhode Island Natural Heritage Program. It is located in a seasonally wet, sandy/gravelly depression near a pond in West Greenwich, Rhode Island. The size of the population is unknown.

Holyoke, Massachusetts -- Late in 2001, Lynn Harper discovered a new population of the taxon in Holyoke, Massachusetts. The plants were growing along the exposed sandy, gravelly shores of a drawn down reservoir. The size of the population was estimated to be in the hundreds.

2. 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 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.