New England Plant Conservation Program

Nabalus serpentarius Pursh

Prenanthes serpentaria Pursh

Lion's Foot

Conservation and Research Plan
For New England

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SUMMARY

Nabalus serpentarius Pursh, previously *Prenanthes serpentaria* Pursh, is a member of the Asteraceae, tribe Lactuceae. Its status is G5 and N5, demonstrably widespread, abundant and secure. It is distributed throughout the southeastern United States from northern Florida, west to Mississippi, Tennessee, Kentucky, and Ohio, and north to New England. There are herbarium collections of the species in New Hampshire, Massachusetts, Rhode Island, and Connecticut, but extant populations are found only in Massachusetts and Connecticut. There are seven populations in Massachusetts where the species is ranked S1, critically imperiled. The largest population contains about 50 individuals. The remaining populations have fewer than 20 plants, and three of these populations have not been seen since 1989. In Connecticut, there may be eight populations, but the state does not rank or track the species. Many of these populations are on protected land, but such small populations are vulnerable to extirpation from natural disasters or random environmental or population fluctuations.

Nabalus serpentarius is considered a long-lived perennial, but recent observations indicate that individuals are monocarpic and flower once and die. The flowers are visited by insects, and the achenes are dispersed by the wind. It is not known whether the species is outcrossing or is able to self-pollinate. Populations that occur on Nantucket and Martha's Vineyard are associated with coastal heathlands, while inland populations are found in open woods or mown sites. The populations are associated with disturbance. Flowering is observed in open habitats, and the use of fire, mowing, or other management to maintain the habitat in an open state is recommended.

If *Nabalus serpentarius* is a short-lived, self-incompatible species, then examples from the literature of species with similar characteristics indicate that a population size of 100 individuals might be the minimum viable population. If *Nabalus serpentarius* is self-fertilizing or apomictic, then smaller populations might suffice. Before a population size and number goal can be adopted, more information on the species biology is needed. Pollination, germination, and longevity studies will provide the information to make an informed decision on minimum viable population size.

Among the actions recommended are continued monitoring to determine whether the smaller populations have disappeared and to determine the status of the species in New Hampshire, Connecticut, and Rhode Island. Continued management of extant populations is strongly recommended. Most important is the collection of species biology information so that an informed decision on minimum population size can be made. If larger populations than can be secured with management alone are the goal, then a supply of seeds or seedlings will be needed for augmentation of existing populations. However, this species is secure in the southeastern United States, and it is recommended that the simpler monitoring and management actions be implemented until more species biology information is available.

PREFACE

This document is an excerpt of a New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. Because they contain sensitive information, full plans 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.

NEPCoP is a voluntary association of private organizations and government agencies in each of the six states of New England, interested in working together to protect from extirpation, and promote the recovery of the endangered flora of the region.

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

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

Completion of the NEPCoP Conservation and Research Plans was made possible by generous funding from an anonymous source, and data were provided by state Natural Heritage Programs. NEPCoP gratefully acknowledges the permission and cooperation of many private and public landowners who granted access to their land for plant monitoring and data collection. If you require additional information on the distribution of this rare plant species in your town, please contact your state's Natural Heritage Program.

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I. BACKGROUND

INTRODUCTION

Nabalus serpentarius, previously called *Prenanthes serpentaria*, is a southeastern plant at the northern limit of its distribution in New England (Table 1 and Figure 1). It is secure in the southeast and is globally ranked G5. In New England, it has never been reported in Maine or Vermont, but is represented by herbarium specimens from New Hampshire, Massachusetts, Rhode Island, and Connecticut. Extant populations are found only in Massachusetts, where the state ranks it S1, and Connecticut, where it is not ranked. One population in Massachusetts has a total of about 50 flowering individuals in 4 or more subpopulations. Two other populations have between 10 and 20 flowering individuals, and three populations have not been observed since 1989. One population has only been observed vegetatively. In Connecticut, flowering plants have not been observed in recent years, but there are reports of vegetative plants from six locations and other reports that need to be investigated. The ranking in *Flora Conservanda* (Brumback and Mehrhoff et al. 1996) is based on L. Mehrhoff's personal knowledge (L. Mehrhoff, Curator, Torrey Herbarium, personal communication). This taxon exists in small, scattered populations throughout its range; the New England populations are adapted to this climate and are deserving of conservation to preserve the adaptation and the geographic range of the species.

Nabalus serpentarius is a member of the Asteraceae, tribe Lactuceae. Until recently, this species was considered to be in the genus *Prenanthes*, which included European, Asian, African and North American species. Recent research has shown that a more accurate representation of the relationships of these species is to separate the European species in the genus *Prenanthes* from the North American species, which are placed in the genus *Nabalus* (Kim et al. 1996). Common names used for this taxon include lion's foot, gall-of-the-earth (Fernald 1950), and cankerweed (USDA 2001).

Nabalus serpentarius is an herbaceous, taprooted, long-lived perennial or monocarpic plant (B. Perry, Property Manager, Nantucket Land Bank Commission, personal communication). The flowering stems can be 1 to 2 meters tall and the leaves are pinnately lobed (or simple in one variant). The paniculate inflorescence contains drooping capitula composed of ligulate flowers. Insects have been observed visiting the flowers, but the pollination biology is unknown. The achenes are dispersed by the wind. Achene germination experiments on Massachusetts collections have been largely unsuccessful (C. Mattrick, New England Wild Flower Society, personal communication).

Five of the populations of this taxon are found on Nantucket and Martha's Vineyard Islands in Massachusetts growing in coastal heathland communities where the soil is sandy and acidic. These are fire-adapted communities (Barbour et al. 1998), and, in the absence of fire, a portion of the site of the largest population is maintained in an open state by mowing. The inland populations occur in open, rocky woods and in a power line right of way. Several of the populations are associated with the disturbance of trails or roadsides, and flowering has only been observed in open habitat. The immediate threats to these existing communities are shading by trees and shrubs and browsing by deer. Herbarium collections indicate that this taxon was more widely distributed in New England 100 years ago (Figure 3). Its current rarity could relate to the absence of open habitat as New England has changed from 25% coverage by forest to 80% since 1850 (O'Keefe and Foster 1998).

Nabalus serpentarius appears to fit the definition of a sparse species with small populations as described by Rabinowitz (1981), and the populations observed in New England may be the normal size for the taxon. However, small populations of plants are at greater risk of extinction (Fischer and Stocklin 1997) and are more vulnerable to random genetic, demographic, and environmental variability than are large populations (Menges 1991). These considerations and a review of some of the literature on minimal viable population sizes (see below) lead to the suggestion that long-term survival of the species in New England might be promoted by populations of 100 or more individuals of *Nabalus serpentarius* or by the addition of more populations of 10 to 20 individuals. Minimum viable population size is derived from data on the pollination biology of the species, on longevity and germination of achenes, on seedling survival, on longevity of individuals, and on demography. Collection of such information is recommended before actions to produce populations of 100 or more individuals are undertaken.

DESCRIPTION

Nabalus serpentarius produces branching, tuberous roots and a flowering stem about 45-190 cm tall with milky latex sap. The stem is green or often purplish in color and glabrous or often rough-hairy in its uppermost portion. Its leaves are alternately arranged on the stem and become smaller in size toward the top. Their overall shape is typically longer than wide with pinnate lobes. Basal leaves may be trifoliate and further divided (Gleason and Cronquist 1991). Very wide leaves may appear palmate (Milstead 1964). Milstead (1964) has sketched leaves of the American *Nabalus* species, and *Nabalus serpentarius* is distinguished from other species by leaves that are longer than wide and pinnately lobed. Identification of this species based on leaf shape may be possible if these characteristics are clear. Leaf petioles are often winged, especially the lower ones, and there may be fine, small hairs on the veins of the lower surfaces. Those plants with leaves entire or dentate and with short winged petioles are named *forma simplicifolia* (Fernald 1942; illustrated in Holmgren 1998). This form has been collected in Rhode Island, Pennsylvania, Virginia, North Carolina, and Georgia.

The inflorescences of this composite are paniculate to corymbiform in the upper 1/3-1/4 of the plant (Milstead 1964), with nodding cylindrical heads mostly clustered at the ends of elongate branches with pubescence, if any, like that of the upper stem. The involucral bracts, or phyllaries, are 2-ranked, an arrangement called calyculate, with about 8 inner, primary phyllaries 8-14.5 mm long, greenish, sometimes with purplish areas, and a short outer series of 5-9 lanceolate phyllaries about 1.5-3 mm long (Milstead 1964). Gleason and Cronquist (1991) further specified that these outer bracts are at least 2.5 times as long as wide. Authors differ somewhat as to the hairiness of the phyllaries. Most have described it as coarse or hispid, and most have said that at least a few hairs, sometimes many, will be present (Milstead 1964, Johnson 1980, Gleason and Cronquist 1991). Others (Fernald 1950, Radford et al. 1964, Magee and Ahles 1999), however, claimed that the involucres may at times be wholly glabrous. Milstead (1964:44) states "no specimens have been examined that were completely glabrous on all the phyllaries."

Each head bears 9-13 flowers with yellow, yellow-green, or cream-yellow corollas that darken with drying (Milstead 1964). Fernald (1950) included pink in the color range. Each flower is 11-14 mm long, with about half its length in the tube (Milstead 1964). The flowers are seated on a small, naked receptable (Gleason and Cronquist 1991), and they develop achenes with an attached pappus and should properly be called cypsela (Haines and Vining 1998). The achenes are subterete or angled in cross-section, elliptic to linear, brown to light tan, indistinctly ribbed, and about 4.5-7.5 mm long (Milstead 1964). Pappi are composed of unbranched capillary bristles and range in color from white through creamy to tan or light brown (Fernald 1950, Milstead 1964, Magee and Ahles 1999).

Among similar genera of the composites, *Crepis* and *Hieracium* differ in flower color, and *Lactuca* and *Sonchus* differ in producing flattened achenes with beaks. In New England, *Lactuca* may be the most similar to *Nabalus*. In addition to the flattened achenes, *Lactuca canadensis* has its yellow flowers upright rather than drooping and at least 13 of them per head. *Lactuca biennis* may have yellow or white flowers, but they are usually blue, and at least 15 per head.

Among *Nabalus* species that occur in New England, *N. racemosus* has hairy phyllaries, but its flowers are usually purplish and more or less erect on short branches in a cylindric inflorescence. Our other species, except for *Nabalus serpentarius*, have hairless phyllaries. *Nabalus nanus* and *N. boottii* are dwarf alpines with blackish phyllaries. The remaining four species occur in woodland or open habitat in New England. Among these, *Nabalus altissimus* has only 5 or 6 flowers per head and a similar number of inner phyllaries; it also has a white pappus and stem leaves sometimes unlobed. *Nabalus albus* has a pappus that is cinnamon-brown or reddish-brown. Among the woodland species, *Nabalus trifoliolatus,* is the most similar to *Nabalus serpentarius*. The former has inner phyllaries about as long as the pappus; in *Nabalus serpentarius* they are slightly shorter. The small outer phyllaries are, in *Nabalus trifoliolatus*, ovate and mostly less than 2.5 mm long; they are generally shorter and proportionately broader than in *N. serpentarius.* According to Gleason and Cronquist (1991), the inner phyllaries of *Nabalus serpentarius* are also often speckled with fine black dots, whereas those of *N. trifoliolatus* show larger, waxy-looking papillae.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Information in this section not otherwise attributed is derived from Milstead's (1964) thesis, *A Revision of the North American Species of* Prenanthes. The genus *Prenanthes* was named by Vaillant in 1721, and six species, two from North America, were included in *Species Plantarum* by Linnaeus in 1753. In 1825, Cassini placed the North American taxa in the new genus *Nabalus*, a practice that continued in manuals through the start of the twentieth century, even though various nineteenth century authors considered *Nabalus* a subgenus of or a synonym for *Prenanthes*. *Gray's Manual of Botany* in 1890 was one of those manuals treating *Nabalus* as a subgenus; and most twentieth century authors used the generic name *Prenanthes*. Pursh described the species *Prenanthes serpentaria* in 1814, and Britton and Brown (1913) used the name *Nabalus serpentarius* (Pursh). Pursh (1814) described the flowers as pale purple in color, whereas later authors described them as yellow or creamy yellow (Milstead 1964; Fusiak and Schilling 1984). This led to confusion of the taxon with *Nabalus albus*, which can have pale purple flowers (Fusiak and Schilling 1984).

In 1964, Milstead suggested dividing *Prenanthes* into two subgenera, *Prenanthes* and *Nabalus*. Subgenus *Prenanthes* has leaves only slightly reduced upward on the stem, 5 or fewer phyllaries and flowers per head, red or purple flowers, simple hairs on the corolla, about 5 vascular bundles in the ovary, and a chromosome number of x=9. Subgenus *Nabalus* has leaves reduced upward on the stem, usually more than 5 phyllaries and flowers per head, white, lavender, or yellow flowers, glabrous corollas, 5-20 vascular bundles on the ovary, and a chromosome number of x=8. Taxa of the subgenus *Prenanthes* occur in Europe, southern and northeastern Asia, and Africa, while taxa of the subgenus *Nabalus* occur in North America, Japan, and northeast China.

Kim et al. (1996) used sequence variations in internal transcribed spacers of nuclear ribosomal DNA to test relationships of several genera of composites related to *Sonchus*, and the investigation included three species of *Prenanthes*. The research showed that *Prenanthes*, as used in the twentieth century to include the subgenera *Prenanthes* and *Nabalus*, is paraphyletic. An African species was not closely related to the other two species. The member of the subgenus *Nabalus*, *Prenanthes altissima*, was more closely related to *Taraxacum officinale* than to a European member of the subgenus *Prenanthes*. Therefore, Milstead's (1964) subgenera *Nabalus* and *Prenanthes* are considered distinct genera, *Nabalus* and *Prenanthes,* in this paper.

Synonyms for *Nabalus serpentarius* are *Prenanthes serpentaria, Nabalus integrifolius* (Britton and Brown 1913); Milstead (1964) found the following synonyms in the literature: *Prenanthes folio scabro inciso, Esopon glaucum, Prenanthes glauca, Prenanthes crepidinea, Harpalyce serpentaria, Nabalus fraseri,* and *Nabalus glaucus*.

Nabalus serpentarius is a member of the family Asteraceae, tribe Lactuceae (or Cichorieae), subtribe Crepidinae (Whitton et al. 1995). All members of the tribe have floral heads or capitula composed solely of ligulate or ray flowers. The distinguishing characteristic of the subtribe is the presence of a pappus of simple, slender bristles

(Stebbins 1953, Milstead 1964). Other genera of the subtribe occurring in New England are *Lactuca, Hieracium, Crepis, Taraxacum,* and *Sonchus*.

Stebbins (1953) studied the tribe Cichorieae (Lactuceae) and found the most primitive members in central Asia. He suggested that its present-day representatives all around the globe could be traced back to that source. Milstead studied the distribution of *Prenanthes* and *Nabalus* and the literature on related genera; he also suggested that the genera originated in eastern Asia, that migration occurred west into Europe and east across the Bering Strait during the late Tertiary. During the spread through North America further differentiation of species of *Nabalus* occurred.

Milstead described thirteen species of *Prenanthes*, now *Nabalus*, in North America; he considered these species to be in subgenus *Nabalus*, section Nabalus. He further suggested categorizing them in three subsections. Subsection Crepidineae contains the more primitive species: *Nabalus crepidineus, N. barbatus, N. alatus, N. sagittatus, and N. boottii*. Two of these species occur in the west: *Nabalus alatus* is found on the coast from Oregon to the Aleutian Islands, and *N. sagittatus* occurs in the mountains of Montana and Idaho and in the adjoining Canadian provinces. Subsection Racemosae includes *Nabalus racemosus, N. asperus,* and *N. autumnalis;* all with racemose inflorescences. Subsection Altissimae occurs in the eastern forests and is composed of *Nabalus roanensis, N. albus, N. altissimus, N. trifoliolatus,* and *N. serpentarius.* They are distinguished from each other by flower color, leaf shape, pubescence and number of phyllaries. *Nabalus roanensis* occurs in the mountains of Tennessee, North Carolina, and Virginia; the other taxa have ranges that extend into New England.

The chromosome number of all the American species is n=8, and *Nabalus albus* is the only polyploid taxon (Vuilleumier 1973). In an investigation of the *Nabalus roanensis* complex, comprising *N. roanensis, N. altissimus,* and *N. serpentarius*, Fusiak and Schilling (1984:340) stated that there are problems with the genus due to "extreme variation in some morphological characters (especially leaves), paucity of characters that distinguish between species, and suspected natural hybridization between species." Their investigations, however, revealed no meiotic abnormalities and thus no evidence of hybridization among the taxa investigated. *Nabalus trifoliolatus* was not included in their study but is similar to *N. serpentarius* in morphology, and the two species have been observed growing together (Everett, personal observation). There is no information on whether hybridization occurs between them.

SPECIES BIOLOGY

The members of the genus *Nabalus* are described as perennial herbs with milky sap and tuberous roots (Fernald 1950, Milstead 1964, Cronquist 1980, Gleason and Cronquist 1991, Magee and Ahles 1999). No one has observed vegetative reproduction in the species except one description on a field form of more than forty leaves covering 1 square meter that the observer suggested were probably part of one genet. The members of this genus in New England grow in dispersed groups of 1 to 20 flowering stems (Everett, personal observation). Observers in the southern United States do not observe groups of hundreds of individuals of *Nabalus serpentarius,* rather they report individual plants or scattered individuals often occurring in disturbed areas (J. Matthews, Habitat Assessment and Restoration, personal communication; M. Pyne, Regional Vegetation Ecologist, NatureServe, personal communication). Rabinowitz (1981:208) has characterized one class of rare plants as "constantly sparse in a specific habitat but over a large range;" *Nabalus serpentarius* seems to fit into this class of plants.

Bruce Perry (personal communication) and Buckley et al. (1998) have observed one population of *Nabalus serpentarius* on Nantucket Island for several years. They have observed that flowering plants marked one year do not return in the next year; this brings into question the belief that members of this taxon are long-lived perennials. They believe that the plants die after flowering and are therefore monocarpic. Perry has observed basal rosettes of leaves that do not produce flowers during the growing season; these rosettes may need to grow for a year or more before flowering.

Nabalus serpentarius produces a flowering stalk in late August and September and releases achenes in late September and October. Bees have been observed visiting the flowers (Everett, personal observation, Buckley et al. 1998), suggesting conformity with the insect pollination seen in many other members of the Asteraceae (Berry and Calvo 1989, Les et al. 1991, Byers 1995, Morgan 1999, Wolf et al. 1999, Luijten et al. 2000). For dispersal, the seeds have a pappus and are spread by the wind. The length of time during which the achenes are viable in the soil is unknown. A study of a species of *Lactuca* (Prince and Hare 1981) showed that the half-life of the achenes in the soil was 1.5 to 3 years.

Germination experiments on seeds of *Nabalus serpentarius* have been carried out at the New England Wild Flower Society (C. Mattrick personal communication). Fifty seeds were planted and kept in a greenhouse over the winter. No germination was observed, and the pots were moved outside. A year later there were 3 seedlings and in the next year there were 8 seedlings. This indicates that a cold treatment may be required for germination. One of these seedlings survived another year but has not yet flowered.

Although no information is available about the breeding system of *Nabalus,* members of the Asteraceae are usually found to have a sporophytic, multiallelic self-incompatibility system (Les et al. 1991, Byers and Meagher 1992, DeMauro 1993, Reinartz and Les 1994, Byers 1995). In this system, incompatibility is determined by the multiallelic S locus; pollen tube growth is prevented if the stigma shares an allele at the S locus with the individual producing the pollen. Partial or complete dominance can complicate an analysis of this breeding system (Byers and Meagher 1992, Reinartz and Les 1994). Some investigations of small populations of rare species of the Asteraceae have found that the rare species have become partly or wholly self-compatible (Reinartz and Les 1994, Byers 1995, Guerrant 1996, Wolf 1999, Luijten et al. 2000). The authors theorize that the small populations lacked diversity in S alleles due to genetic drift or founder effects and that this favored the evolution of self-compatibility. In two other cases, small populations remained self-incompatible (DeMauro 1993, Byers 1995). Calculations have shown that a population size of 50 or fewer genets will lose S alleles so that individual plants will find a lower frequency of compatible mates, and this would cause a decrease in seed set (Byers and Meagher 1992). Byers (1995) showed an example of this effect. She compared compatible and incompatible crosses in populations of *Eupatorium resinosum*. In a population of 546 plants 40% of crosses were incompatible while in a population of 8000 plants 17% of crosses were incompatible.

Another possibility for reproduction in the small, dispersed populations of *Nabalus serpentarius* is the production of seeds by apomixis; seeds are formed vegetatively without meiosis or fertilization. Apomixis is observed in species of *Crepis, Hieracium,* and *Taraxacum* (Proctor et al. 1996). These genera are all members of the tribe Lactuceae, subtribe Crepidineae, as is *Nabalus,* and *Taraxacum officinale* appears to share a recent common ancestor with *Nabalus altissimus* (Whitton et al. 1995, Kim et al. 1996).

The largest population of *Nabalus serpentarius* in New England consists of about 50 flowering plants; all the other populations are smaller than 20 plants. The large population consists of several subpopulations separated by hundreds of meters. In experiments on pollen dispersal by insects, the majority of the pollen is carried less than 50 meters from a source plant (Meagher 1986, Smyth and Hamrick 1987, Palmer et al. 1988). However, the distribution of the pollen has a long tail to distances as great as several hundred or a thousand meters (Ellstrand 1992) so that the subpopulations may not be isolated. The other populations of *Nabalus serpentarius* are isolated by larger distances. If these other populations of fewer than 20 flowering plants produce viable seed, it is possible that they are self-compatible or apomictic.

HABITAT/ECOLOGY

The habitat of *Nabalus serpentarius* in the southeastern United States, where it is widely distributed, is described as sandy soil and dry, open woods, thickets, fields, and roadsides (Radford et al. 1968, Cronquist 1980, Wofford 1989). Carl Nordman (State Botanist, Tennessee Natural Heritage Program, personal communication) has observed the plant in sandy woods and on hillsides with canopy openings and dry-mesic conditions. Milo Pyne (personal communication) finds the species on roadsides and under power lines and believes the habitat should be kept open by mowing or burning for better reproduction. It is found in the Blue Ridge Mountains (Wofford 1989), the Cumberland Mountains, Appalachian Plateau, and eastern knobs of Kentucky (N. Drozda, Botanist, Kentucky State Nature Preserves Commission, personal communication; Brown and Athey 1992).

Nabalus serpentarius is also found in the coastal plain. In the Carolinas and Georgia, it is infrequent on the coast (Radford et al 1968, Jones and Coile 1988). In Maryland, it is infrequent on the eastern shore and common elsewhere (Brown and

Brown 1984). However, Tatnall (1946) finds it associated with the coastal plain in Delaware, and it is common in the pine barrens of New Jersey (Stone 1973). Fogg (1930) discussed plants with southern affinities that extend to the north on the coastal plain and listed *Nabalus serpentarius* as one of these plants. He found that 20% of the flora of the Elizabeth Islands, 50% of the Nantucket flora, and a majority of the flora of the middle Cape have southern affinities, so these are areas where *Nabalus serpentarius* might reasonably be found.

In New England, five of the extant populations occur on Nantucket and Martha's Vineyard in coastal grassland and heathland, and one Nantucket population occurs on an eroding cliffside. Among the observed inland populations, one is found growing in a power line right-of-way that shares many associated species with heathland, and the others are found in open, rocky woodlands. These populations occur in open or lightly shaded habitats. The heathland has been kept open by mowing or fire in the past (Barbour et al.1998), and the rocky woodland populations are found in open canopy (50-60% cover), possibly maintained by fire (E. Farnsworth, New England Wild Flower Society, personal communication; Everett, personal observation). Flowering has not been seen in the woodlands; the plants observed flowering are in open, unshaded habitat. Observers in the southeastern U.S. mention the association of this species with disturbance created by roadsides and trails (Radford et al 1964; Johnson 1980; Wofford 1989; Rhoads and Klein 1993; Fleming 1995; M. Pyne, personal communication). The populations on the Massachusetts islands and at two of the inland New England sites are also associated with trails or roads. For instance, the Massachusetts population found growing under a power line occurs within 1 meter of a trail and was not found in apparently similar habitat more than 1 meter from the trail (Everett, personal observation). The soil supporting the coastal heathland populations is sandy, dry, and acidic while the descriptions of inland habitats mention rich, circumneutral soils underlain by basalt (E. Farnsworth, personal communication; B. Moorhead, Consulting Field Botanist, personal communication). There is no information on habitat for the historic collections of the taxon in New Hampshire and Rhode Island.

The most detailed description of habitat for *Nabalus serpentarius* in New England is provided by Buckley et al. (1998) for a population on Nantucket Island. This population occurs on types of sandplain grassland and coastal heathland that are described by Dunwiddie et al. (1996) who found that the soil in these habitats was 89 to 96% sand and less than 5% clay and that the pH was between 3.3 and 3.52. According to Buckley et al. (1998: 12) the associates of *Nabalus serpentarius* are "*Gaylussacia baccata* (black huckleberry), *Carex pensylvanica* (Pennsylvania sedge), *Epigaea repens* (trailing arbutus), *Rosa virginiana* (Virginia rose), *Aronia arbutifolia* (red chokeberry) and *Rubus flagellaris* (dewberry). The typical habitat for this endangered species is within a zone encompassing the outer edge of the huckleberry-Pennsylvania sedge ecotone or within a huckleberry clone where height is less than one meter and coverage does not exceed 50%…*Prenanthes serpentaria* seems to thrive in areas of some disturbance, such as formerly mowed sites and small game trails."

The communities in which *Nabalus serpentarius* occurs are tracked by the Massachusetts Natural Heritage and Endangered Species Program. The maritime sandplain natural communities with which it is associated are globally endangered and are threatened by habitat loss and by fire suppression (Barbour et al. 1998). Swain and Kearsley (2000) list the taxon as occurring in two specific community types – maritime erosional cliff community, ranked S2 ("typically 6-20 occurrences, few remaining acres or miles of stream, or very vulnerable to extirpation in Massachusetts for other reasons"), and sandplain heathland, ranked S1 ("typically 5 or fewer occurrences, very few remaining acres or miles of stream, or especially vulnerable to extirpation in Massachusetts for other reasons"). In addition, a recently discovered inland population of this taxon occurs in the oak-hickory natural community ranked S4 (apparently secure in Massachusetts) (Swain and Kearsley 2000).

Swain and Kearsley (2000) described the vegetation that makes up these communities. For the maritime erosional cliff community, they listed *Toxicodendron radicans, Parthenocissus quinquefolia, Rosa carolina, Rosa rugosa, Myrica pensylvanica, Comptonia peregrina, Prunus maritima, Prunus serotina, Gaylussacia baccata, Arctostaphylos uva-ursi,* and *Smilax rotundifolia*. The sandplain heathland vegetation is composed of *Quercus ilicifolia, Gaylusacia baccata, Arctostaphylos uva-ursi, Vaccinium angustifolium, Deschampsia flexuosa, Carex pensylvanica, Schizachyrium scoparium, Ionactis linariifolius, Myrica pensylvanica, Hudsonia ericoides, Aronia arbutifolia, Quercus prinoides,* and *Comptonia peregrina*. Among the plants listed for the oak-hickory forest are *Quercus rubra, Q. alba, Q. coccinea, Q. velutina, Carya ovata, C. tomentosa, C. glabra, C. ovalis, Fraxinus americana, Ostrya americana, Viburnum acerifolium, Vaccinium angustifolium, V. pallidum,* and *Carex pensylvanica.*

Since *Nabalus serpentarius* is a southern plant at the northern limit of its range in New England, the occurrence of global warming could affect its distribution and increase its presence in the north. However, if the distribution of this taxon in New England is primarily limited by lack of habitat, global warming might have little influence; the impact could even be negative. For instance, Fox et al. (1999) studied the effect of predicted global warming on a grassland perennial, *Hypericum perforatum*, at the northern boundary of its distribution in Europe. They observed some positive effects such as better spring growth and some negative effects such as greater insect damage and reduced reproduction. Fox et al. (1999) concluded that *Hypericum perforatum* may not benefit from global warming. Such studies suggest that benefits of global warming for *Nabalus serpentarius* and other species at their northern limits should not be assumed without careful investigation.

THREATS TO TAXON

Nabalus serpentarius occurs throughout the southeastern states and is not threatened there. Historically, it has been collected as far north as New Hampshire and in scattered locations in Massachusetts, Rhode Island, and Connecticut (Figure 3). Plants at the limit of their distribution could be expected to occur infrequently and to exist in scattered pockets of favorable habitat. Some evidence for this can be found in earlier botanical publications. For instance, Dame and Collins (1888) said that *Nabalus serpentarius* was not common in Middlesex County, Massachusetts, and Jackson (1909) recorded the taxon as occasional in Worcester County, Massachusetts. Historically, southeastern Massachusetts may have provided favorable habitat; Hervey (1911) described the taxon as frequent in New Bedford and Buzzards Bay. In Connecticut, Blewitt (1926) described it as rare in Waterbury, and Bissell and Andrews (1902) found it to be rare in Southington. However, Bishop (1901) described the species as common in the state.

The modern distribution of *Nabalus serpentarius* has contracted from that observed in the past (Figure 2, Figure 3). A major threat from loss of habitat is suggested by analysis of Table 2. Seventy-seven occurrences of *Nabalus serpentarius* are described in the table. More than 85% of these are herbarium specimens collected between 1850 and 1949. This distribution of collection dates may simply reflect the changing activity of plant collectors over the past century and a half, but it may also reflect a changing distribution of the species. Between 1850 and 1949, the area of Massachusetts occupied by forest was increasing from 25% to 80% (O'Keefe and Foster 1998), and the change in landscape from farms and fields to second-growth forest may have limited appropriate habitat and account for the current rarity of the species. Most of the extant populations of this species now occur in open habitat, and are associated with disturbance such as trails or mowing. In addition, the control of fire has reduced the area covered by open woods, fields, and heathland. Sandplain heathland, where the largest population of the taxon occurs, is an endangered community in Massachusetts and is a fire-adapted community. *Nabalus serpentarius* might also have been associated with the disturbance of grazing; the rosette growth habit of the plants during the spring and summer may be an adaptation permitting the plants to exist in grazed fields (Wessels 1999); such fields are now less frequent. Milo Pyne (personal communication) suggests that the milky sap of the species may be distasteful to grazing animals and that this would permit plants to exist in grazed fields. However, deer browse on flowering plants in a Nantucket population (B. Perry, personal communication).

The small size and isolation of the extant populations of this taxon in New England also pose a threat to the survival of the species in this area. Small populations are more vulnerable than large populations to random, or stochastic, effects related to natural catastrophes, or to genetic, environmental, or demographic fluctuation (Menges 1991, Fischer and Stocklin 1997, Eisto et al. 2000). For example, Fischer and Stocklin (1997) report on communities of plants growing on calcareous grasslands in Switzerland. This type of habitat has decreased due to agriculture. The species of plants and their abundance in specific locations had been recorded between 1946 and 1953 and then again between 1983 and 1987. Fischer and Stocklin used these records to determine that 39% of the populations of specific species disappeared between the two dates of observation and that the lower the abundance of the species in the community, the greater was its risk of extinction. Annuals and short-lived taxa were more likely to disappear than perennials and colonizing plants. The causes of these disappearances are not known, but are in agreement with the theory that small populations are more vulnerable to extinction. Based on these observations, *Nabalus serpentarius* populations would face increased risk of extirpation because individuals exist in small populations and appear to be short-lived.

Various reasons have been proposed for the vulnerability of small populations of plants to extirpation. For plants that are outcrossing, small populations have been shown, in some experiments, to be affected by inbreeding depression (Polans and Allard 1989, Barrett and Kohn 1991), loss of genetic variation (Les et al. 1991, Ellstrand and Elam 1993, Luijten et al. 2000) and decreased seed set (Morgan 1999, Luijten et al. 2000) when compared to large populations of the same species. Whatever the mechanism, fitness, measured as the ability to leave offspring, and survivability are found in some experiments to be decreased in small populations compared with large populations (Heschel and Paige 1995, Eisto et al. 2000, Kery et al. 2000, Luijten et al 2000). All these experiments have been carried out with species that are primarily outcrossed. Since it is not known whether *Nabalus serpentarius* is cross-pollinated, self-pollinated, or apomictic, these explanations for the vulnerability of small populations to extirpation may not apply to this taxon.

Nabalus serpentarius populations in New England consist of 50 or fewer individuals. Such small populations may be normal for the species over its entire range (M. Pyne, personal communication; J. Williams, personal communication), but the number of such populations has decreased over the last 150 years (Figure 2, Figure 3, Table 2). This decline might have been caused by a decrease in suitable habitat resulting from reforestation and control of fire in coastal heathlands. Alternatively, the cause may be the increased risk of extirpation that small populations face due to natural catastrophes or to random demographic variations or to lack of genetic variability and fitness (Menges 1991, Fischer and Stocklin 1997). Whatever the cause, the populations of *Nabalus serpentarius* in New England are small in number and in size, and these characteristics increase the risk of extirpation of the populations.

DISTRIBUTION AND STATUS

General status

Nabalus serpentarius is ranked G5, globally secure (NatureServe 2000). The taxon is found throughout the southeastern United States as far south as northern Florida and as far west as Mississippi, Kentucky, Tennessee, and Ohio (Figure 1, Table 1). It is not found in Louisiana (Ghandi and Thomas 1989), Arkansas (T. Witsell, Botanist/Field Ecologist, Arkansas Natural Heritage Commission, personal communication), or Indiana (Deam 1940). The occurrences in the states outside of New England are labeled SR (reported), SU (unrankable or unknown), S?, S4 in Delaware, S3 in Pennsylvania, and S5 in North Carolina (NatureServe 2000, Table 1, Appendix 1).

Status of all New England occurrences -- current and historical

In New England, *Nabalus serpentarius* has not been found in Maine (Brumback and Mehrhoff et al. 1996, Arthur Haines, New England Wild Flower Society, personal communication, NatureServe 2000) or Vermont (Seymour 1969, Brumback and Mehrhoff et al. 1996) although NatureServe ranks the taxon as SU, not known, in Vermont. In New Hampshire, the species is historic (Brumback and Mehrhoff et al. 1996, NatureServe 2000); the state does not list or rank the species (S. Cairns, NH Natural Heritage Inventory, personal communication). Five herbarium specimens from New Hampshire are noted in Table 2. These provide no detailed location or habitat information. Two of the specimens were collected in Coos County, but a flora of Coos County does not list the species (Pease 1964). Three of the herbarium specimens are given EO numbers by the state. The species is also historic in Rhode Island, and is listed SH in the state (Brumback and Mehrhoff et al. 1996). NatureServe ranks it SU, unknown. Table 2 lists 12 herbarium specimens collected between 1878 and 1926 in Rhode Island; very little specific site information is provided.

In Massachusetts, *Nabalus serpentarius* is listed by the state as endangered and is given a rank of S1 (Brumback and Mehrhoff et al. 1996). There are 42 Element Occurrence records in the state database; seven of these have been observed in the field since 1980. In addition, one other extant population has been reported, and there is an additional 1969 record of the taxon on one of the Elizabeth Islands (Cherau 1998). The herbarium collections were made throughout the state, although only three were found west of the Connecticut River. Only a few of the herbarium labels contain specific site locations.

Nabalus serpentarius is not tracked by the state in Connecticut. It is listed as SR in NatureServe (2000) and as S1 with three populations by Brumback and Mehrhoff et al. (1996), based on L. Mehrhoff's knowledge of the species (L. Mehrhoff, personal communication). The three populations are two reported from the Storrs area, but not yet verified, and one 1990 collection in the Torrey Herbarium of a non-flowering specimen (L. Mehrhoff, personal communication). In addition, one other non-flowering population was reported in 2001 (E. Farnsworth, personal communication), and four non-flowering populations were observed in 2002 although the identification is not certain (B. Moorhead, personal communication). In addition, some of the reports published on Connecticut flora contain references to specific locations that should be investigated (see below). Table 2 lists 14 herbarium collections made before 1941; the notations on most of the herbarium sheets lack sufficient detail to guide any new searches.

Arthur Haines (personal communication) has reviewed herbarium specimens at the New England Botanical Club Herbarium and Gray Herbarium at Harvard University, and he has verified the identification of the specimens listed in Table 2 from those herbaria.

Table 1. Occurrence and status of *Nabalus serpentarius* 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)**
Massachusetts (S1, E): 7 extant and 35 historic occurrences	Delaware (S4) infrequent (Tatnall 1946 and Phillips 1978)	Connecticut (SR and not state listed): 8 possible extant and 12 historic occurrences	New Hampshire (SH but not state listed): 5 herbarium records
	District of Columbia (S?): common (Fleming 1995)	Alabama (SR): occurs in 25 counties (Fusiak and Schilling 1984)	Rhode Island (SU and not state listed): 11 herbarium records; rare (Gould et al. 1998)
	Kentucky (S?): 2 counties (Fusiak and Schilling 1984); may be S4/S5 (Drozda, personal communication)	Florida (SR): 1 county (Fusiak and Schilling 1984); northern counties (Clewell 1985)	
	North Carolina (S5): 48 counties (Fusiak and Schilling 1984)	Georgia (SR): 6 counties (Fusiak and Schilling 1984); 16 counties (Jones and Coile 1988)	
	Pennsylvania (S3): 12 counties (Rhoads and Klein 1993)	Maryland (SR): 1 county (Fusiak and Schilling 1984); common (Brown and Brown 1984)	
	West Virginia (S?): common (Strausbaugh and Core 1977)	Mississippi (SR): 3 counties (Fusiak and Schilling 1984)	
		New Jersey (SR): frequent in pine barrens (Stone 1973, Anderson 1989)	
		New York (SR): occurs (Mitchell and Tucker 1997)	
		Ohio (SR): 13 counties (Fisher 1988)	
		South Carolina (SR): 30 counties (web site); 24 counties (Fusiak and Schilling 1984)	
		Tennessee (SR): 15 counties (Fusiak and Schilling 1984)	
		Vermont (SU): does not occur (Seymour 1969)	

Table 1. Occurrence and status of *Nabalus serpentarius* 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)**
		Virginia (SR): occurs except in the west (Harvill et al 1986); 23 counties (Fusiak and Schilling 1984)	

Figures 2 and 3 show the New England distributions of *Nabalus serpentarius.*

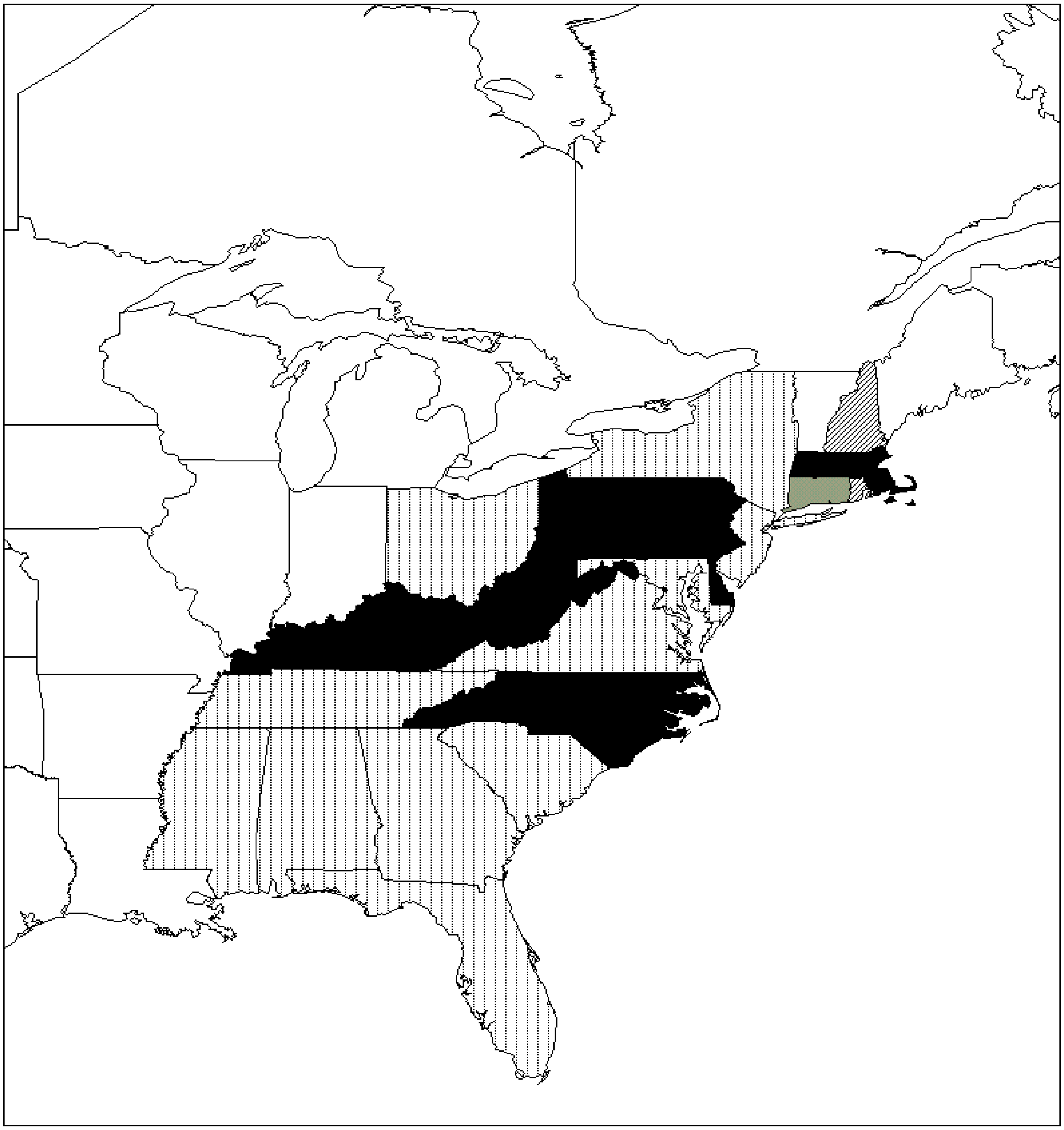

Figure 1. Occurrences of *Nabalus serpentarius* in North America. States and provinces shaded in gray have one to five current occurrences of the taxon. States shaded in black have more than five confirmed occurrences. States with diagonal hatching are designated "historic" or "presumed extirpated," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported" but not necessarily verified). See Appendix 1 for explanation of state ranks).

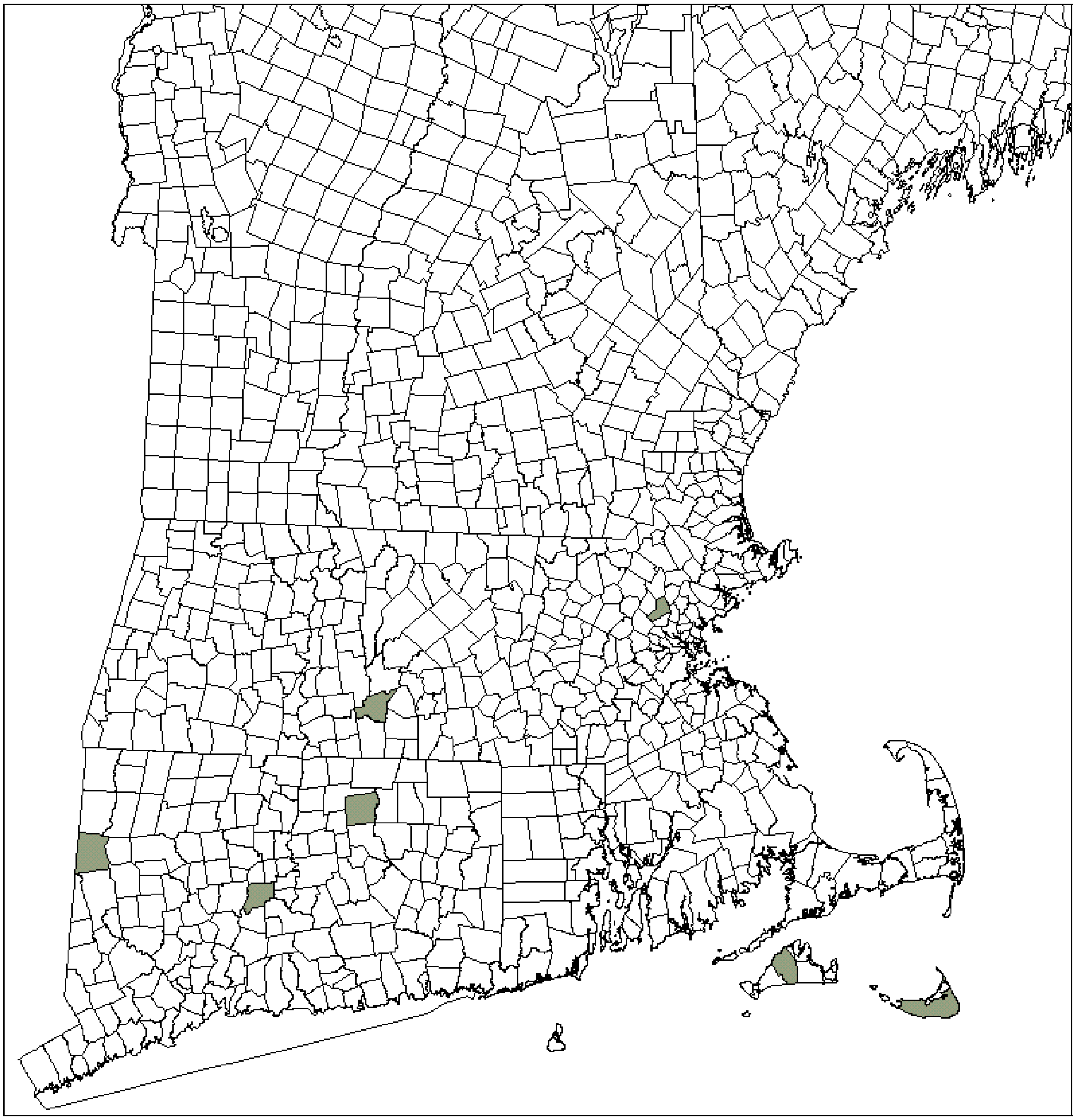

Figure 2. Extant occurrences of *Nabalus serpentarius* in New England. Town boundaries for New England states are shown. Towns shaded in gray have one to five current occurrences of the taxon.

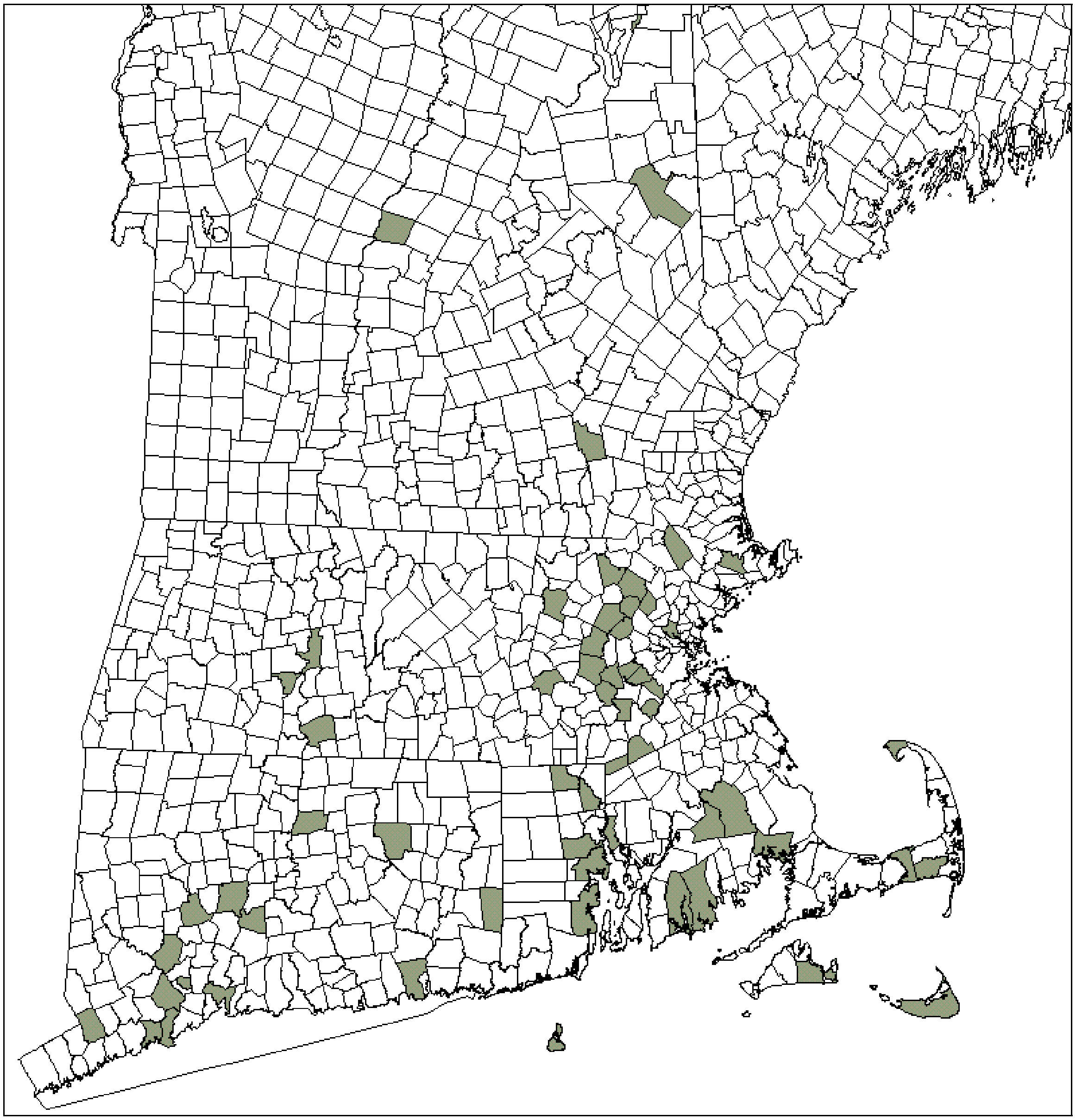

Figure 3. Historic occurrences of *Nabalus serpentarius* in New England. Towns shaded in gray have one to five historic records of the taxon.

Table 2. New England Occurrence Records for *Nabalus serpentarius.* Shaded occurrences are considered extant.			
State	**EO #**	**County**	**Town**
NH	.001	Hillsborough	Manchester
NH	.002	Grafton	Lebanon
NH	.003	Coos	Pinkham's Grant
NH		Coos	Tuckerman's Ravine
NH		Carroll	Ossipee
MA	.001	Hampshire	Hadley
MA	.002	Hampden	Springfield
MA	.003	Worcester	Harvard
MA	.004	Worcester	Westborough
MA	.005	Middlesex	Lincoln
MA	.006	Middlesex	Bedford
MA	.007	Middlesex	Burlington
MA	.008	Middlesex	Chelmsford
MA	.009	Middlesex	Framingham
MA	.010	Norfolk	Milton
MA	.011	Norfolk	Needham
MA	.012	Middlesex	Natick
MA	.013	Norfolk	Norwood
MA	**.014**	**Middlesex**	**Woburn**
MA	.015	Middlesex	Billerica
MA	.016	Middlesex	Medford

Table 2. New England Occurrence Records for *Nabalus serpentarius.* Shaded occurrences are considered extant.			
State	**EO #**	**County**	**Town**
MA	.017	Essex	North Andover
MA	.018	Barnstable	Dennis
MA	.019	Barnstable	Eastham
MA	.020	Norfold	Plainville
MA	.021	Norfolk	Wellesley
MA	.022	Norfolk	Dedham
MA	.023	Bristol	Westport
MA	.024	Bristol	Dartmouth
MA	.026	Plymouth	Lakeville
MA	.027	Plymouth	Wareham
MA	.028	Plymouth	Middleborough
MA	**.029**	**Nantucket**	**Nantucket**
MA	.030	Norfolk	Dover
MA	.031	Norfolk	Foxborough
MA	.032	Norfolk	Medfield
MA	.033	Middlesex	Sudbury
MA	.034	Middlesex	Sherborn
MA	.035	Middlesex	Concord
MA	.036	Barnstable	Harwich
MA	**.037**	**Nantucket**	**Nantucket**
MA	**.038**	**Nantucket**	**Nantucket**
MA	**.039**	**Nantucket**	**Nantucket**
MA	.041	Barnstable	Provincetown
MA	.042	Nantucket	Nantucket
MA	**.043**	**Dukes**	**West Tisbury**
MA	**.044**	**Hampden**	**Palmer**
MA		Dukes	Edgartown
RI		Kent	Warwick
RI		Kent	Warwick
RI		Kent	Warwick
RI		Providence	Smithfield
RI		Washington	Ashaway
RI		Washington	Avondale
RI		Providence	Lincoln
RI		Providence	Cranston
RI		Providence	Cranston
RI		Providence	Rumford
RI		Newport	Block Island
RI			Warnicle(?) or Warwick(?)
CT		**Litchfield**	**Kent**

Table 2. New England Occurrence Records for *Nabalus serpentarius.* Shaded occurrences are considered extant.			
State	**EO #**	**County**	**Town**
CT		**Hartford**	**Berlin**
CT		**Tolland**	**Storrs**
CT		Hartford	Southington
CT		Hartford	Southington
CT		New Haven	Ansonia
CT		New Haven	Oxford
CT		New Haven	Waterbury
CT		New London	Waterford
CT		Tolland	Mansfield
CT		New London	Voluntown
CT		Fairfield	Stratford
CT		Fairfield	Bridgeport
CT		Hartford	S. Windsor
CT		New Haven	Meriden
CT		New Haven	New Haven
CT		Fairfield	Shelton
CT		Fairfield	Wilton

CURRENT CONSERVATION MEASURES IN NEW ENGLAND

Land Protection

Massachusetts has seven extant populations of *Nabalus serpentarius*. These populations all occur on land owned by a town, the state, or a conservation organization.

In Connecticut, there are potentially eight extant populations. The two populations reported in the Storrs area are at present unverified and land ownership is unknown. Two populations occur on state or town-owned land, and the precise location of four recently discovered populations has not been reported.

Land Management

In Massachusetts, one of the populations on Nantucket Island (MA.037) is being managed by mowing to benefit *Nabalus serpentarius* (B. Perry, personal communication). Two other populations, one in Woburn (MA.014) and one on Martha's Vineyard (MA.043) are mowed for other reasons, and the populations appear to benefit from the mowing. Fire is being considered for the largest Nantucket population (B. Perry, personal communication).

Population Monitoring

All of the extant Massachusetts populations except the recently located population in Palmer, MA, (MA.044) are being monitored. No monitoring is occurring in Connecticut.

Seed Banking

Seed collections from two populations (MA.014 and MA.037) are stored at the New England Wild Flower Society. Chris Mattrick has carried out some seed germination experiments with limited success (C. Mattrick, personal communication).

II. CONSERVATION

CONSERVATION OBJECTIVES FOR TAXON IN NEW ENGLAND

Nabalus serpentarius is a southern plant with a range extending into New England, and it occurs in small isolated populations here. Its preferred habitat of open sites associated with some disturbance was more abundant in New England 100 years ago, and the taxon was more frequent then than it is now. Although it is globally secure (NatureServe 2000) and Division 2, uncommon in New England but common elsewhere in *Flora Conservanda* (Brumback and Mehrhoff et al. 1996), conservation actions are recommended to maintain the species in New England. It is possible that these plants are adapted to the New England environment and that southern members of the taxon would be unable to survive New England conditions.

The number and size of populations of *Nabalus serpentarius* in New England that are required to insure the existence of the species for the next 100 years could be determined by population viability analysis. Not enough information about the demographics of the existing populations of the taxon is available to carry out such an analysis, but an investigation of the literature on such calculations gives some idea of the required numbers. Menges (1991) stated that environmental stochasticity is the primary threat to a population's viability and that population sizes between 1,000 and 1,000,000 individuals are required to insure survival. Pavlik (1996) made the generalization that short-lived herbaceous outcrossers need 1500 to 2500 individuals for a viable population but that a perennial, self-compatible species would require a smaller minimal viable population. Several studies on endangered composite species yielded estimates of viable population sizes of 200 to 500 individuals and the suggestion that populations of 20 individuals lacked genetic variability and were not viable (Demauro 1993, Young et al. 1999, Luijten et al. 2000). Research results like these suggest that since the New England populations of *Nabalus serpentarius* consist of 50 individuals or less, their viability is in doubt, especially if the plants are obligate outcrossers.

A viability analysis of a rare plant that is not a member of the Asteraceae but shares many growth characteristics with *Nabalus serpentarius* provides another set of numbers. *Campanula cervicaria* (Campanulaceae) was studied by Eisto et al. (2000). It is a monocarpic species that is cross-pollinated by insects but can self-pollinate. This species is a grassland plant, and its populations have declined in Finland. Populations are found along roads, railroads, and power lines and in fields and meadows. The authors monitored 52 populations, ranging in size between 1 and 240 flowering plants, for eight years. They observed that 60% of the populations of less than 5 flowering plants lost all flowering individuals over a period of 8 years and that the mean number of flowering plants in all the populations dropped from 24 to 14 individuals. Half of the 52 populations disappeared in the 8-year observation period. However, of 16 populations that had lost all flowering plants over a period of two years, 6 populations later produced 1 to 3 flowering plants. Using this information, the authors calculated that the risk of losing all reproducing individuals in populations smaller than 5 flowering plants was 50% over 8 years and 20% over 8 years for populations larger than 100 flowering plants.

New England has six *Nabalus serpentarius* populations in which flowering has been observed in the past 20 years. One population has more than 50 flowering individuals; two populations have had between 10 and 20 flowering individuals; and the remaining three populations had 5 or fewer flowering plants. The discussion in the two preceding paragraphs and in earlier sections indicates that the populations with fewer than ten or twenty flowering individuals are in danger. Based on these considerations, the minimal size for a population of *Nabalus serpentarius* that could be expected to persist for years would appear to be of the order of 100 flowering individuals. As is the case with the large population on Nantucket, these 100 individuals might be arranged in scattered subpopulations.

However, this may be a sparse species (Rabinowitz 1981) that can persist in small populations. Either this is a species that can survive in small isolated populations for years, or at the time of writing this report, the populations are, coincidentally, being observed just before extinction. Since one population now numbering under 20 individuals (MA .014) has apparently persisted for over 100 years and another with about 50 individuals has been observed for 13 years (MA .037), it may be that small populations of the size observed in New England could be normal for the species. In addition, if self-compatibility or apomixis were to be demonstrated in this taxon, small populations of 10 to 50 individuals might be considered viable (Pavlik 1996).

The number of populations of *Nabalus serpentarius* has declined in New England (Table 2), and the cause may habitat loss. An increase in the number of populations in New England would increase the chances for survival of the species. Nantucket and Martha's Vineyard have suitable habitat on protected land; several populations of 50 to100 individuals or a number of populations of about 20 individuals could be established. However, this sandplain heathland habitat is considered rare in the state (Swain and Kearsley 2000), and only 2 or 3 large populations or 5 or 6 small populations are recommended for this habitat. There is interest in grassland restoration in Massachusetts (J. Oehler, Upland Program Coordinator, Mass Wildlife, personal communication), and one or more inland locations for *Nabalus serpentarius* introduction might be available. Since the viable population size is unknown, it is recommended that a goal of 3 or 4 populations of 50 to 100 individuals and/or 10 populations of about 20 individuals be considered. This could be accomplished by careful management of existing populations, by augmentation of existing populations, by reintroduction of populations or by creation of new populations.

The creation of large or small populations would be expensive, time consuming, uncertain to succeed, and of questionable scientific merit (New England Wild Flower Society 1992, Falk et al. 1996). Therefore, given that the taxon is secure in the southeast, such actions should be reviewed carefully and will have low priority among the actions suggested for preservation of the taxon in New England. Before such actions are taken, more information on the longevity of individual plants, on the pollination biology of the flowers, on the soil seed bank and seed germination, and on the demography of the existing populations is needed to make informed decisions on augmentation or introduction.

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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 known to be extirpated. Not all EO's have received such ranks in all states, and ranks are not necessarily consistent among states as yet.