New England Plant Conservation Program

Eleocharis microcarpa Torrey var. *filiculmis* Torrey
Tiny-fruited Spikerush

Conservation and Research Plan
for New England

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SUMMARY

Eleocharis microcarpa Torrey var. *filiculmis* Torrey (small-fruited spike-rush) is a small, caespitose, annual of the Cyperaceae. Its current distribution in New England is limited to a single macrosite (two subpopulations) in abandoned sandpits in eastern Massachusetts. The only other New England record for the species is from a historic (1907) population on a Connecticut pondshore. *Eleocharis microcarpa* var. *filiculmis* is widespread and locally abundant on the coastal plain of the Mid-Atlantic, Southeastern, and Gulf States where it is secure. To the north of New Jersey, it becomes rare and has a ranking of SH in Connecticut, and S1 in Massachusetts. It is also listed in Arkansas (S2), Indiana (S1), and Michigan (S1).

The species has a strong affinity for unshaded, shallowly flooded habitats that dry down at least occasionally. It is a generalist with respect to substrate, growing on sand, peat, and organic muck, but appears to make best growth on mineral soils. Most reports are from coastal plain pond shores and flooded depressions on coastal sandplains. Populations respond positively to disturbance including fire and mechanical soil disturbance.

Eleocharis microcarpa var. *filiculmis* has always been exceedingly rare in New England and there is no evidence that its precarious position here is the result of historic declines. It is best treated as a casual immigrant from population centers further south that has never succeeded in spreading from colonization loci sufficiently to build a viable New England population base. There is ample suitable habitat on the New England coastal plain and there are no obvious constraints preventing the species from becoming more common here.

The species' limited distribution in New England leaves it highly vulnerable to regional extinction, and it will not be secure until it has spread to three-or-four additional sites. However, management strategies for the species are complicated by the fact that the populated habitat is artificial – the result of sand and gravel extraction – and local population vigor and spread appear to be promoted by off-road-vehicle use. Recognizing that the longer the existing population persists, the more likely it is to succeed in colonizing additional sites, the recommended conservation strategy for *E. microcarpa* var. *filiculmis* is to take actions necessary to prolong its residency at the site and maintain maximal reproductive output. This goal can be facilitated by managing competing vegetation, managing disturbance regimes, and ensuring hydrologic regimes are maintained.

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 microcarpa Torrey var. *filiculmis* Torrey (small-fruited spike-rush) is a small, tufted, annual, grass-like plant of the Cyperaceae (sedge family). It is amphibious in habit; growing in small pools and on pond shores that are typically flooded, but dry down periodically. It tolerates a variety of substrate types but is most often found on mineral soils. It appears to be a disturbance specialist, expanding in numbers following fire (Lemon 1949) and mechanical soil disturbance (Reid 1999; Hickler, personal observation). It has a strong affinity for unshaded habitats where there is little competition from other plants. *Eleocharis microcarpa* var. *filiculmis* is an annual (Fernald 1950, Gleason and Cronquist 1991) or usually so (Smith et al. 2002), and relies on seed production and, perhaps, seed banking for persistence between years. It also spreads vegetatively during the growing season by producing pseudoviviparous propagules (proliferation) in place of some florets. Favored habitats include pools in abandoned sand pits (U. S. Fish and Wildlife Service 1997, Reid 1999, Knapp and Frye 2002) and coastal plain pond shores (Fernald 1943, U. S. Fish and Wildlife Service 1997).

Eleocharis microcarpa var. *filiculmis* has a range that generally follows the East Coast from Massachusetts to Florida and west along the Gulf Coast to Texas. Disjunct populations occur in the Great Lakes States of Michigan and Indiana. It is globally secure (G5), but rare in New England, with a NEPCoP rank of Division 2 (Brumback and Mehrhoff et al. 1996). It is secure or unranked in most of the southeastern states (S4, S5, SR or S?), critically imperiled (S1) in Massachusetts, Michigan, and Indiana, and imperiled (S2) in Arkansas. Connecticut lists the species as SH based on a single historic population. Explanations of conservation ranks appear in Appendix 3.

The two extant New England occurrences (about 1.5 km apart in southeastern Massachusetts) are in flooded portions of abandoned sand and gravel excavations, which were developed for highway construction in the late 1960's (Reid 1999). Lacking evidence of other populations in the region, the most likely scenario is that one of the two stations was colonized by long-distance dispersal from population centers to the south of New England following abandonment of the excavation. The second site was probably colonized by local dispersal from the original locus. The two stations, although insular, are probably insufficiently isolated from each other to prevent occasional exchange of disseminules and can, therefore, properly be considered subpopulations. They should, however, continue to be tracked as separate Element Occurrences (EOs).

There are many routes to species rarity in a given geographic region (Rabinowitz 1981, Fiedler and Ahouse 1992). More information is needed, but some evidence suggests that *Eleocharis microcarpa* var. *filiculmis* is a casual immigrant to New England from southern population centers that has yet to spread from colonization loci sufficiently to be recruited as a viable member of the regional flora. There are no obvious constraints

limiting its spread; the species appears to have strong "biological potential" (species-specific potential for reproduction, local proliferation, and dispersal), and there is ample suitable habitat in New England, so its current rarity may simply reflect the early colonization phase typically shown by newly arrived species.

The demography of *Eleocharis microcarpa* var. *filiculmis* leaves it highly vulnerable to extinction in New England (Ferson and Burgman 1990) and implementing a conservation plan for the species will help secure its future. Several additional stations around the current population center in Dartmouth, Massachusetts and three or four additional population centers around New England would have to establish before the species is secure. However, because the species has apparently never maintained more than a single population in New England (presuming the Connecticut population was extirpated prior to its establishment in Massachusetts), introducing new populations is not recommended. The longer the Massachusetts population remains extant and vigorous, the more likely it will spread naturally to additional sites. It is unclear whether *Eleocharis microcarpa* var. *filiculmis* will be a welcome recruit to the region's flora or if its spread would be cause for alarm (it is often among the dominant species on coastal plain pond shores to the south).

To promote the viability of the species in New England, the recommended conservation strategy is to try to prolong its residency at the Massachusetts macrosite in hopes that it will spread from the sandpits to nearby pond shores and wetlands. This may entail removing encroaching woody vegetation if the natural hydrologic regime fails to keep it at bay. Off-road-vehicle (ORV) traffic, although destructive, appears to benefit the populations in the long run by exposing fresh mineral soil, which provides an ideal seedbed. Monitoring ORV traffic and making a careful assessment of impacts (both positive and negative) is necessary. Too much ORV use could threaten the population, but if this traffic is eliminated, some other means of artificially scarifying the soil may be needed to maintain local population vigor. *Eleocharis microcarpa* var. *filiculmis* requires specific hydrologic regimes, therefore, activities that could alter the area's hydrology should be avoided.

Authors Note - Conservation objectives for rare species are readily justified when founded on knowledge about historic changes in a species' distribution or abundance (or threats thereto), which have been caused, directly or indirectly, by human activities. Desirable goals are restoring populations to historic levels, and ensuring that the habitats and ecological processes necessary to promote long-term viability of the species are intact. Enhancing rare species populations to levels greater than that which would be expected under natural conditions is not usually warranted. Thus, the conservation objectives for *Eleocharis microcarpa* var. *filiculmis* are rooted in inferences about the species historic distribution in New England, and changes that have occurred over time. There are many routes to rarity, and many causes for its persistence. Generic remedies, applied without the insight obtained from a careful diagnosis of species-specific causal mechanisms and historic distribution patterns are likely to lack the acuity needed to be effective. For example, where a species has always been rare due to a natural paucity of suitable habitat, conservation might entail locating and preserving appropriate parcels of

land. For a species that has declined due to habitat loss, restoration and reintroduction might be considered. If anthropogenic changes to important ecological factors (for instance, fire suppression) have caused population declines, restoring the natural regimes could be an appropriate management tool. The available data are insufficient to draw unequivocal conclusions about the history of *Eleocharis microcarpa* var. *filiculmis* in New England or why it is rare. Lacking perfect information, I have applied Occam's Razor liberally, relying on what factual information we *do* have and accepting the simplest explanations, which rely on the fewest assumptions and hypotheses. For the purposes of this plan, I will consider the extant occurrence in Massachusetts to be native (see Appendix 2); to have been absent from the Dartmouth site prior to excavations that created suitable habitat; and to have been recruited to the site from the nearest known large populations, which occur south of New England. Reviewers of previous versions of this plan have correctly pointed out that there are many other possibilities (maybe the species survived excavation of the sand pit *in situ*; maybe it colonized from nearby undocumented populations; maybe it was formerly common on the coastal plain; maybe it depended on historic fire regimes, which are no longer intact; maybe it is more common than we know, but under-reported; maybe it is a human introduction. Following each of these possibilities to its natural conclusion, we may arrive at different conservation inferences. New information may lend credence to some of these scenarios or suggest alternatives. In the meantime, with the intent of producing a conservation plan with unambiguous goals and objectives, I have done my best to draw sufficient (and singular) conclusions from woefully insufficient information currently available. I have listened carefully to those who would prefer alternate explanations for the species' rarity and history in New England, and in one case (the issue of native status) have altered my initial perspective. I recognize that the recommendations presented here rest on an imperfect foundation, but I have resisted the temptation to passively present multiple-choice possibilities in the sure knowledge that this would hamstring implementation of conservation management, which relies on clear, unambiguous goals.

DESCRIPTION

The following technical description is drawn primarily from Smith et al. (2002) with some additional details from Fernald (1950) and Gleason and Cronquist (1991). *Eleocharis microcarpa* var. *filiculmis* is an annual (or usually so), with a tufted growth form, sometimes forming clonal mats from proliferous inflorescences born on arching stems. Individual plants bear culms of varying height, which are filiform, quadrangular-sulcate, arching to erect, 2–40 cm long; rarely exceeding 0.4 mm in diameter. Distal sheaths are membranaceous with an acute apex. Spikelets are 2–10.7 mm long, dark purple-black, often proliferous, ovoid to lanceoloid with a distinctly acute apex. Spikelets are subtended by a prominent sterile scale, which is wider than (0.8–1 mm) and typically differing in color and texture from floral scales. Achenes are minute, 0.35–0.5 mm wide x 0.5–0.8 mm long. Perianth bristles are 0.6–1 mm long, slightly shorter than to barely exceeding the achene. *Eleocharis microcarpa* var. *microcarpa* (which does not occur in New England) differs from the native var. *filiculmis* in having shorter perianth

bristles (0.2–2.4 mm long), which are conspicuously shorter than the achenes, and a narrower proximal scale (0.4–0.5 mm wide).

Eleocharis microcarpa var. *filiculmis* is unlikely to be mistaken for other species with which it is sympatric in New England. It may superficially resemble common filiform-stemmed species such as *E. acicularis* (L.) R. & S. and *E. tenuis* (Willd.) Schult. from which it is readily distinguished in the field based on its intermediate stature and tendency to produce culms of variable length. Spikelet proliferation (when present) is a characteristic shared with only two other New England *Eleocharis* species (*E. rostellata* Torr.; a species restricted to saline marshes, and *E. melanocarpa*; a larger species with the potential to co-occur with *E. microcarpa* var. *filiculmis*).

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

The treatment of *Eleocharis* by Smith et al. (2002) in the *Flora of North America* recognizes two varieties of *Eleocharis microcarpa*: the typical variety, which has a range limited to extreme southeastern United States, and var. *filiculmis*, which has a more northern distribution. All New England material is var. *filiculmis* according to this treatment. Botanical manuals that cover the New England area have been inconsistent in their treatment of subspecific taxa. Fernald (1950) recognizes both varieties; however, others, for instance, Gleason and Cronquist (1991) and Magee and Ahles (1999) recognize only the typical variety. The typical variety of *Eleocharis microcarpa* is sympatric with *E. microcarpa* var. *filiculmis* in the southeastern United States. The authors of published and unpublished materials upon which this Conservation Plan is based have been inconsistent in distinguishing between the two varieties, and much useful information is simply ascribed to "*Eleocharis microcarpa*". I have taken the liberty of applying sub-specific epithets in cases where they were omitted by authors, but were reasonable to infer from location information. For clarity, I have used the name "*Eleocharis microcarpa*" only where original authors intended information to apply equally to both subspecific taxa, or where it is unclear to which subspecific taxa the author was referring. The only synonym for the taxon is *Eleocharis torreyana* Boeckeler (Smith et al. 2002).

SPECIES BIOLOGY

Reproductive Biology

Most descriptions of *Eleocharis microcarpa* characterize the species as being strictly annual (Fernald 1951, Gleason and Cronquist 1991, Magee and Ahles 1999). However, Smith et al. (2002) state that the species is "usually annual," allowing for the possibility of perennation under some, unspecified circumstances. Like all members of the genus, *E. microcarpa* var. *filiculmis* is wind-pollinated. Flowers are produced throughout the growing season and achenes can be found from spring through fall (Smith et al. 2002).

Eleocharis microcarpa is among a small number of *Eleocharis* species that reproduce vegetatively via proliferation of inflorescences (a form of pseudovivipary). Beyond noting its occurrence, descriptions of the proliferation process in *E. microcarpa* appear to be lacking in the literature. However, Hill (1898) provided a detailed description of proliferation in *Eleocharis melanocarpa* Torr. The following is drawn primarily from Hill's work and presumes that observations on *E. melanocarpa* are applicable to *E. microcarpa*. When an inflorescence proliferates, a few individual flowers in the spikelet are replaced by vegetative bulblets, which appear in the axils of scales in place of the achenes. Most of the remaining ovules in the proliferous spikelet abort. Each bulblet consists of a small "bud" topped by a single stem enclosed in a sheath and, in time, a basal protuberance which will expand into a root system. Proliferate culms develop positive geotropism and an arching growth form that eventually places the bulblets in contact with the ground where they soon become rooted. The connection between daughter plants and the parent culm remain tenacious until the offspring are well established, after which the connection becomes fragile and easily broken. Plants bearing proliferous culms may bear normal looking, but largely infertile spikelets. Observations made by Matt Hickler, Brian Reid, and Tom Rawinski during periodic visits to the MA .001 (Dartmouth) station have documented much variation from year to year in the amount of proliferation in the population. About 50% of the plants were proliferous in 1987, less than 5% in 1998, and proliferous plants were all but absent in 2002.

Information from periodic site visits to the two extant New England populations of *Eleocharis microcarpa* var. *filiculmis* suggests that abundant mature achenes are reliably produced. However, no germination was observed in a trial conducted at Garden in the Woods on 49 seeds from a 1999 collection (Christopher Mattrick, New England Wild Flower Society, personal communication). In this trial, seeds were dried to 20% relative humidity, then given a 90 day cold, moist stratification period, and finally sown outdoors in April. It is not clear whether the poor success was due to low seed viability, the small number of seeds sampled in the trial, or a need to adjust the protocol followed in the trial. However, presuming a strictly annual life history (more observations are needed to confirm this), seed germination under natural conditions has clearly been sufficient to maintain the oldest known population (MA .001 [Dartmouth]) since its discovery in 1987.

Dispersal

Seed dispersal in *Eleocharis microcarpa* has apparently not been studied. However, some inferences can be drawn from information on other members of the genus and field observations. Fresh achenes scattered on a bowl of water float for approximately 48 hours before finally sinking (Hickler, personal observation). The species has a strong affinity for periodically flooded habitats, suggesting hydrochory as a mechanism for local dispersal. Achenes of *Eleocharis* spp. are commonly eaten by water birds (Woodin and Swanson 1989, Ramey 1999) and, in one species (*E. quadrangulata*),

have been experimentally shown to remain viable after passing through the digestive systems of mallards and killdeer (de Vlaming and Proctor 1968). Passive hitchhiking of seeds in feathers of waterfowl or clinging mud is a well-known mechanism for dispersal in aquatic and wetland plants (Gleason and Cronquist 1964) and, because of the species affinity for pond shores and periodically flooded habitats, waterfowl could provide a competent vector for long-distance dispersal.

HABITAT/ECOLOGY

There are two extant stations and one historic record of *Eleocharis microcarpa* var. *filiculmis* in New England. This is insufficient for generalizing about the species habitat preferences and ecology, so I have fleshed out the discussion with information from regions where the species is more common. It should be understood that the ecological characteristics of a species might vary across its geographic range.

The two extant New England stations for *Eleocharis microcarpa* var. *filiculmis*, both in Dartmouth, Massachusetts, are on mineral soil in abandoned sand and gravel excavations. Both sites were excavated to below normal water table level and, thus, are shallowly flooded much of the time but periodically dry down. The only habitat information on the historic Connecticut station comes from a herbarium label noting that the collection came from the gravelly shore of the pond. South of New England, where *Eleocharis microcarpa* var. *filiculmis* becomes more common, typical habitats include coastal plain pond shores, wet sandy or peaty depressions in pine barrens, pine flatwoods, and wet pastures. Common features of these habitats include hydric soils, periodic flooding, and plenty of sunlight. The species appears to be indifferent to substrate type, growing anywhere from organic peat and mud to sand and gravel so long as hydrology and sunlight are suitable.

Eleocharis microcarpa var. *filiculmis* responds positively to disturbance that is severe enough to remove or inhibit competing species. Lemon (1949) classified *E. microcarpa* var. *filiculmis* among the "fire followers:" a group of species that rapidly colonize and spread in newly opened areas immediately following a fire, but decline in abundance in subsequent years. In seasonally flooded sand-pits, the species thrives in areas heavily disturbed by off-road-vehicle traffic (Reid 1999; Hickler, personal observation) with tire ruts from the previous season providing ideal seed beds for the following year's population. Coastal plain pond shores, one of the favored habitats for the species (Fernald 1943, U. S. Fish and Wildlife Service 1997), also fall in the class of high disturbance habitats (Wisheu and Keddy 1991) in the sense that the cycle of long duration flooding and periodic draw downs inhibits both obligate hydrophytes and shoreline wetland species, ensuring large expanses of open strand habitat, free from persistent competitors during low water years.

In suitable habitats, *Eleocharis microcarpa* var. *filiculmis* is often found in abundance. In southern New Jersey, it is often among the dominant species in coastal plain ponds with fluctuating water levels (U. S. Fish and Wildlife Service 1997) and is

also abundant in seasonal ponds and vernal pools. Pools in abandoned sandpits are an often-cited habitat (U. S. Fish and Wildlife Service 1997, Reid 1999, Knapp and Frye 2002). Interestingly, on Cape May, New Jersey, gravel pits that have been excavated down to the water table have species composition similar to that of coastal plain ponds. In Massachusetts, Reid (1999) has made similar observations, remarking on the abundance of coastal plain pond species in the abandoned sand and gravel excavations that support *E. microcarpa* var. *filiculmis* populations. Fernald (1937) considered *E. microcarpa* var. *filiculmis* to be among the "almost ubiquitous" species of the southeastern coastal plain of Virginia. Fernald (1943) documented carpets of *E. microcarpa* var. *filiculmis* covering a 50-foot-wide sandy strand on a Virginia coastal plain pond and noted that the population had broad amplitude with "some stranded, some deeply drowned."

Population History in New England

For purposes of this plan, I presume the rare New England occurrences represent immigration from population centers further south. There have been two documented colonizations in New England; one at a Connecticut pond shore and one at a Dartmouth Massachusetts sand pit that has spread to a second nearby station, also in an abandoned sand pit. The Connecticut station is documented by a single herbarium collection from 1907. There is no information about how long this population persisted at the site, but recent searches have not been successful (Les Mehrhoff, University of Connecticut, personal communication) and it is currently considered extirpated in Connecticut (Nancy Murray, Connecticut Natural Diversity Database, personal communication). Reports of *E. microcarpa* var. *filiculmis* from Rhode Island (e.g., Brumback and Mehrhoff et al. 1996) are based on this historic Connecticut station, which was on a pond that spans the Connecticut/Rhode Island state line (Rick Enser, Rhode Island Natural Heritage Program, personal communication).

Tom Rawinski discovered the first of two Dartmouth, Massachusetts stations in 1987. It occurs in a seasonally-flooded depression in a massive sand and gravel excavation site. According to Reid (1999), the site was stripped in the late 1960's to provide fill for the construction of Interstate 195, and prior to that time was covered in natural vegetation (this observation based on examination of aerial photos from the 1950's). Reid (1999) conducted a thorough search for additional stations and found one (sub)population in a nearby sandpit but failed to turn up any new occurrences in the abundant and varied natural wetland habitats surrounding the sites. He concluded that the sandpit populations could be remnants of former populations at the locus of the sand and gravel extractions. Given the absence of other populations anywhere in Massachusetts, I think it is more likely that the populations were established by long-distance dispersal from population centers further south after gravel extraction was completed. It is probable that one of the two Dartmouth stations was the original locus, with the second population established by local dispersal from the first (a distance of about 1500 meters). Both Dartmouth sites are heavily used by ORVs, which could provide a means of local dispersal in addition to natural vectors such as waterfowl.

Lacking evidence of any nearby historic or extant populations from which the Dartmouth site could have been colonized, a likely scenario is that, following creation of suitable habitat at the Dartmouth macrosite in the late 1960's, seeds from population centers in the mid-Atlantic or southeastern states were transported to the site either by natural means (e.g., waterfowl) or on construction equipment used for gravel extraction (highway construction equipment is commonly transported over long distances between distant work sites). An alternative possibility – that MA .001 (Dartmouth) was established from disseminules originating at the (closer) CT .001 (Voluntown) population–is, in my estimation, less probable than long distance dispersal from more distant population centers (e.g., New Jersey). The probability of seed dispersal to a new site is a function of both distance from the seed source and the quantity of seed produced at that source. Even if the Voluntown, Connecticut population (67 km from Dartmouth) was still extant after the late 1960's, population size (and reproductive output) would have been orders of magnitude lower than that in the more distant population centers (minimum distance ~450 km from Dartmouth). Thus, consideration of a more distant source for the parent population seems justified here. I assume that the two Dartmouth EOs are genetically isolated from all other populations, but genetically closely related to each other, and insufficiently isolated to preclude occasional exchange of genetic material (disseminules or pollen) between sites. For these reasons, I prefer to treat MA .001 [Dartmouth] and MA .002 [Dartmouth] as subpopulations. Founder effects in small, disjunct populations (low genetic diversity and high homozygosity) can increase extinction risk (Gilpin and Soulé 1986). However, disjunction and isolation may also promote genetic differentiation through selection, increasing genetic diversity of the species as a whole (Utter and Hurst 1990). Thus, the Massachusetts population may be, at once, less resilient in response to environmental challenges, and disproportionately important for the species' genetic diversity, than similar size populations in the center of its range.

In the course of preparing this Conservation Plan, questions arose about whether *Eleocharis microcarpa* var. *filiculmis* is indigenous or introduced to New England. At the request of the author, the Massachusetts Natural Heritage and Endangered Species Program (MNHESP) has completed a thorough review of the species status, which included evaluation of information compiled for this report and consultations with knowledgeable botanists (Appendix 2). Although recognizing that it is not possible to definitively establish whether the taxon is native or not, a conservative approach is warranted and the MNHESP will continue to track *E. microcarpa* var. *filiculmis* as a rare native species.

Population Potential in New England

Although rare in New England, *Eleocharis microcarpa* var. *filiculmis* is widespread and locally abundant on the Atlantic coastal plain to the south. The kinds of habitats the species favors in the center of its range (coastal plain pond shores, wet depressions in sandy pine forests, abandoned sand and gravel excavations) are common on the coastal plain of southern New England, and the species' limited distribution here

is apparently not due to lack of suitable habitat. *Eleocharis microcarpa* var. *filiculmis* is at the northern limit of its range in Massachusetts, and it may be that the species cannot tolerate more northerly climatic conditions. However, the population at MA .001 (Dartmouth) is robust and has persisted since at least 1987, indicating that it can survive and reproduce (short-term) under local climatic conditions. Published accounts of the species' habits outside New England indicate it can be regionally widespread and locally dominant in suitable habitats (see discussion under Habitat/Ecology above).

Population models for newly-recruited species with high biologic potential, where ample habitat is available, typically show a J-shaped curve; with a prolonged period of slow expansion, followed by logarithmic proliferation **(**Silvertown 1987). Given the species' biological potential and the abundance of suitable habitat in the region, it is reasonable to predict future population expansion – including recruitment to coastal plain pond communities. This brings up a difficult management issue: Would recruitment of *E. microcarpa* var. *filiculmis* to the region's rare coastal plain pond shore communities be a welcome expansion of a rare species or would it be cause for concern?

The Holocene expansion of southern species into the previously glaciated Northeast is well documented (Davis 1983) and presumably ongoing. Thus, the northward range expansion of southern species is a natural process and occasional recruitment of new species to the New England flora is to be expected. However, distinguishing between naturally-recruiting species and those whose range extension has been facilitated by human activities is a difficult issue facing biologists needing to discern native from non-native species (see Les and Mehrhoff [1999] for discussion). An introduced species would not normally be considered for listing or conservation management and may, in some instances, become a pest.

There is ample precedent for erstwhile rare North American species becoming aggressive to the point where they are considered invasive. For instance, *Najas guadalupensis* was formerly a listed rare species in Massachusetts (Sorrie 1987), but the proliferation of this species since the early 1970's has resulted in its more recent listing as a high-priority non-native invasive species in Massachusetts (Hellquist 1997, Les and Mehrhoff 1999). Similarly, the first occurrences of *Cabomba caroliniana* in New England were heralded with much interest among botanists (Manning 1937) but by the late 1950's its spread and aggressive behavior was causing alarm (Les and Mehrhoff 1999) and it is currently among New England's least wanted invasive species (Hellquist 1997). Like the aforementioned species, *Eleocharis microcarpa* var. *filiculmis* is a southern species with a history of being rare or absent in New England, and the biologic potential to be widespread and locally abundant in regions where it is well established (Fernald 1937, 1943; U. S. Fish and Wildlife Service 1997).

THREATS TO TAXON

The primary threats to *Eleocharis microcarpa* var. *filiculmis* in New England (which are common to most rare species) stem from the small number of populations

occupying a tiny geographic area, making a random walk to extinction due to stochastic population fluctuations highly probable (Ferson and Burgman 1990). Small, disjunct populations often have low genetic diversity and high homozygosity, resulting in reduced fitness, and less resilience in the face of environmental challenges, when compared to more genetically diverse populations (Utter and Hurst 1990). Both of these threats decrease with increasing population size, which is a primary goal of recommended conservation actions.

The species appears to have exacting hydrologic requirements, and although there are no current threats, alterations to hydrologic regimes are a potential threat to both populations. Problems with encroaching woody vegetation and off-road vehicles have been observed and identified as immediate threats at the Dartmouth macrosite.

Woody Plant Encroachment

Eleocharis microcarpa var. *filiculmis* appears to require open, sunny areas. Woody species are gaining prominence in the former graminoid/herbaceous wet meadows that surround the two Dartmouth sites and are encroaching on the edges of the areas occupied by *E. microcarpa* var. *filiculmis* (particularly at MA .002 [Dartmouth]). Hydrologic fluctuations in the occupied habitat may be sufficient to inhibit woody species invasion of prime habitat, but monitoring would be in order, and a plan for removal developed in the event active management at the sites is deemed appropriate.

Off-Road Vehicles

Off-road vehicles use both Dartmouth sites. Substantial mortality of *Eleocharis microcarpa* var. *filiculmis* was documented in 1998 and 2002. MA .001 (Dartmouth) is the more heavily impacted site, and in September of 2002 I estimated that about 30% of the prime habitat had been rendered bare sand by ORV traffic. However, Brian Reid (University of Montana, personal communication) and I independently came to the conclusion, following careful observations at the site, that far from being a threat to survival, disturbed soil provides an ideal seedbed for seedling establishment. *Eleocharis. microcarpa* var. *filiculmis* is an annual and depends on seeds for establishing each years population. Tire ruts and disturbed patches appear to be favored sites for seedling establishment the following year. Late-season destruction of adult plants (following seed set) is of little consequence to the population and a moderate amount of mechanical disturbance probably benefits the population overall. ORVs may also provide an effective vehicle for seed dispersal. Riders seem to find mud and shallow water irresistible and mud-bound seeds adhering to vehicles could be carried some distance between suitable sites. It is notable that the two subpopulations at the Dartmouth macrosite are both on active ORV trails.

DISTRIBUTION AND STATUS

General Status

Eleocharis microcarpa var. *filiculmis* ranges along the east coast of North America from Massachusetts south to Florida and along the Gulf Coast west to Texas. It becomes less common with distance from the coast and at higher latitudes. Disjunct populations occur in the Great Lakes region in Indiana and Michigan. It is globally secure (G5) but regionally rare in New England with a *Flora Conservanda* Division 2 rank (Brumback and Mehrhoff et al. 1996). In the mid-Atlantic, southeastern, and Gulf states, it is ranked S4, S5, SR or S? It is probably secure in those states where it has an SR rank. Its status in New York and Pennsylvania, near the edges of its range, needs to be determined (S?). The species is critically imperiled (S1) in Massachusetts, Michigan, and Indiana at the northern and western extremes of its range. Arkansas lists *Eleocharis microcarpa* var. *filiculmis* as imperiled (S2). Connecticut lists the species as historic (SH) based on a single collection from 1907. It is widespread and locally abundant in the center of its range along the coast from roughly Cape May New Jersey to Louisiana and Texas. The State Ranks (above) and in Table 1 (below) are from NatureServe (2002). A description of the ranking system is provided in Appendix 3.

Table 1. Occurrence and status of *Eleocharis microcarpa* var. *filiculmis* 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)
Arkansas (S2)	Georgia (S4)	Alabama (SR)	Connecticut (SH): One historic occurrence; last observed in 1907.
Indiana (S1)	Maryland (S4)	Delaware (SR)	
Massachusetts (S1, E): 2 extant occurrences	New Jersey (S4)	Florida (SR)	
Michigan (S1)	New York (S?)	Louisiana (SR)	
	North Carolina (S5)	Mississippi (SR)	
	Pennsylvania (S?)	South Carolina (SR)	
		Tennessee (SR)	
		Texas (SR)	
		Virginia (SR): Considered “almost ubiquitous” on the southeastern coastal plain by Fernald (1937)	

Note: Brumback and Mehrhoff et al. (1996) list *Eleocharis microcarpa* var. *filiculmis* from one Rhode Island site. This citation was based on a specimen from Connecticut on a pond that spans the CT/RI state line, but the species has not been documented from the Rhode Island shore (Rick Enser, personal communication).

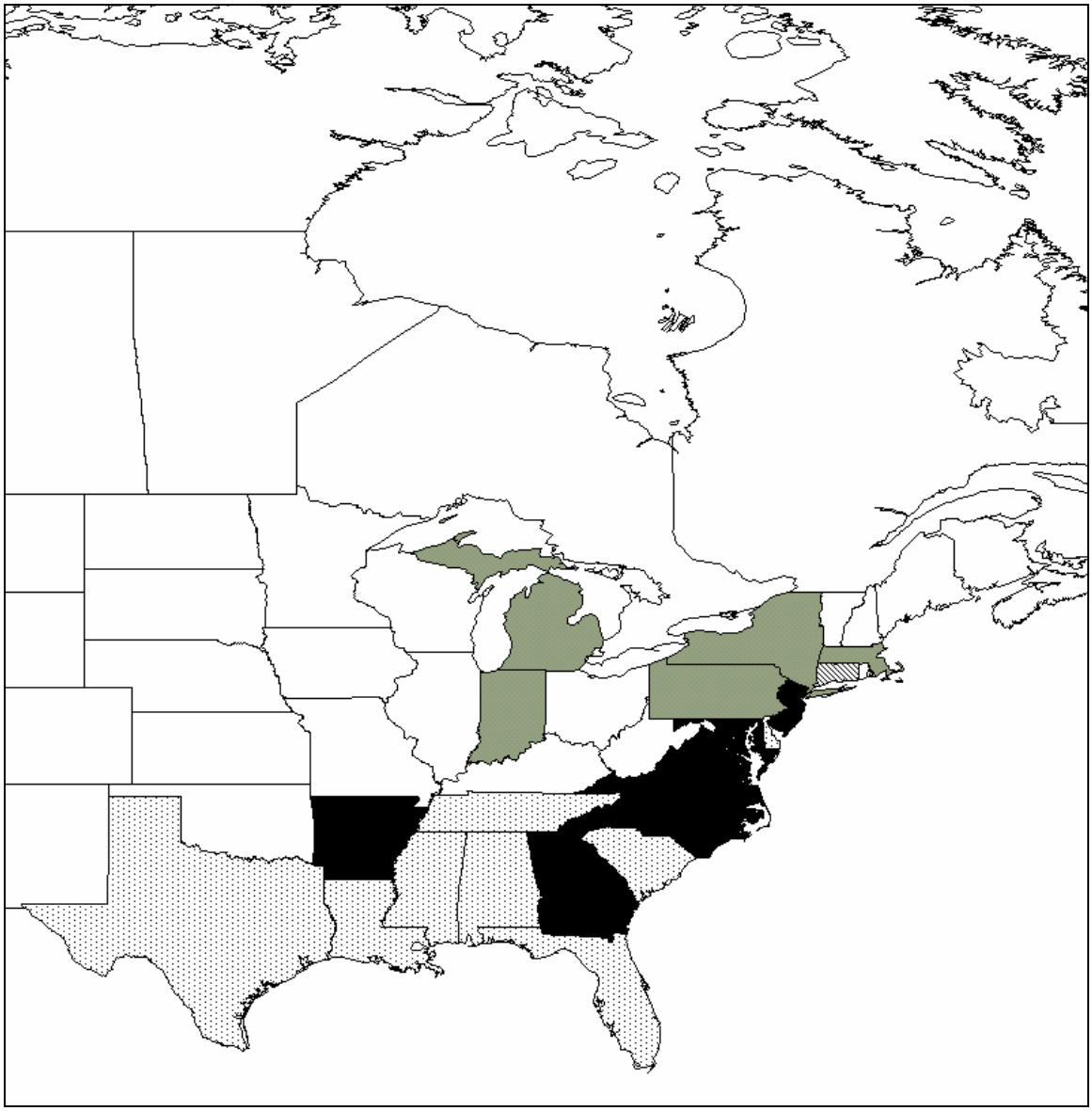

Figure 1. Occurrences of *Eleocharis microcarpa* var. *filiculmis* in North America. States shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. States shaded in black have more than five confirmed occurrences. The state (Connecticut) with diagonal hatching is designated "historic," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported" but not necessarily verified). See Appendix 3 for explanation of state ranks.

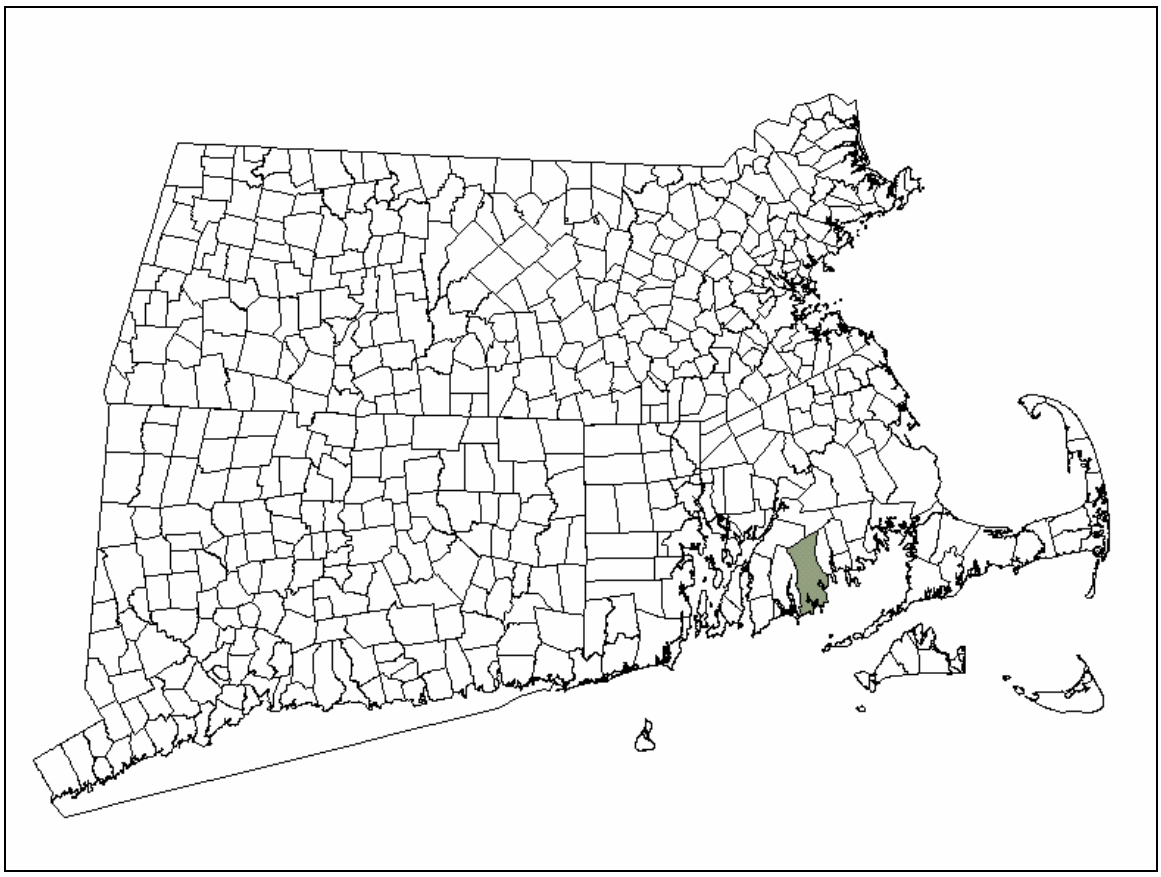

Figure 2. Extant occurrences of *Eleocharis microcarpa* var. *filiculmis* in New England. Town boundaries for southern New England states are shown. Towns shaded in gray have one to five extant occurrences of the taxon.

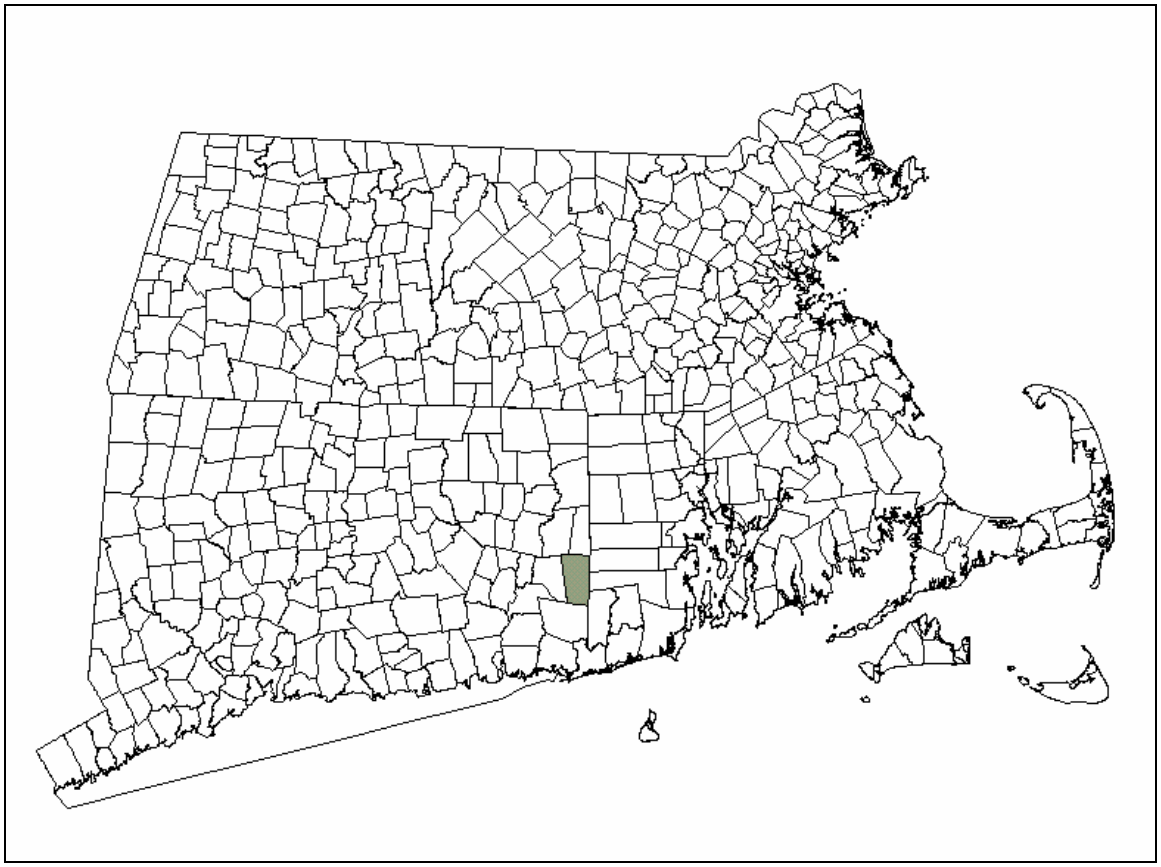

Figure 3. Historical occurrences of *Eleocharis microcarpa* var. *filiculmis* in New England. Towns shaded in gray have one to five historical records of the taxon.

Table 2. New England Occurrence Records for *Eleocharis microcarpa* var. *filiculmis.* Shaded occurrences are considered extant.			
State	**EO #**	**County**	**Town**
MA	**.001**	**Bristol**	**Dartmouth**
MA	**.002**	**Bristol**	**Dartmouth**
CT	.001	New London	Voluntown

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

In general, conservation measures for rare species are geared towards mitigating changes in a species' distribution or abundance that have been caused, directly or indirectly, by human activities. The objective is typically to restore populations to historic levels, and ensure that the ecological processes necessary to promote long-term viability of the species are intact. Conservation professionals do not usually endorse artificially enhancing rare species populations to levels greater than that which would be expected under natural conditions (Ken Metzler, Connecticut Natural Diversity Database, personal communication).

The case of *Eleocharis microcarpa* var. *filiculmis* is unusual in that, based on the best information available, the taxon has always been exceedingly rare in New England and populations have never achieved levels that would be considered viable by usual standards. The two currently extant New England stations in Dartmouth, Massachusetts (perhaps best treated as two subpopulations of a single population) represent the highest population level ever documented. Indeed, between 1907 (the only record for CT .001 [Voluntown]) and 1987 (the first report for MA .001 [Dartmouth]) the species was not verified from anywhere in New England. There is no reason to implicate human activities with loss of the historic Connecticut population, and thus, without the sand and gravel excavations, which provided habitat for the Dartmouth Massachusetts populations, the species would likely be absent from New England today.

Because the habitat at the Dartmouth macrosite is entirely artificial, and favorable disturbance regimes have been maintained at the site by human activities, restoring the natural landscape or ecological processes would jeopardize the species. The occupied sites are in the process of recovering from mining; a thin, peaty organic layer is forming over the exposed sand, and woody vegetation and more aggressive perennial species are becoming more prominent (Reid 1999). Because the species is shade-intolerant, succession at the sites could pose a problem for *Eleocharis microcarpa* var. *filiculmis*.

Evidence suggests that *Eleocharis microcarpa* var. *filiculmis* is a newly arrived species (or a casual immigrant from southern population centers) which has yet to successfully spread from initial colonization loci, or to proliferate sufficiently, to be recruited as a viable member of the New England flora. Theory predicts that following initial colonization, a newly arrived species will go through a period when it is necessarily rare, and must expand sufficiently before being considered a viable recruit to the regional flora. In the period between colonization and recruitment, a species is highly vulnerable to extinction and even a well-adapted species may experience multiple colonization and extinction events before finally becoming firmly established. Following a sometimes-protracted period of rarity, a colonizing species with strong biologic potential and ample habitat may experience logarithmic expansion.

Observations on *Eleocharis microcarpa* var. *filiculmis* habits, habitat preferences, distribution and demography in regions where it is well established suggest no reason why it could not become widespread and locally abundant on the coastal plain of New England. From New Jersey south, the species is a prominent – often dominant – component of coastal plain pond floras and is a conspicuous component of many other wetland community types. Suitable habitat is plentiful in coastal New England and population expansion from the Dartmouth, Massachusetts locus is likely.

Prior to designing management strategies for *Eleocharis microcarpa* var. *filiculmis* in New England, it is essential to objectively evaluate its current status, population history, population potential, and factors that have contributed to its current distribution. *Eleocharis microcarpa* var. *filiculmis* has broad ecological amplitude, high local population potential, and affinity for natural habitats with high conservation value and concentrations of rare species (e.g. coastal plain ponds). The Massachusetts Natural Heritage and Endangered Species Program has reviewed the status of *E. microcarpa* var. *filiculmis* in Massachusetts and concluded that it is a native species, effectively removing the potentially contentious issue of whether implementing a conservation strategy that might result in the species proliferation is warranted.

The prognosis for *Eleocharis microcarpa* var. filiculmis in New England is not good unless it can spread to additional sites. Long-term maintenance of the status quo (two nearby sites with a total occupied area of a few hundred square meters) is not viable, simply by virtue of the fact that such a limited and spatially concentrated distribution leaves the species highly prone to extinction. Prospects for long-term viability of *Eleocharis microcarpa* var. *filiculmis* will improve once it has spread to multiple sites in the local area around the current stations, and the species will be relatively secure once it has spread to two or three areas remote from the current locus.

Conservation measures need to consider the fact that the favorable conditions at the site are wholly the product of human activities, and effective management may require provisions perpetuating some unnatural ecological processes. However, success of a newly established colony, even under ideal conditions, is never assured, and heroic efforts to prevent the natural failure of the population at the Dartmouth macrosite would be misguided.

The primary conservation objective for *Eleocharis microcarpa* var. *filiculmis* is its expansion to three or four wide-ranging population centers on the southern New England coastal plain. Suitable habitat is plentiful from southern Maine south to New York, and there is little reason to favor any particular regions, however, having populations scattered over a wide geographic range will provide the best security. The species' propensity to occupy small, insular, disturbance-prone habitat patches suggests it may function well as metapopulations (clusters of subpopulations linked by dispersal). Thus, each population center should consist of several subpopulations in a local region. I do not recommend introducing new populations, which would have the effect of *artificially* increasing the species' distribution and population levels beyond those which can be historically documented. Rather, I suggest these objectives as desirable goals,

which, if met through the natural expansion of the species, would help ensure its long-term viability. The first benchmark to look for is local expansion to natural habitats surrounding the Dartmouth, Massachusetts site. Prospects for expansion to new (local) sites improve the longer the current population remains extant and robust. Prospects for regional expansion improve as the local population grows and reproductive output increases. Thus, the recommended management strategy centers on prolonging the species' residency and promoting local vigor at the Dartmouth Massachusetts macrosite.

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IV. APPENDICES

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1. **Status of *Eleocharis microcarpa* var. *filiculmis* in Massachusetts**

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

2. Status of *Eleocharis microcarpa* var. *filiculmis* in Massachusetts

Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries & Wildlife

November 6, 2003

Dear Matt,

Thank you very much for your recent email explaining the reasons you question whether *Eleocharis microcarpa* var. *filiculmis* should be considered indigenous to Massachusetts. We very much appreciate the points you raised in your letter, which spurred us to re-examine our position on the status of this taxon, and even to re-examine our definition of "native." In the process, we have also gratefully received comments from Bruce Sorrie and Tom Rawinski.

Paul and I both agree that it is not possible (at this point in time, at least) to definitively know whether this taxon is native to Massachusetts or not. However, for now the Natural Heritage and Endangered Species Program (NHESP) will continue to consider *Eleocharis microcarpa* var. *filiculmis* as native here in the Commonwealth for the following reasons:

1) It has been found growing in Massachusetts in habitat that is very characteristic of the species in its natural range; namely, disturbed, seasonally wet, acidic habitat along the coastal plain. In other words, it is found precisely where you would expect to find it were it native here.

2) It has been found growing in Massachusetts with the associates with which it typically grows in its natural range, such as *Sabatia kennedyana*, *Rhynchospora capitellata*, *Euthamia tenuifolia*, *Eleocharis tuberculosa*, *Cladium mariscoides*, and *Drosera intermedia*. In other words, it grows with precisely the species you would expect were it native here.

3) Less disturbed wetland habitats supporting similar plant communities have been documented in close proximity to the existing habitat of *E. microcarpa* var. *filiculmis*. Both Tom and Bruce recall a nearby "*Cladium* swale" just north of the EO which could very well have supported this species in previous times, and been a seed source for the existing population. You mention in your conservation plan that *E. microcarpa* is considered a "fire follower;" Paul suggests the possibility that a residual seedbank could be present from past decades when the landscape was more open due to burning and grazing.

4) While immediate areas of appropriate, natural habitat were searched for this species during one season, this should not be considered an exhaustive search. We contend that we cannot assume that seed arrived from out-of-state until careful searches for this inconspicuous species have been made throughout Southeastern Massachusetts. As Bruce points out, "very few botanists can walk through mixed populations of *E. microcarpa*, *E. aciculare*, and *E. olivacea* and see differences, unless they are specifically looking for them." We need to give serious consideration to the possibility that the species may not be newly arrived here, but merely recently detected.

5) Even if seed did arrive from sources to our south relatively recently, we cannot rule out the possibility that the species arrived naturally, as in the case of bird dispersal, and that this is simply a natural extension of the species' range. As you point out, the flora of any region is not static. Bruce takes the position that this species likely came to be here through natural dispersal, and that it should be treated as a more recently arrived member of our native flora. This point begs the question: How should one evaluate whether newly-arrived species are new members of our native flora undergoing natural range expansion (welcome), or other (unwelcome) introductions? Natural range expansion certainly blurs the line of "native" vs. "introduced," and illustrates the artificiality of establishing one point in time at which present plants are

considered “native.” We may need to adjust our definition of “native” so that there is not such a temporal emphasis, but more of an emphasis on natural vs. anthropogenic dispersal. Of course, that emphasis has its own set of drawbacks. Any suggestions?

In the case of *E. microcarpa* var. *filiculmis*, the current habitat was obviously anthropogenically created, but we can’t be sure that the seed was “artificially” introduced by construction equipment (at least not any more sure than any natural means of dispersal). Neither can we be sure that there was not *formerly* natural habitat at that site, nor that there is not other natural habitat currently occupied by this species in Massachusetts. I think it is quite plausible that the seed either arrived naturally, or has been present and simply uncommon, and is as yet undetected in other places here. Until we know for certain that the introduction was anthropogenic from another state, I think NHESP has the responsibility of “giving the plant the benefit of the doubt” (a Rawinski-ism!), especially since it is growing in characteristic habitat and with predictable associates.

6) The documentation of the species in coastal Connecticut suggests that there could possibly be more local seed sources in New England. Though the population in Voluntown is no longer thought to be extant, Connecticut has considered this population to be native and lists the species as of “Special Concern.” Have careful searches of appropriate habitat been conducted in Connecticut? I’ve been trying to reach Les for more details on the amount of searching in that area, as well as for a defense of why Connecticut considers the plant to be native.

7) Disjunct populations of *E. microcarpa* var. *filiculmis* have been documented in other northern states, such as Indiana and Michigan. Both of these states consider their disjunct populations of *E. microcarpa* var. *filiculmis* to be native and list the species as Endangered.

I hope this letter sufficiently explains why, while acknowledging the possibility that *E. microcarpa* var. *filiculmis* could be an anthropogenically-introduced species in Massachusetts, we will continue to treat it as a native species until proven otherwise. Thank you again for inspiring a re-evaluation of our position on this species!

Sincerely yours,

Melissa Dow Cullina
Botanist, Massachusetts Natural Heritage and Endangered Species Program

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.