New England Plant Conservation Program

Eleocharis quadrangulata (Michaux) Roemer & Schultes
Square-stemmed spike-rush

Conservation and Research Plan for New England

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SUMMARY

Eleocharis quadrangulata (Micheaux) Roemer & Schultes (square-stemmed spike-rush) is a large, rhizomatous, perennial, aquatic graminoid of the Cyperaceae. It typically forms large stands in shallowly flooded habitats with plenty of sunlight, but is otherwise a habitat generalist, occurring in ponds, reservoirs, small pools, flooded sand-pits, fresh tidal marshes, brackish marshes, roadside ditches and abandoned rice fields.

The species has a broad range east of the Mississippi River, having been documented from 31 states and the province of Ontario. Disjunct populations occur in California and Oregon. It generally becomes less common at higher latitudes and inland from the coastal plain, but even in the center of its range is often infrequent with a spotty or local distribution. Its global rank is G4. It is listed as S1 or S2 in nine states and the province of Ontario, SX or SH in two states, S3 in two states, and is demonstrably secure (S4 or S5) in only four states (several additional states where the species is probably secure have not ranked the species). It is regionally rare in New England (NEPCoP Division 2), and, apparently, has always been so. Massachusetts and Connecticut are the only New England states where *Eleocharis quadrangulata* has been documented. Its current distribution is limited to five natural populations in Connecticut, where it is ranked S1.

The small number of populations leaves the species in a precarious position, and it is essential that all five populations be maintained if *Eleocharis quadrangulata* is to remain a viable component of the New England flora. Currently, three populations are robust and appear to be relatively secure. Two populations are too small or limited in spatial extent to have high viability. The primary conservation goal is to have all five populations routinely producing 5000 or more fertile culms annually within the next 20 years. A second goal is to achieve a wider geographic dispersal for the species. Historically, *E. quadrangulata* has been documented from four well-dispersed areas in Massachusetts and Connecticut. Currently, four of the five populations are in a small area in Groton, Connecticut. Reestablishing a more dispersed distribution would help insulate the species from local phenomena (e.g., climatological events or disease outbreaks) that could simultaneously affect a tightly clustered population group. Achieving this goal through natural recruitment (artificial introductions are not recommended) is far from certain, but can be facilitated by maintaining good vigor and reproductive output in existing populations, and research on reproduction, dispersal and recruitment limitations in the species. There appears to be ample suitable habitat in New England and the most likely factor hindering population expansion is in the regeneration niche – some exacting requirement for seed germination, colonization, or persistence during the juvenile phase. Research into the requirements (and possible limitations) for recruitment to new sites and local proliferation is essential for designing effective management strategies that will promote the conservation goals. No currently active threats to the taxon have been identified at occupied sites; however, potential future threats include competition from non-native invasive species, sedimentation, and excavation. These potential threats can be minimized through management activities specified in this plan.

PREFACE

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

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

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

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

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

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I. BACKGROUND

INTRODUCTION

Eleocharis quadrangulata (Michaux) Roemer & Schultes (square-stemmed spike-rush) is among the largest of New England's spike-rushes (growing up to one meter tall) and is atypical in having square rather than round stems (Smith et al. 2002). It grows as an emergent aquatic and spreads clonally by rhizomes, often forming large, dense stands in shallowly flooded habitats (Boyd and Vickers 1971). The species does well in cultural landscapes and is often found in disturbed, degraded and artificial ponds, as well as in more natural settings. Habitats where the species has been reported throughout its range include ponds, reservoirs, small pools, lime-sinks, sand-pits, fresh tidal marshes, roadside ditches, abandoned rice fields, and brackish marshes (Svenson 1929, Eyles and Robertson 1944, Fernald 1950, Radford et al. 1968, Baden et al. 1975, Perry and Herschner 1999, Flora of Texas Consortium 2002). All New England records are from the shores of artificial or natural ponds and pools on the coastal plain.

Eleocharis quadrangulata ranges from Massachusetts west to Wisconsin and south to Florida and Texas (Smith et al. 2002). It is also found in the Great Lakes region of Ontario, Canada (NatureServe 2003). Disjunct populations occur in California, where it is considered probably native (Roxanne Bittman, California Natural Diversity Database, personal communication), and Oregon where it is considered unquestionably introduced (Peter Zika, Oregon State University, personal communication). Within this range it has been reported from 31 states. It is less common at higher latitudes and inland from the coastal plain, but even in the center of its range is often infrequent with a spotty or local distribution. It has a global rank of G4, but is listed as regionally rare (Division 2) in New England by Brumback and Mehrhoff et al. (1996). Nine states and the province of Ontario list the species as S1 or S2 (NatureServe 2003). It is thought to be extirpated in Massachusetts and Wisconsin. Connecticut, with five natural populations, is the only New England state where *Eleocharis quadrangulata* is currently known to occur.

Eleocharis quadrangulata reaches the northern limit of its eastern range in New England, where historic records indicate it has always been rare. Prior to 1982, when the first of five Groton, Connecticut stations was discovered, it was known from only three historic sites, and had not been seen in New England since 1912. The loss of three historic sites (MA .001 [Wellesley], MA .002 [Wellesley] and CT .001 [Guilford]), although balanced by newer discoveries, has resulted in a more poorly dispersed distribution than it enjoyed formerly.

Habitat suitable for *Eleocharis quadrangulata* appears to be plentiful on New England's coastal plain. The species has excellent dispersal capability and a proven ability to spread to new habitats around established populations. Thus, there is no obvious obstacle hampering population expansion. Its rarity may be due to exacting

requirements for regeneration or recruitment to new sites rather than a scarcity of (adult) habitat or colonization barriers.

The primary conservation objective for *Eleocharis quadrangulata* is to ensure that the five known populations are secure. Three populations (CT .002 [Groton], CT .003 [Groton], and CT .009a [Groton] are currently robust (occupying large areas with from 2,500 to more than 20,000 stems) and need only be maintained at current levels to achieve this objective. Two populations have low numbers of plants (CT .009b [Groton]) or occupy very small areas (CT .006 [Danbury]) and will need to expand to meet this goal. The 25-year objective is to have all populations on par with the more robust occurrences (i.e., covering extensive areas and routinely producing more than 5,000 fertile culms annually). A second conservation goal for the species is to see it become more widely distributed regionally. Currently, four of five populations are in a (spatially) small cluster in Groton, Connecticut. Historically, the species has been documented from a wider geographic range (four counties in Massachusetts and Connecticut), and reestablishing a wider distribution would be highly desirable. Artificially introducing new populations is not recommended at this time; rather, the recommended strategy is to take actions to promote maximal reproductive output at extant sites, which will increase the probability of natural dissemination.

DESCRIPTION

The following technical description is drawn, except where otherwise noted, from Svenson (1929), Fernald (1950), Gleason and Cronquist (1991), and Smith et al. (2002). *Eleocharis quadrangulata* is a rhizomatous, perennial spike-rush. The culms are sharply quadrangular, 2–5.4 mm thick, and mostly 45–105 cm tall. Lower leaf sheaths are membranaceous with an acute to acuminate apex, sometimes prolonged into a blade-like portion up to 8 cm long. Spikelets are coarse, hardly (if at all) thicker than the culms and 20–76 mm long. Fertile scales are typically straw-colored, with conspicuous scarious margins and a darker colored submarginal band. Scale apices are usually sub-cartilaginous with a rounded to obtuse apex. Perianth bristles number 6–7, are shorter than to barely equaling the body of achene, and often unequal in length. Achenes are biconvex, variable in color, from pale yellow to brown or even somewhat purple-tinged; they are obovoid, textured with longitudinal rows of alveolae (small pits), or occasionally nearly smooth. Tubercles are variable in color, deltoid to high-pyramidal or lanceoloid, often separated from achene apex by a constricted neck. Smith et al. (2002) specifically state that tubers are not produced by the species. However, Wiegand (1909a) documented tubers (or tuber-like structures) produced on the roots in a now extinct population in Massachusetts (MA .001 [Wellesley]), and many technical descriptions of *E. quadrangulata* written since this publication have included tuber production among the species attributes. Additional evidence that tubers are, in fact, produced by the species comes from Stutzenbaker (1999) who notes that muskrat, nutria, snow geese, and many duck species eat *E. quadrangulata* tubers.

The sharply angled, quadrangular stem is unique among the larger *Eleocharis* species and it would be difficult to mistake this species for any others with which it is sympatric.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Information on nomenclature and taxonomy of *Eleocharis quadrangulata* presented below was taken from: The Plant Names Project (1999); Fernald (1925, 1935); and Svenson (1929, 1939). Some original references cited in the text (below) were taken from these sources and were not verified by the author.

Eleocharis quadrangulata was originally described as *Scirpus quadrangulatus* Michaux (*Flora Boreali-Americana* [Hooker]; *or, the Botany of the Northern Parts of British America* [1803]), and the species name was retained when *Eleocharis* was separated from *Scirpus* following the work of Roemer and Schultes (*Systema Vegetabilium* (ed. 16) ii. 155 [1817]).

Muhlenberg, apparently unaware of Michaux's publication, independently described the taxon as *Scirpus marginatus* (*Descriptio Uberior Graminum* 1817). This name had previously been applied to another taxon and was subsequently changed to *Scirpus albomarginatus* by Roemer and Schultes (*Systema Vegetabilium* (ed. 16) vi. 1824).

Nathaniel Lord Britton, in the first two editions of the *Illustrated Flora of Eastern North America* (1896 and 1913) reduced *Eleocharis quadrangulata* to the tropical *E. mutata* (Fernald 1925). Fernald (1925) firmly rebuked Britton for failing to critically examine collections of the distinctly different temperate and tropical taxa, and all subsequent taxonomic works have treated the two taxa as distinct species.

Fernald (1935) separated out a new variety (*Eleocharis quadrangulata* [Michx.] Roem. & Schult. var. *crassior* Fern.) based primarily on a more robust morphology (the type specimen is from a now historical Wellesley, Massachusetts population). However, Svenson (1939) disagreed with Fernald's interpretation, feeling that the plants with the more robust growth form, upon which Fernald's description was based, were simply an ecotype. Botanical manuals and regional floras published since the late 1930s have been inconsistent in their acceptance of E. *quadrangulata* var. *crassior* as a valid taxon. Smith et al. (2002), in *The Flora of North America*, recognize no subspecific taxa in *Eleocharis quadrangulata*, and this treatment should be adopted in future works.

Synonymy

- *Scirpus* L. [Linnaeus, *Species Plantarum (1 May 1753)*]. This is the basonym for the genus name *Eleocharis.*

- *Heleocharis* Lestib. (Lestibudois, *Essai sur la Famille des Cyperacees* [1819]). This is an orthographic variant of the name *Eleocharis.*
- *Scirpus quadrangulatus* Mich. (Hooker, *Flora Boreali-Americana; or, the botany of the northern parts of British America* i. 30 1803).
- *Scirpus maginatus* Muhl. (Muhlenberg, *Descriptio Uberior Graminum* 28 1817.)
- *Scirpus albomarginatus* (Muhl.) Roem. & Schult. (Roemer and Schultes *Systema vegetabilium* [ed. 16] 1824).
- Eleocharis mutata (L.) Roem. & Schult. (Roemer and Schultes *Systema vegetabilium* [ed. 16] 1817).
- *Eleocharis quadrangulata* (Michx.) Roem & Schult. var. *crassior* Fernald (Fernald 1935).

SPECIES BIOLOGY

Eleocharis quadrangulata is an emergent, aquatic perennial. Like all members of the genus, it is wind-pollinated. It reproduces sexually by seeds (achenes) and vegetatively by rhizomes. Tubers have been reported on the roots of some plants (Wiegand 1909a) and could provide an additional means of reproduction and local spread (but see Smith et al. 2002). It often forms extensive monospecific stands (Boyd and Vickers 1971), presumably through clonal growth.

Flowers are produced continuously from late spring through fall, and achenes begin to mature in late summer and continue up to the time of senescence in late fall. Magee and Ahles (1999) list June as the beginning of the flowering period in New England. On August 27, 2003 (Hickler, personal observation) the population at CT .002 (Groton) had some individuals that were just coming into flower, others that had already shed mature fruit, and a gradient of maturities between the two extremes was observed. Collins and Wein (1995) reported *Eleocharis quadrangulata* among the species germinated from wetland soil samples, suggesting the species can produce a persistent seedbank. In Texas, individual populations vary considerably in fertility, with some (extreme) populations producing achenes that do not germinate under experimental conditions (Kika de la Garza Plant Material Center 2001). Achenes collected from (unspecified) Groton, Connecticut populations have been successfully germinated and grown to maturity by Richard Snarsky, New England Environmental Services (personal communication) – showing that at least some of the New England populations are fertile.

Achenes of *Eleocharis quadrangulata* are a favored food of ducks and shorebirds (Woodin and Swanson 1989, Ramey 1999). Working with captive killdeer and ruddy ducks, de Vlaming and Proctor (1968) documented high viability of *Eleocharis quadrangulata* seeds recovered from droppings and exceptionally long internal retention times, prompting the conclusion that ducks and shorebirds are an effective vector for long-distance dispersal of the species. At least three of five Groton, Connecticut populations (CT .003, CT .009a and CT .009b) have become established (presumably naturally) in recently created ponds. This observation is strong evidence that local populations have dispersal capability.

Vegetative growth rates are highest in mid-spring. One study on a South Carolina population of *Eleocharis quadrangulata* (Boyd and Vickers 1971) reported about 50% of the annual biomass production accumulated in a 27-day period between May 5 and June 1. Culms of *Eleocharis quadrangulata* are packed with aerenchyma tissue (Hickler, personal observation), an indication that the species is effective at oxygenating roots and rhizomes, and conferring fitness in habitats with anaerobic substrates (Armstrong 1978).

HABITAT/ECOLOGY

Throughout its range, *Eleocharis quadrangulata* is found in permanently but shallowly-flooded fresh to somewhat brackish waters (Fernald 1950, Radford et al. 1968, Gleason and Cronquist 1991). It will tolerate occasional dry-downs, but is not typically found in areas that experience large seasonal or interannual variations in water level. Substrates range from mineral soils to peat, but sandy to gravelly shores appear to be favored. Stands have been reported in freshwater tidal marshes (Perry and Hershner 1999) and brackish marshes with chlorinities as high as 2.8% (Baden et al. 1975). The species requires ample light and is absent from areas with excessive shading. Disturbed areas such as roadside ditches, abandoned rice paddies, and sandpit pools are often cited as habitats. All New England records are from the shores of natural or artificial ponds and small pools.

The Kika de la Garza Plant Materials Center [(2002) citing Stutzenbaker (1999)] notes that *Eleocharis quadrangulata* can tolerate fire, periodic drawdowns, heavy livestock use, and goose grazing and grubbing. The species appears to be well-adapted to a cultural landscape, is highly resistant to anthropogenic disturbance, and is often found in man-made habitats. It is readily introduced to artificial ponds and quickly spreads to form dense, monospecific stands (Boyd and Vickers 1971). This characteristic has made it a long time favorite for wetland restoration/creation projects in the southeast (McKnight 1992, Kika de la Garza Plant Materials Center 2002) and more recently has been used successfully in several New England restoration projects (Richard Snarsky, personal communication).

The species is most abundant on the southeastern Atlantic coastal plain and Gulf Coast, where pond shores and shallow pools are its principal habitat. Even at the center of its range, where it is demonstrably secure, distributions are usually qualified as "widely scattered" or "local" (Fernald 1950, Radford et al. 1968). Speculating on causes for the species low regional frequency in spite of seemingly abundant habitat and effective means of dispersal, de Vlaming and Proctor (1968) postulated that *Eleocharis quadrangulata* might have very exacting habitat requirements. Regardless of the causes, it appears to be normal for the species to be distributed in widely scattered locales across a region, but to develop large local populations at occupied sites.

Although *Eleocharis quadrangulata* will tolerate occasional stranding during low-water periods, it is typically an emergent marsh species, growing in shallowly

flooded habitats with water depths up to about a meter. Lists of associated species from personal observations, Connecticut Natural Diversity Database records, and published literature show that the species forms local associations with whatever other species happen to be resident at a given site. Associates that have been documented with the species include submersed aquatic plants, floating-leaved species, herbaceous and graminoid emergents, and a wide array of species from bordering wetlands. Associated species that have been reported during recent surveys (CT. 002 [Groton], CT .003 [Groton], CT .006 [Danbury], and CT .009 [Groton]) include: *Pontederia cordata, Elodea nuttallii, Nuphar variegata, Nymphaea odorata, Eriocaulon septangulare, Cladium mariscoides, Eleocharis palustris, Carex stricta, Juncus effusus, Juncus canadensis, Juncus pelocarpus, Scirpus cyperinus, Dulichium arundinaceum, Phragmites australis, Gratiola aurea, Lysimachia terrestris, Proserpinaca palustris, Ludwigia palustris, Bidens cernua, Polygonum hydropiperoides, Lycopodiella inundata,* and *Thelypteris palustris.*

Historic data on plant distributions and population trends are always incomplete, but given the information at hand it is reasonable to infer that:

1) *Eleocharis quadrangulata* has always been scarce in New England.

2) Human activities (collecting and hydrologic changes) may have contributed to losses at two historic sites (CT .001 [Guilford] and MA .001 [Wellesley]).

3) As many as four natural populations of *E. quadrangulata* are in habitats created (inadvertently) by human activities.

4) On balance, although precarious, the prognosis for the species in New England appears as good today as it has ever been and there is evidence to suggest that negative impacts from human activities are balanced by positive impacts from habitat creation.

THREATS TO TAXON

The primary threat to *Eleocharis quadrangulata* in New England stems from the small number of populated sites concentrated in a small geographic area, making a random walk to extinction due to stochastic population fluctuations and random events a threat (Ferson and Burgman 1990). Small, disjunct populations often have low genetic diversity, making them less resilient in the face of environmental challenges (Utter and Hurst 1990) and thus, more prone to extinction than populations in the center of the range. The New England populations are concentrated in a small geographic area in Groton, Connecticut. The species' poor success at establishing a wider ranging population base in New England in spite of ample (apparently) suitable habitat is a serious concern. Causes for the species continued rarity are discussed in more detail elsewhere, but are probably related to peculiarities of species-biology or specialized regeneration requirements rather than a scarcity of habitat.

William Brumback and Richard Snarsky noted abundant *Lythrum salicaria* at CT .002 (Groton) on September 17, 1998, but felt it was not adversely affecting the Element Occurrence (EO). I visited the site on August 27, 2003 and noted that *L. salicaria* was still abundant and concur with Brumback and Snarsky that the EO is not threatened by the invasive species. The two species are well-segregated along the water depth gradient, making competitive exclusion unlikely. William Brumback and Richard Snarsky visited CT .003 (Groton) on September 17, 1998, and documented extensive *Phragmites australis* present on the pond and considered the invasive species a potential future threat to the EO. I visited the EO on August 27, 2003 and the situation does not appear to have changed since the 1998 visit. *Phragmites* has the potential to grow in the deeper water favored by *Eleocharis quadrangulata* and remains a potential threat.

The species' affinity for man-made ponds (e.g. sand pit excavations) puts some populations (CT .003 [Groton] and CT .009a [Groton]) in harm's way from routine activities such as dredging and excavation.

DISTRIBUTION AND STATUS

General Status

Eleocharis quadrangulata ranges from Massachusetts west to Wisconsin and south to Florida and Texas. Disjunct populations occur in California and Oregon. It is also found in the Great Lakes region of Ontario Canada. Within this range, it has been reported from 30 states (NatureServe 2003), one of which (New Hampshire) is almost certainly erroneous (Sara Cairns, New Hampshire Natural Heritage Bureau, personal communication). It is listed as extirpated (SX) in Massachusetts and historic (SH) in Wisconsin. Schuyler (1986) reported it extirpated in Pennsylvania after failing to relocate it at its only known station; however, the Natural Heritage Network still lists it as S1 there (NatureServe 2003). In California, although its status is not certain, *Eleocharis quadrangulata* is officially tracked as a native species (Roxanne Bittman, personal communication). Other reputable sources, (e.g., Calflora 2000) consider the species as introduced and adventive in California. In Oregon, the species is certainly introduced (Peter Zika, personal communication). Nine states and the Province of Ontario list *Eleocharis quadrangulata* as S1 or S2, and, although the pattern is not perfect, states where the species is rare (or historic) tend to be at higher latitudes and inland from the Atlantic and Gulf coastal plains. Only four states list the species as being secure (S4 or S5); however, 11 states, in many of which the species appears to be secure, have not ranked the taxon (Table 1). In Michigan and the District of Columbia, the status of *Eleocharis quadrangulata* is uncertain and it is ranked S?.

Figure 1. Occurrences of *Eleocharis quadrangulata* in North America. States and provinces shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. States shaded in black have more than five confirmed occurrences. The states with diagonal hatching is designated "historic" or "extirpated," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported" but without additional documentation). The state (Oregon) with horizontal hatching report that *E. quadrangulata* is introduced. See Appendix for explanation of state ranks.

Table 1. Occurrence and status of *Eleocharis quadrangulata* 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)
California (S1S2)	Delaware (S3)	Alabama (SR)	Massachusetts (SX): One historic occurrence
Connecticut (S1): 5 native extant populations and 1 historic. Four introduced pops. (not tracked).	District of Columbia (S?)	Arkansas (SR): Populations documented in 20 counties (Smith 1988)	Wisconsin (SH)
Illinois (S1S2)	Georgia (S4)	Florida (SR): Reported from seven counties in northern half of state (Digital Atlas of Florida Vascular Plants 2002)	
Kansas (S1): Eight populations in as many counties (Craig Freeman, personal communication).	Kentucky (S5)	Indiana (SR)	
New Jersey (S2)	Maryland (S4)	Louisiana (SR)	
New York (S1): Populations documented in seven counties (Young 2001).	Michigan (S?)	Missouri (SR): Vouchered records from 29 counties (Weber et al. 2000)	
North Carolina (S2)	Mississippi (S4)	New Hampshire (SR): Erroneous report; should be ranked "SRF"	
Pennsylvania (S1) Extirpated according to Schuyler (1986)	Ohio (S3)	Oklahoma (SR)	
West Virginia (S2)	Oregon (unranked): Introduced	South Carolina (SR): Widely distributed in ponds and marshes (Beal 1977)	
Ontario (S1)		Tennessee (SR)	
		Texas (SR): Vouchered records from 28 counties (Flora of Texas Consortium 2002)	
		Virginia (SR)	

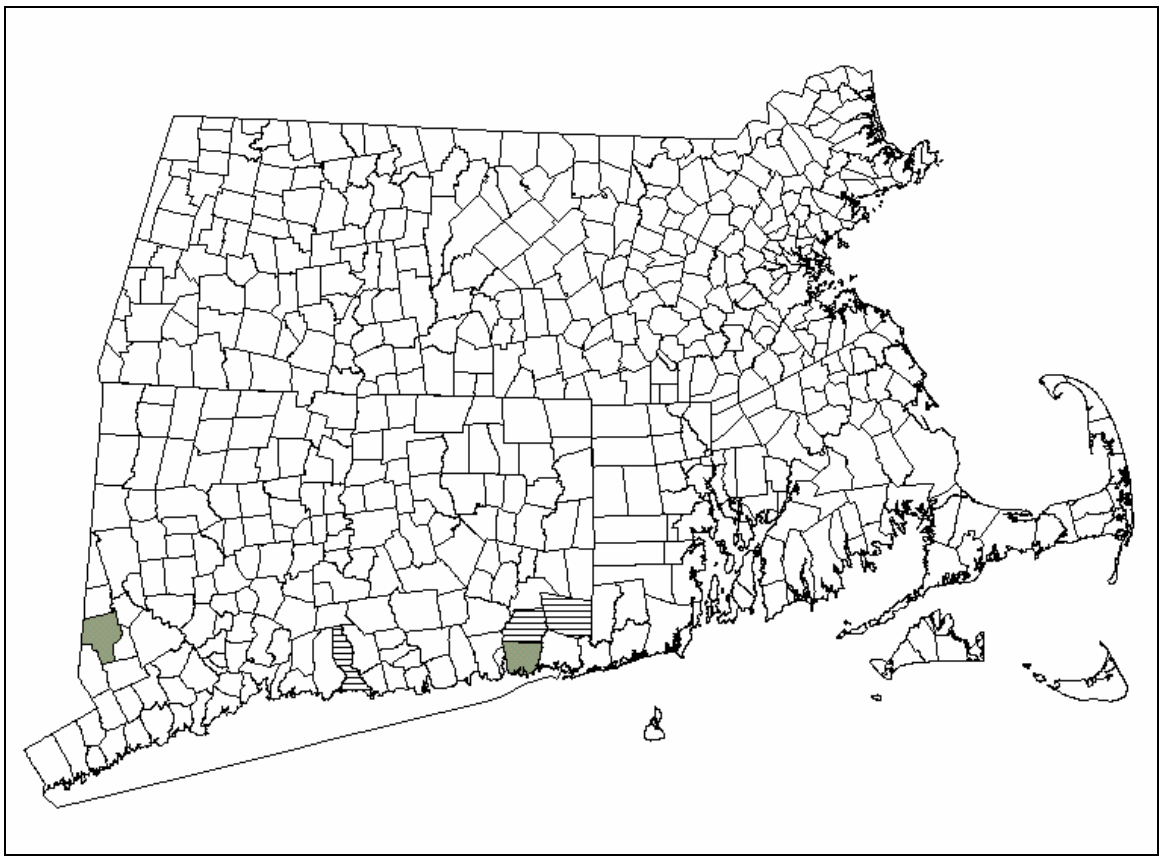

Figure 2. Extant occurrences of *Eleocharis quadrangulata* in New England. Town boundaries for southern New England states are shown. Towns shaded in gray have one to five extant occurrences of the taxon. Towns with horizontal hatching report that *E. quadrangulata* is introduced.

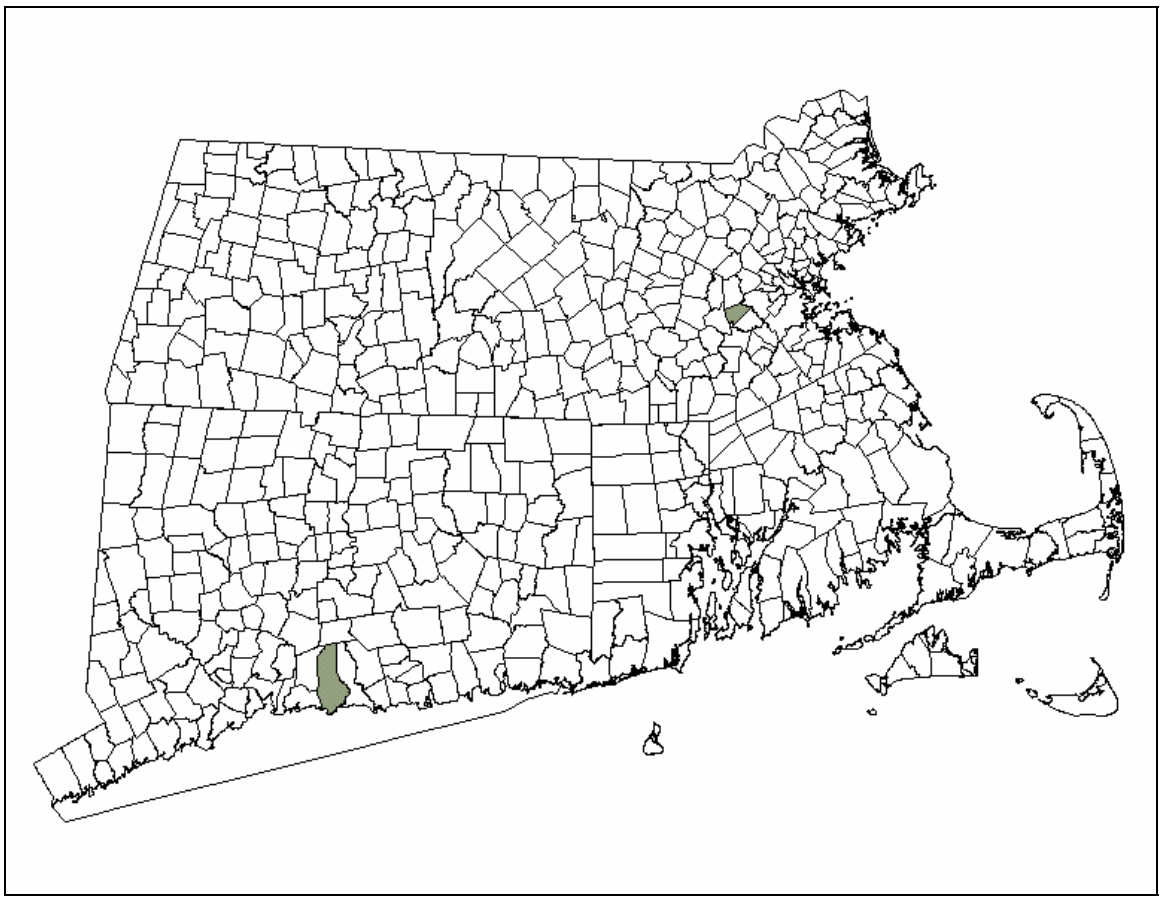

Figure 3. Historical occurrences of *Eleocharis quadrangulata* in New England. Towns shaded in gray have one to five historical records of the taxon.

Table 2. New England Occurrence Records for *Eleocharis quadrangulata.* Shaded occurrences are considered extant.			
State	**EO #**	**County**	**Town**
MA	.001	Norfolk	Wellesley
MA	.002	Norfolk	Wellesley
CT	.001	New Haven	Guilford
CT	**.002**	**New London**	**Groton**
CT	**.003**	**New London**	**Groton**
CT[1]	**.004**	**New London**	**Ledyard**
CT[1]	**.005**	**New London**	**North Stonington**
CT	**.006**	**Fairfield**	**Danbury**
CT[1]	**.007**	**New London**	**Ledyard**
CT[1]	**.008**	**New Haven**	**Madison**
CT	**.009**	**New London**	**Groton**

[1] Introduced population

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

Conservation goals for Eleocharis *quadrangulata* must be established based on estimates of the population levels and geographic distribution needed to ensure long-term survival of the species in New England. But this goal must be balanced by constraints imposed by the species' biological potential, habitat requirements, population demographics, and historic distribution. Historically, the species has been documented from four relatively distinct geographic areas (Norfolk County, Massachusetts; and New London, New Haven, and Fairfield Counties, Connecticut). The current distribution is limited to New London County, Connecticut (four sites in Groton, two of which are currently combined under CT .009), and Fairfield County, Connecticut (one site in Danbury). One conservation objective for the species is to re-establish a wider geographic distribution in New England with expansion to four well dispersed population centers. At each population center, the goal, (modeled after the highly viable population demographics that appear to be at work at the Groton Connecticut population center), is to have four or more spatially clustered subpopulations. This kind of local distribution with several insular (but not biologically isolated) populations can be more robust than an equivalent number of more isolated populations (e.g., Hanski and Gilpin 1997). Each station should support extensive stands that routinely produce five thousand or more fertile culms annually.

Eleocharis quadrangulata appears to have wide amplitude with respect to habitat requirements, and has a good track record of doing well in highly cultural landscapes. Lack of suitable habitat does not appear to limit the species potential for expansion in New England. This thesis is supported by the ease with which the species has been introduced in diverse settings. Furthermore, experimental evidence suggests *Eleocharis quadrangulata* has good seed dispersal ability and, at least in some populations, good seed viability. The cluster of natural populations on artificial ponds in Groton, Connecticut suggests that New England populations are capable of spreading to new sites by seed.

Although there are no obvious constraints to population expansion in New England, the fact remains that it is, and always has been, scarce and locally distributed. Research on seed viability, dispersal, colonization and regeneration will be necessary to uncover possible constraints that might help explain the species continued rarity and help guide effective conservation strategies. Although artificial introductions would be the surest way to meet the goal of increasing the species geographic distribution, this (controversial) option is not recommended at this time. Rather, I recommend maximizing the potential for natural dispersal by working with existing populations to ensure that conditions promoting vigor and maximal reproductive output are maintained.

III. LITERATURE CITED

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IV. APPENDICES

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

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

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

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

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

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

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

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

Within states, individual occurrences of a taxon are sometimes assigned element occurrence ranks. Element occurrence (EO) ranks, which are an average of four separate evaluations of quality (size and productivity), condition, viability, and defensibility, are included in site descriptions to provide a general indication of site quality. Ranks range from: A (excellent) to D (poor); a rank of E is provided for element occurrences that are extant, but for which information is inadequate to provide a qualitative score. An EO rank of H is provided for sites for which no observations have 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.