New England Plant Conservation Program

Potamogeton strictifolius A. Bennett
Straight-leaved pondweed

Conservation and Research Plan
for New England

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SUMMARY

Potamogeton strictifolius A. Bennett (Potamogetonaceae) is an uncommon narrow-leaved pondweed with 40 recorded sites in New England, of which 27 are extant. The species is listed as G5 globally, but is ranked S1 by the states of Maine and Connecticut and S2 by Vermont. It is proposed as an S1 species (State-Endangered) by Massachusetts and also as State-Endangered as of 2003/2004 for Connecticut. Eight other states and provinces also list the species as S1, two list it as S2, two list it as Endangered, and one lists it as Special Concern. *Potamogeton strictifolius* is most abundant around the Great Lakes, especially in Michigan, Wisconsin, Minnesota, and Ontario. In northeastern and northwestern North America, it becomes more uncommon. *Potamogeton strictifolius* is found in alkaline ponds, lakes, and slow flowing streams. Eutrophication and competition with invasive species (and impacts from their management and/or control) pose the greatest threats to *P. strictifolius*.

Conservation Objectives

1. Maintain and improve the conditions at the current locations in New England with an eventual goal of about 100 plants at each site in 20 years.
2. Through concerted surveys of historical and new sites, attempt to locate 15 to 20 new viable populations, recovering its historical range in New England.

Conservation Actions Needed

1. Make sure the identification of plants from unverified sites is correct.
2. Attempt to locate specimens from the sites that have not been verified as *P. strictifolius.*
3. Attempt to relocate populations if the identity is verified.
4. Closely monitor known populations for fluctuations in numbers, and survey potential habitats for new *P. strictifolius* sites.
5. Attempt to reduce invasive species in waters where *Potamogeton strictifolius* occurs through education and management practices.
6. Conduct water chemical analyses to determine the parameters of the species and to evaluate levels of eutrophication at extant sites.
7. Educate boaters, fisherman, and abutting landowners about the impacts of introducing and transporting invasive species and of discharging nutrients into public waters.
8. Resurvey the putative sites listed in Appendix 2.
9. Conduct *de novo* searches in New England.

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

The straight-leaf pondweed, *Potamogeton strictifolius* A. Bennett (Potamogetonaceae) is confined to North America. It ranges across North America from Newfoundland and New England west to British Columbia and Utah, being the most abundant around the Great Lakes. Globally, the species is listed as a G5 (demonstrably secure) and is not federally-listed. It is relatively common in the states of Michigan, Minnesota, Wisconsin, and the province of Ontario. However, it is becoming increasingly rare in much of the eastern and western portion of its range away from the Great Lakes. The main threats to this aquatic species appear to be competition from invasive species and eutrophication. The conservation objectives for *Potamogeton strictifolius* are to maintain and improve the conditions at the current locations in New England with an eventual goal of about 100 plants at each site in 20 years; conduct concerted surveys of historical and new sites, attempting to locate 15 to 20 new, viable populations, recovering its historical range in New England.

DESCRIPTION

Potamogeton strictifolius, subsection *Pusilli*, is an aquatic plant with rigid, two-ranked, submersed leaves 0.5 to 1.5 mm wide with 3-5(7) veins including the midrib. The leaf tips are usually acute and often bristled, but occasionally may be mucronate. A pair of nodal glands is present. The stipules are free, becoming whitish and fibrous with the tips easily shredded. The stem of *P. strictifolius* may be simple or branched and is generally rounded with slight ridges. The peduncles are filiform, elongate and slightly clavate at the tip (Fernald 1932, Haynes 1974, Wiegleb and Kaplan 1998, Haynes and Hellquist 2000).

Potamogeton strictifolius produces both fertile fruit and turions (winter buds). The turions are terminal or lateral, 2.5-4.8 cm long and 0.8-2.2 mm wide (Haynes 1974). The fruit is green to brown without lateral or dorsal keels and ranges from 1.9-2.1 mm long and 1.3-1.8 mm wide. The beak is central and about 0.3-0.5 mm long and 0.2-0.4 mm in diameter. The fruit sides are rounded and often have a central depression, although the wall texture remains smooth (Haynes 1974). The chromosome count is $2n = 52$ (Les 1983).

Below is a key to the closely related species of *Potamogeton* and those that often occur with *P. strictifolius* (Hellquist and Hilton 1983, Hellquist 1984, Hellquist 1986, Crow and Hellquist 2000) and might be confused with *P. strictifolius*. Haynes and Hellquist (2000) note that many of the records of *P. strictifolius* are misidentifications.

1. Submersed leaves with 3 veins

2. Plants lacking nodal glands at the base of the leaves; peduncles mostly axillary.

3. Leaf tips bristled, occasionally apiculate or blunt; fruit 2.3-4 mm long ....*P. hillii*

3. Leaf tips acute; fruit1.4-2.3 mm long………………………...……*P. foliosus*

2. Plants with nodal glands present at the base of the leaves; peduncles terminal and axillary.

4. Plants with delicate stipules remaining entire, usually green…...*P. pusillus*

4. Plants with fibrous stipules, white…………………*P. strictifolius* (in part)

1. Submersed leaves with 5-35 veins

5. Leaf tips rounded or apiculate, leaves 5-veined; winter buds with inner leaves at right angles to the outer leaves..................…........……*P. friesii*

5. Leaf tips acute or bristle-tipped, leaves 5-35 veined; winter buds flattened with inner and outer leaves in the same plane.

6. Leaves with 3-5(-7) prominent veins, no minor or incomplete veins ……...............................………………………….. *P. strictifolius* (in part)

6. Leaves with 3-35 prominent, some prominent and/or some incomplete veins

7. Nodal glands usually absent, stem extremely flattened ....…*P. zosteriformis*

7. Nodal glands usually present, stem terete or slightly flattened

8. Leaves 7-21-veined; stipules white, fibrous; winter buds with outer leaves divergent, arcuate, and in-roll……….*P. ×haynesii*

8. Leaves (3-)7-13-veined; stipules brown, fibrous; winter buds with outer leaves occasionally undifferentiated, flattened. ....…*P. ogdenii*

Potamogeton strictifolius is very often misidentified. Many specimens have been annotated to *P. pusillus* and *P. friesii* Rupr. Many unverified specimens are probably *P. friesii.* The easiest way to distinguish *P. strictifolius* and *P. friesii* apart is by the turions (winter buds) as shown in the above key.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Potamogeton strictifolius (subgenus Eupotamogeton, section *Axillares,* subsection *Pusilli,* series *Pusilli,* series *Pusilli connati*, subseries *panormitani*) was described by Bennett in 1902 based on material collected from Wolf Lake, Indiana (Fernald 1932). One year earlier, Bennett also described a separate species, *P. pusillus* L. var. *pseudo-rutilus* Ar. Benn., based on an earlier sample of seemingly sterile material from Wolf Lake and from fruiting samples collected from Lake Scugog, Ontario in 1897 (Fernald 1932). Hagström (1916) later reviewed additional material from Rev. E. J. Hill and proposed that this was a hybrid between *P. foliosus* Raf. and *P. rutilus* Wolfg.. However, this was subsequently shown not to be the case. Hagström (1916) indicated that the original specimen was from Lake George in East Chicago and not Wolf Lake. Haynes (1974) noted that the type was indeed from Wolf Lake and that Lake George and Wolf Lake may be the same lake.

Fernald (1932) recognized *P. strictifolius* as a valid taxon with two varieties, *P. strictifolius* A. Bennett var. *strictifolius* and *P. strictifolius* A. Bennett var. *rutiloides* Fernald (Fernald 1932). This was based on the leaf shape, rigidity and the texture of the stipules (Haynes 1974). In 1974, Haynes determined that the two taxa were actually variations, not only between populations, but within a single population resulting from environmental influences rather than having a genetic origin. Therefore, Haynes placed *P. strictifolius* var. *rutloides* in synonymy under *P. strictifolius.* The name *P. strictifolius* var. *typicus* Fernald and *P. longiligulatus* Fernald are presently in synonymy under *P. strictifolius* (Haynes 1974, Haynes and Williams 1975, Hellquist and Crow 1986). *Potamogeton strictifolius* is closely related to *P. rutilus* Wolfgang in Schultes et Schultes f. from Europe and western Asia (Wiegleb and Kaplan 1998).

Synonymy

The synonymy for the species is as follows (Haynes 1974):

- *P. pusillus* L. var. *pseudo-rutilus* Ar. Benn, 1901, *Journal of Botany* 39: 201.
- *P. pusillus* L. var. *rutloides* (Fernald) Boivin, 1967, *Canadian Naturalist* 94: 527.
- *P. strictifolius* var. *typicus* Fernald, 1932, *Memoirs of the American Academy of Arts* 17: 56.
- *P. strictifolius* var. *rutloides* Fernald, 1932, *Memoirs of the American Academy of Arts* 17: 57.
- *P. longiligulatus* Fernald, 1932, *Memoirs of the Academy of Arts* 17: 66

SPECIES BIOLOGY

Potamogeton strictifolius is a linear-leaved aquatic that grows totally submerged with the occasional exception of the flowering spikes. *Potamogeton strictifolius* is considered an annual, reproducing by seeds and winter buds (turions) (Haynes 1974). Some populations of *P. strictifolius* produce abundant fruit, while others rarely fruit. Moore (1915) indicated that once the seeds germinate and develop into a plant, several sequences of vegetative reproduction were needed before producing flowers and fruits. Hagström (1916) was of the opinion that most *Pusilli* rarely reproduce by fruit. *Potamogeton strictifolius* has been documented as hybridizing with *P. zosteriformis* Fernald and described as *P.* × *haynesii* Hellquist & Crow. This hybrid is most abundant in the northern portion of the lower peninsula of Michigan (Hellquist and Crow 1986).

The most successful method of reproduction is most likely through the production of winter buds (Fernald 1932). Fernald indicated that even with species that produce numerous fruits, the production of winter buds may be the only means of effective reproduction. The winter buds are formed during the later part of the summer. They may be very abundant on a single plant. Plants have been observed with winter buds at the end of almost every branch. Some plants may have 20 or more winter buds in the late summer (Hellquist, personal observation). The plant eventually dies off for the winter and all of the winter buds fall to the substrate. These will form roots and give rise to new plants. No rhizomes or stolons have been observed in *P. strictifolius.*

The winter buds are actually a short stem apex with shortened internodes. The leaves are of two types, outer and inner. The outer leaves are longer, flare out, and closely resemble normal vegetative leaves. The inner leaves are similar to the outer leaves but are shorter and more tightly packed (Haynes 1974). The winter buds of *P. strictifolius* are somewhat fan-shaped.

The inflorescence of *P. strictifolius* is a cylindrical spike consisting of three to four whorls of flowers. Fernald (1950) noted that members of the Potamogetonaceae have no true perianth, but have four-valvate sepal-like structures, similar to sepals. Singh (1965) chose to consider the flowers of the Potamogetonaceae as normal flowers. Haynes (1974) chose to follow the work of Singh. Flower structure is almost identical in all members of the *Pusilli.* The fruit of the Potamogetonaceae has generally been described as being drupaceous, containing one seed with a curved embryo (Haynes and Hellquist 2000).

Potamogeton are mostly wind-pollinated (Sculthorpe 1967), but Haynes (1974), Hellquist (personal observations), and Voss (1972), all have observed that the inflorescence of many of the *Pusilli* are never emergent, so may be water-pollinated. Hellquist (personal observation) has noted the pollen floating on the surface of the water, suggesting water pollination is indeed a possible method of pollination. The mature, viable fruits might be formed as a result of apomixis (Haynes 1974).

Potamogeton species have been shown to be important food sources for wild ducks (Metcalf 1931, Kubichek 1933, Martin and Uhler 1939). Sculthorpe (1967) indicated that the *Potamogeton* fruits are a valuable source of food for ducks, coots, geese, grebes, swans, marsh birds, shore birds, and other game birds. Haynes (1974) in discussing Lohammar (1954) has shown that a high percentage of germination occurs when the fruits are passed through the digestive system of waterfowl. The waterfowl generally digest both the exocarp and mesocarp, while the endocarp passes through the digestive system. No records concerning the viability of fruits and seed banking are known. Muenscher (1936) indicates that the germination rate of *Potamogeton* fruits are greatly reduced if allowed too dry. Muenscher also notes that a cold stratification of one to three months is needed to promote germination.

Sculthorpe (1967) reported the foliage of the pondweeds to be of moderate importance as fish food, but of great importance as a spawning medium and as a source of shade and shelter. King and Hunt (1967) found that carp feed on *Potamogeton foliosus* Raf. *Potamogeton foliosus* is a pusilloid pondweed, so *P. strictifolius*, another pusilloid pondweed, may also be eaten by carp or other herbivorous fish. Pondweeds may also serve as a mechanical support for algae, which are utilized as a food source by many fish and birds (Pond 1905).

Potamogeton strictifolius, unlike many of the *Pusilli*, seems to maintain relatively stable populations. Most of the linear-leaved pondweeds for no known reason will undergo marked population reductions, often followed by gradual increases in numbers (Hellquist, personal observation).

Arens (1936) and Steemann Nielsen (1946), as cited by Sculthorpe (1967), studied the various potential sources of carbon to submersed aquatics for photosynthesis. These sources are in the form of carbon dioxide, bicarbonate, and carbonate ions. Schulthorpe (1967) noted that it was unknown at that time whether the bicarbonate, once inside the plants, is utilized directly or converted to carbon dioxide, which is then fixed. The photosynthesis of plants that are able to use bicarbonates will not be inhibited if the pH of the water rises too high for free carbon dioxide above 9.0. Sculthorpe (1967) further notes that this is advantageous to plants that inhabit alkaline waters where the bicarbonate ion is the principal form of available carbon. Elzenga and Prins (1988) noted with *Elodea* that bicarbonate utilization depends on the pH reaction on the lower surface of submersed leaves with carbon dioxide uptake by the leaf. Aquatic angiosperms have the ability to establish a low pH on the lower surface of the leaf. The utilization of the bicarbonate at the lower pH is also dependent of the activity of the enzyme carbonic anhydrase. When the pH on the lower surface is less acidified, the plant depends more on enzyme production for the utilization of the carbon dioxide. *Potamogeton strictifolius* appears to be one of the species that utilizes the bicarbonate ion as a source for carbon dioxide.

Potamogeton strictifolius is confined to waters of high bicarbonate alkalinity in New England (see Habitat/Ecology, below). The leaves of *P. strictifolius* are usually encrusted with marl (calcium carbonate). Marl is a deposition of calcium carbonate on aquatic vegetation that naturally forms in alkaline waters as a result of photosynthesis (Wetzel 1975). The deposits on the submersed vegetation are caused by the by the absorption and transfer of bicarbonate ions by the leaves. Some of the bicarbonate ions move to the lower leaf surface, where they react with hydroxyl ions, producing carbonate that is precipitated as marl. If carbon dioxide is absorbed from water with high calcium bicarbonate content, it would produce the same effect (Schulthorpe 1967).

HABITAT/ECOLOGY

Potamogeton strictifolius is normally found in lakes, ponds, and slow-flowing streams to depths of three meters of water on sandy or hard, muddy substrates. It is found in alkaline waters throughout North America. In New England, it occurs in the alkaline waters of Aroostook County, Maine; northern and western Vermont; Berkshire County, Massachusetts; and Litchfield County, Connecticut. The range of alkalinity for *P. strictifolius* in New England has been documented from 29.0 to 169.0mg/l $CaCO_3$, with a mean value of 114.31mg/l $CaCO_3$ (Hellquist, unpublished data) or 73.3-109.8 mg HCO_3^- liter $^{-1}$ with a mean of 84.8 mg HCO_3^- liter^{-1} (Hellquist 1980).

Nichols (1999) reports the following chemical parameters from Wisconsin: pH median of 7.7, conductivity in µmhos/cm (25^{O}C) median 200, total alkalinity mg/l $CaCO_3$ and with the sulfate concentration less than 10 mg/l. Hellquist (1975), in sampling waters throughout New England, found *P. strictifolius* only at five sites and found the following means for the following chemical factors:

- total alkalinity, 69.5 mg/l $CaCO_3$;
- free carbon dioxide, 4.3 mg/l;
- pH 7.7; nitrate 2.88 mg/l;
- phosphates .19 mg/l;
- chlorides; 9.0 mg/l.

Hellquist concluded that total alkalinity had the highest significant relationship between *Potamogeton* distribution and the total alkalinity of the water in which the taxa were found. Hydrogen ion concentration (pH); nitrates and chlorides had a statistical influence on distribution, but not as great as the total alkalinity. Total phosphates had no statistically significant influence on *Potamogeton* distribution in New England.

Hellquist (1975) noted that Baine and Yonts (1937) and Mulligan (1969) had indicated that when temperature, currents, and wind action are low, submerged plants contribute most of the oxygen in the water. Plants are essential for proper aeration of water and are especially important in shallow ponds of limited area (Titcomb 1909).

Mulligan (1969) indicated that benthic macrophytes also influence other environmental factors by shading and cooling the sediments of the littoral zone, slowing water currents and movement, providing habitats for sessile organisms, converting inorganic material to organic matter, and holding the soil in place by their root systems.

Stuckey (1971) noted that *P. strictifolius* and the closely-related *P. friesii* Rupr. were considered plants of non-polluted, clear water (Hellquist 1975). Presently in New England, *P. strictifolius* is found in non-polluted waters only in northern Maine. The rest of the current New England *P. strictifolius* sites are in waters where weed growth is great. This is most likely due to higher nutrient levels at these sites. Hellquist (personal observation) has noted that *P. strictifolius* is found in waters of a range of nutrient levels.

Since this plant is found in a variety of depths and with varying degrees of current, it seems that *P. strictifolius* is quite adaptable ecologically. Natural or controlled draw-downs will probably not affect the species to any major extent. This is due to the persistence of the winter-buds in the mud of the exposed areas and in the waters unaffected by the drawdown. Many of the confirmed sites for *P. strictifolius* are subject to boat and swimmer traffic, and one site (VT .006 [Glover]) is even mowed occasionally to reduce the tangle of aquatic plants in the lake. None of these factors seem to inhibit the ability of *P. strictifolius* to maintain a healthy, if not prolific population.

Potamogeton strictifolius is normally found growing in conjunction with other plants of alkaline waters. In New England, such plants include: *Potamogeton friesii* Rupr., *P. zosteriformis*, *P. foliosus*, *P. pusillus* L. subsp. *pusillus, Stuckenia pectinata* (L.) Börner, *Nuphar variegata* Engelm., *Myriophyllum verticillatum* L., *Elodea canadensis* Michx., and *Ceratophyllum demersum* L.

Potamogeton strictifolius in New England has been found in lakes that are natural or those that have been dammed for flood control. Invasive species, particularly *Myriophyllum spicatum* L. and *P. crispus* L. are found in many of the lakes in New England. *Potamogeton strictifolius* seems to compete with the invasive species. At the Massachusetts EO .001 (Lanesborough) site, for example, *P. strictifolius* is widely dispersed among the native and invasive plants and appears to be doing well (Hellquist, personal observation).

Potamogeton strictifolius is uncommon in New England because it is at the northeast edge of its range and there is a general lack of alkaline waters in the region. It is more abundant in western New England, which is closer to the major populations in the Great Lakes region. Western New England has more alkaline lakes supplying the high bicarbonate levels that the species typically needs.

THREATS TO TAXON

Eutrophication caused by extensive runoff from adjacent farmland, lawns, and paved areas may provide additional nutrients to lakes and ponds. Surrounding land use at *P. strictifolius* sites in Vermont, for example, are mostly crop and dairy farming. Some lakes, especially in Connecticut, have extensive residential buildup along the shores. In either case, land development contributes to the nutrient loading of the bodies of water. Runoff can lead to extensive algal blooms and weed growth.

Nutrient loading has also aided the buildup of aquatic weeds at many of the sites, particularly at VT .015 (Sudbury), CT .005 (Sharon), and CT .006 (Salisbury). Invasive aquatic species found at the *P. strictifolius* sites include *Myriophyllum spicatum*, *Potamogeton crispus*, and *Trapa natans* L. Invasive and native aquatic plants can over-populate a pond. Chemical control and mechanical harvesting of invasive species may present a major problem for *P. strictifolius* populations since they often grow interspersed with the invasive species. Chemical control could also destroy the winter buds, thus causing the plant to rely on fruits for repopulation. As noted by Fernald (1932), the fruits may not help repopulate a lake.

Most invasive aquatics probably have been transported into these lakes by boaters and fishermen. Both groups tend to move their boats from lake to lake. If boats are not thoroughly inspected and cleaned prior to leaving the pond or lake, plants are sure to be transported and introduced into other water bodies.

DISTRIBUTION AND STATUS

General Status

Potamogeton strictifolius is a widespread species of northern distribution. It is globally listed as G5; globally widespread, abundant, and secure. In Canada, it is found from western Newfoundland and eastern Quebec, throughout the western provinces from the Northwest Territories to British Columbia and south. Presently, it is listed as S1 in three of ten provinces in which it occurs. In the United States, it ranges from northern Maine south to Connecticut, west to New York, Indiana, Michigan, Nebraska, Wyoming, and Utah. The Virginia record is a disjunct and may be questionable. In the United States, the species is listed in seven states as S1, critically imperiled. In the states and provinces surrounding New England, *P. strictifolius* is listed as S1 in New York and New Brunswick. Table 1 and Figure 1 summarize the conservation status and distribution of *P. strictifolius* in North America. No records or specimens of *P. strictifolius* are known to occur in the states of New Hampshire or Montana. New Hampshire is cited in the *Flora of North America* (Haynes and Hellquist 2000) as having a record for *P. strictifolius.* This is in error.

Many of the earliest records of *P. strictifolius*, especially from Vermont, were from Lake Champlain. It has not been found there since the late 1800’s. Why no populations have been discovered in such a long time is unknown.

Table 1. Occurrence and status of *Potamogeton strictifolius* in the United States and Canada based on information from Natural Heritage Programs and NatureServe records unless otherwise specified

OCCURS & LISTED (AS S1, S2, OR T & E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE VERIFIED FROM HERBARIUM RECORDS AND OR WRITTEN RECORDS	HISTORIC (LIKELY EXTIRPATED)
Maine (S1): Special Concern, (proposed for Threatened status in 2003). 5 sites, 4 current	Iowa (Special Concern)	Idaho (SR)	Ohio (SH) (B. Burkholder, Ohio Department of Natural Resources, personal communication)
Vermont (S2): 29 sites* with 19 known to be extant, no formal status	Michigan (S?): very common (Voss 1972, GH, NASC)	Minnesota (SR): (Fernald 1932, GH)	Pennsylvania (SH)
Connecticut (S1): presently Special Concern, but proposed for Endangered status in 2003. 5 sites, 3 current	Manitoba (S3): (Fernald 1932, White and Johnson 1980, GH, NASC)	Montana (SR)	
New York (S1, E): 17 sites, 3 current	Ontario (S4): (Fernald 1932, Dobson and Catling 1983, GH, NASC)	New Hampshire (SU): record based on false identification	
Indiana (S1, E): GH, NASC		Northwest Territories (SR): 3 sites (Haynes 1974, GH)	
Illinois (Endangered–SH): 1 current (Natural Land Institute 1981)		Nunavut (SR): 1 site (McJannet et al. 1993)	
Massachusetts (S1), proposed Endangered in 2003. 1 current site		Quebec (SR): 7 sites (Faubert 2000, GH)	
Nebraska (S1)		Wisconsin (SR): common (Nichols 1999, GH)	
North Dakota (S1): Critically Endangered, 2 sites, (Barkley 1977) (Seifert-Spilde, personal communication)			
Utah (S1): (GH, NASC, Fernald 1932, Cronquist et al. 1977), no formal status			
Virginia (S1): (Townsend 2002), no formal status			
Wyoming (S1): 4 sites, 1 possibly current, GH, no formal status			
Alberta (S2): (Argus and White 1978), no formal status			

Table 1. Occurrence and status of *Potamogeton strictifolius* in the United States and Canada based on information from Natural Heritage Programs and NatureServe records unless otherwise specified			
OCCURS & LISTED (AS S1, S2, OR T & E)	**OCCURS & NOT LISTED (AS S1, S2, OR T & E)**	**OCCURRENCE VERIFIED FROM HERBARIUM RECORDS AND OR WRITTEN RECORDS**	**HISTORIC (LIKELY EXTIRPATED)**
British Columbia (S1S2): 3 sites (Brayshaw 2000, Češka and Češka 1980, Staley et al. 1985)			
Newfoundland (S1): 2 sites, 1 current (Bouchard et al. 1991, NASC), no formal status			
New Brunswick (S1): 2 sites (Hinds 2000, NASC), no formal status			
Saskatchewan (S2): (Haynes 1974, GH, NASC)			

* The Vermont number of sites is based upon both confirmed and unconfirmed records.
The acronyms used are those internationally recognized in Holmgren et al. (1990). (GH) = Gray Herbarium, (NASC) = Massachusetts College of Liberal Arts Herbarium

Status of all New England Occurrences — Current and Historical

Potamogeton strictifolius occurs in the states of Maine, Vermont, Massachusetts, and Connecticut (Table 2). In Maine, it is listed as S1 with four current localities discovered by Don Cameron (Maine Natural Areas Program). Vermont lists it as S2 (imperiled), with 19 current localities listed. Appendix 2 lists unverified sites by various Vermont State agency personnel. The author has not seen any specimens to confirm their identification. These sites should be surveyed. In Massachusetts, it was just rediscovered at a previous location and will be listed as S1, State-Endangered (Melissa Dow Cullina, Massachusetts Natural Heritage Program, personal communication). Connecticut lists it as S1 with only three extant sites. Overall, the species is ranked by the *Flora Conservanda:* New England as ".IND" (Indeterminate) due to "uncertainly about its status in the wild" (Brumback and Mehrhoff et al. 1996). All Element Occurrence (EO) numbers are designated by the appropriate state agencies. Sites that have not received EO designations are either from herbarium records that have not been entered into the data file or from field records that have not been entered. Figures 2 and 3 show the distribution of extant and historical occurrences of *Potamogeton strictifolius* in New England, respectively.

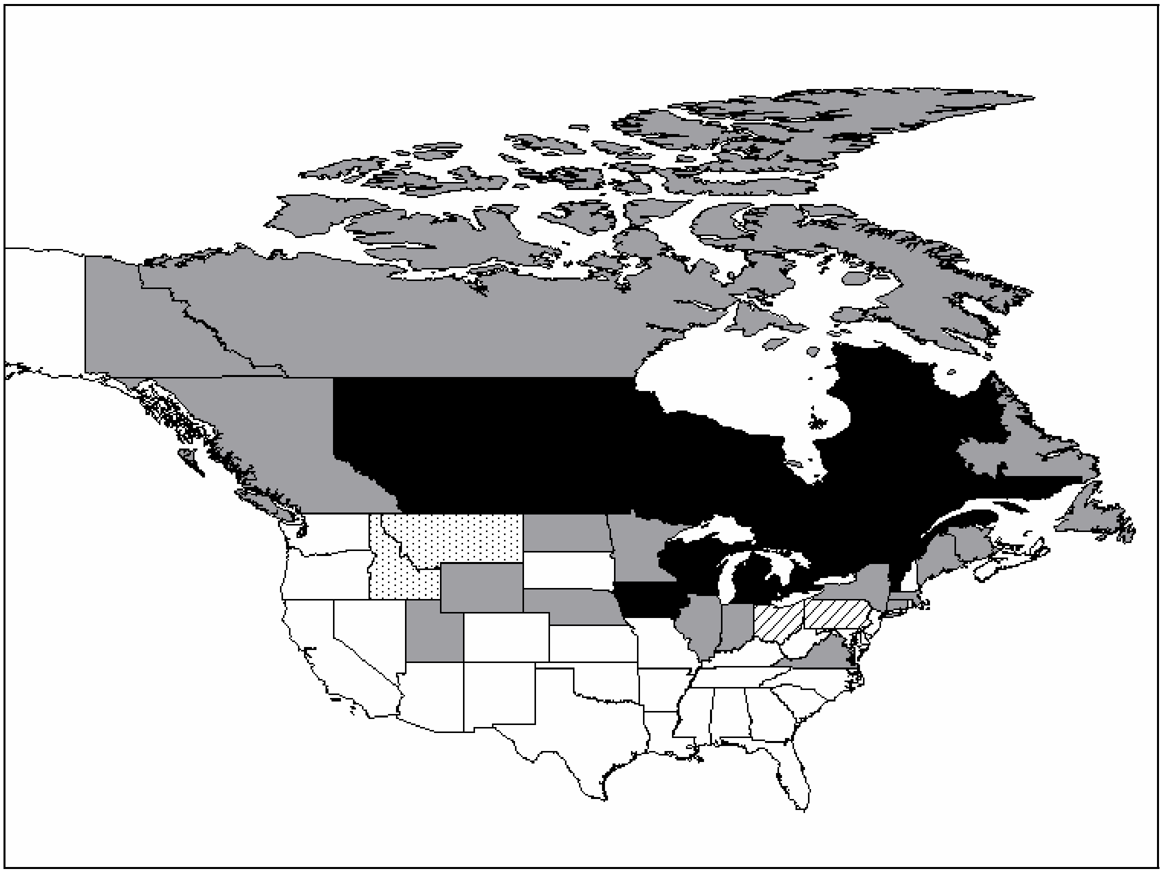

Figure 1. Occurrences of *Potamogeton strictifolius* in North America. States and provinces shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. Areas shaded in black have more than five confirmed occurrences. The states (Ohio and Pennsylvania) with diagonal hatching are designated "historic," where the taxon no longer occurs. States with stippling are ranked “SR” (status “reported” but not necessarily verified). See Appendix for explanation of state ranks.

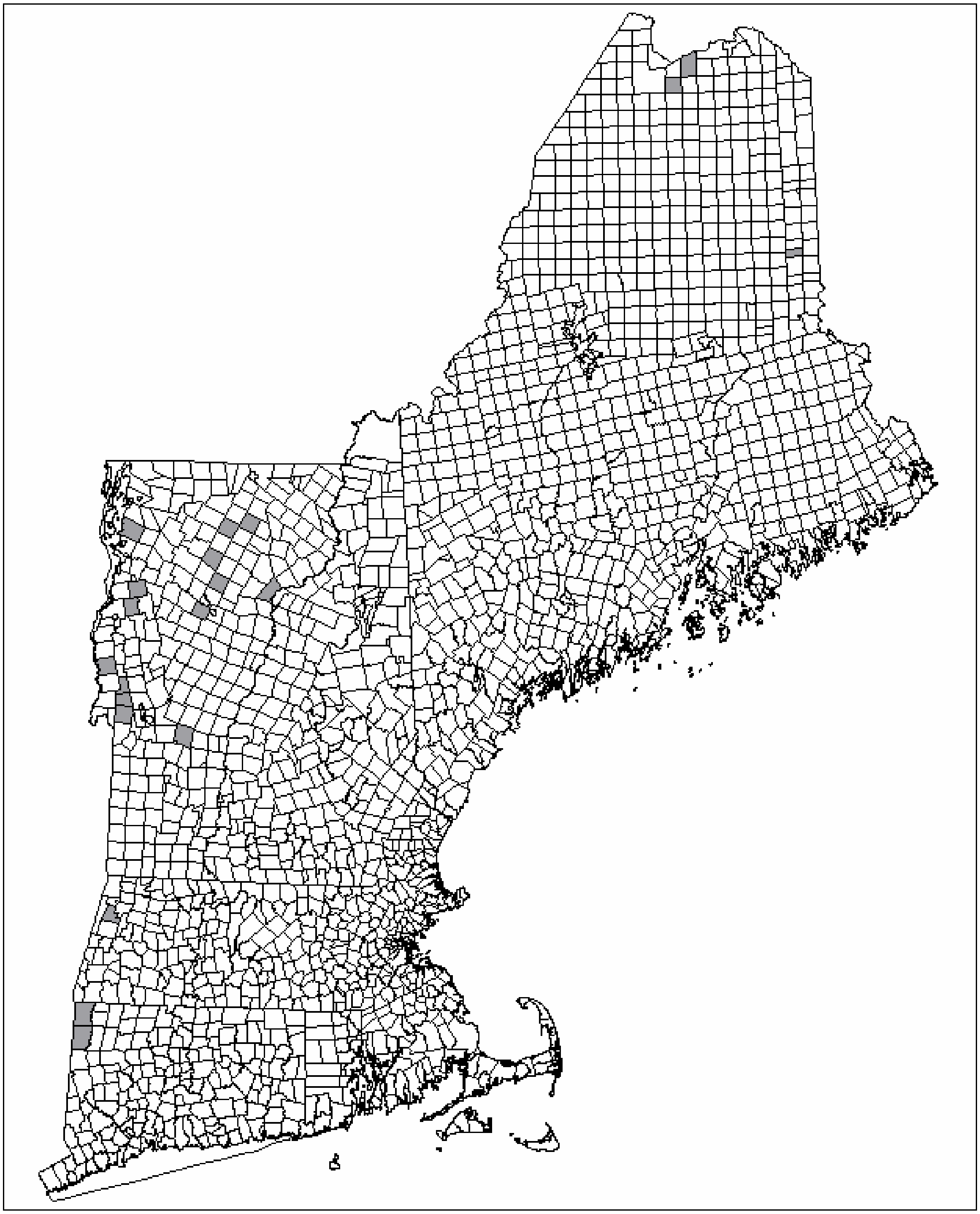

Figure 2. Extant occurrences of *Potamogeton strictifolius* in New England. Town boundaries for New England states are shown. Towns shaded in gray have one to five extant occurrences of the taxon.

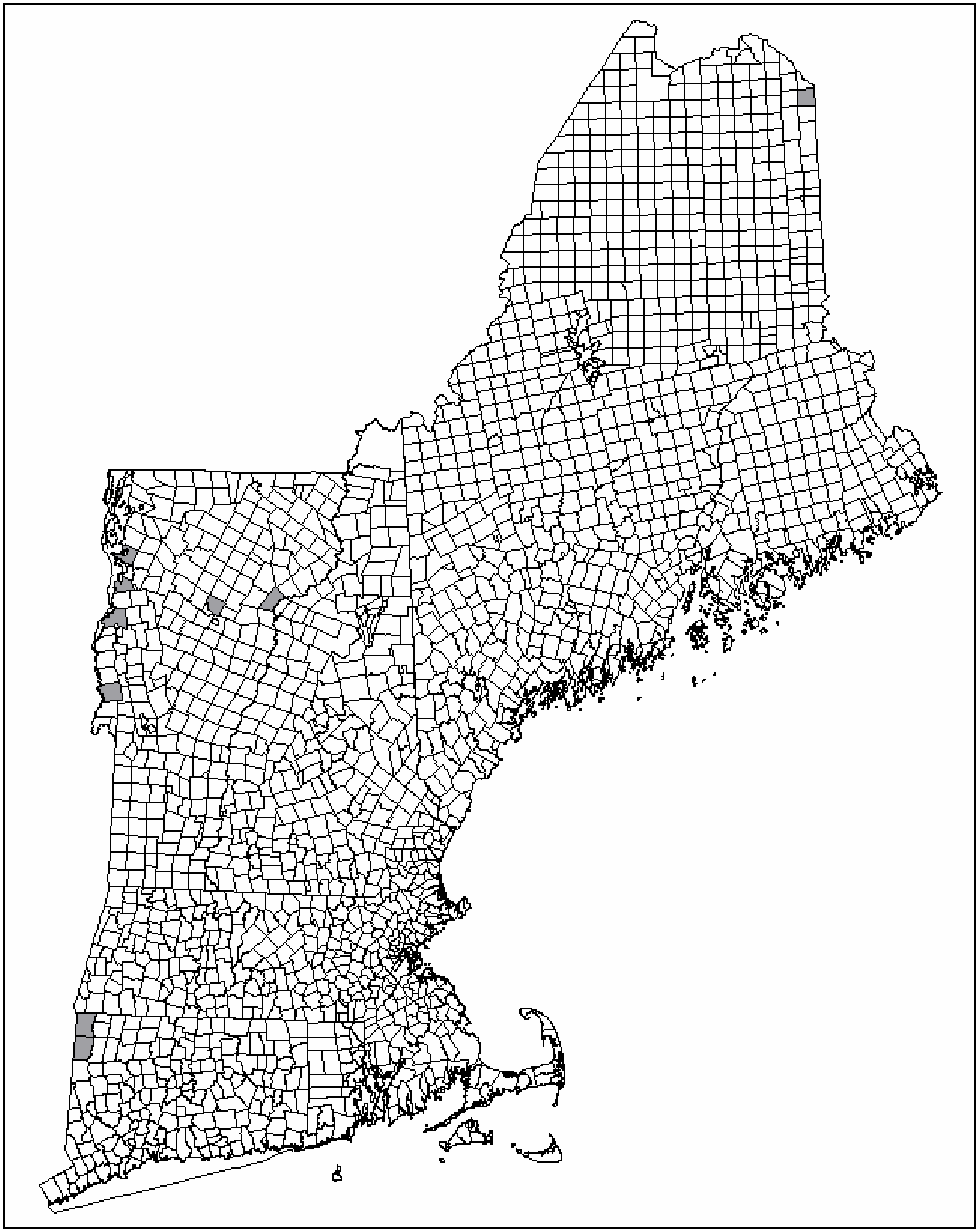

Figure 3. Historical occurrences of *Potamogeton strictifolius* in New England. Towns shaded in gray have one to five historical records of the taxon.

Table 2. New England Occurrence Records for *Potamogeton strictifolius*. Shaded occurrences are considered extant.

State	EO #	County	Town
ME	.001	Aroostook	Caswell
ME	**.002**	**Aroostook**	**T16 R9 WELS**
ME	**.003**	**Aroostook**	**T16 R9 WELS**
ME	**.004**	**Aroostook**	**St. John Plantation**
ME	**.005**	**Aroostook**	**New Limerick**
VT	**.001**	**Rutland**	**Castleton**
VT	**.002**	**Rutland**	**Hubbardton**
VT	**.003**	**Rutland**	**Hubbardton and Sudbury**
VT	.004	Windsor	Windsor
VT	**.005**	**Addison**	**Monkton**
VT	**.006**	**Orleans**	**Glover**
VT	**.007**	**Washington**	**Berlin**
VT	**.008**	**Washington**	**Calais**
VT	**.009**	**Orleans**	**Craftsbury**
VT	**.010**	**Rutland**	**Sudbury**
VT	**.012**	**Windsor**	**Plymouth**
VT	**.013**	**Lamoille**	**Elmore**
VT	**.014**	**Rutland**	**Sudbury**
VT	**.015**	**Rutland**	**Sudbury**
VT	**.016**	**Chittenden**	**Hinesburg**
VT	**.017**	**Caledonia**	**Ryegate**
VT	**.018**	**Addison**	**Shoreham**
VT	**.019**	**Rutland**	**Hubbardton**
VT	**.020**	**Chittenden**	**Milton**
VT	Site 1	Addison	Ferrisburg
VT	Site 2	Addison	Ferrisburg
VT	Site 3	Addison	Orwell
VT	Site 4	Caledonia	Barnet
VT	**Site 5**	**Caledonia**	**Barnet**
VT	Site 6	Chittenden	Shelburne
VT	Site 7	Chittenden	
VT	Site 8	Chittenden	Colchester
VT	Site 9	Grand Isle	North Hero
VT	Site 10	Washington	East Montpelier
MA	**.001**	**Berkshire**	**Lanesborough**
CT	.001	Litchfield	Salisbury
CT	**.002**	**Litchfield**	**Salisbury**
CT	.003	Litchfield	Sharon
CT	**.005***	**Litchfield**	**Sharon**
CT	**.006***	**Litchfield**	**Salisbury**

*Proposed listings

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

The primary goal for *P. strictifolius* is to maintain and regularly monitor the populations at the 27 current, verified sites and to maintain a mean of at least 100 plants per site in a six year sampling rotation. A population of at least 100 plants over a six-year sampling period could easily sustain itself due to the abundance of winter buds produced. Sampling should be conducted biannually for the first six years to obtain an estimate of the population variability, then once every six years afterward. Biannual sampling should be conducted at the sites that presently appear to be more vulnerable due to extensive invasive weed populations, Such sites are CT .005 (Sharon) and CT .006 (Salisbury) and MA .001 (Lanesborough). This study uncovered more location data than previously known, yielding an increased number of extant sites. With more intensive surveys, 15 to 20 new populations should also be located in the next 20 years in Maine, Vermont, and Massachusetts, bringing the total number of extant sites to a distribution approximating the historical distribution of the taxon. When an area is monitored, it is important to take water samples for a baseline to determine the habitat parameters of *P. strictifolius* and to detect nutrient increases. Any invasive plants and their relative abundance should also be noted.

Presently, the most secure sites in New England are ME .002 (T16 R09 WELS), ME .003 (T16 R09 WELS), ME .004 (Wallagrass Lakes), VT .006 (Glover), VT .007 (Berlin), and MA .001 (Lanesborough). This is despite competition with *Myriophyllum spicatum* at the VT .007 (Berlin) site. The MA .001 (Lanesborough) site has a healthy population in competition with *M. spicatum, P. crispus,* and numerous native species. These sites should receive the highest priority for protection. The other sites are low in numbers but are known to fluctuate year to year. The Calais, Vermont population, VT. 008, was not relocated in 2001, but that was probably due to the time of the year that the site was sampled. Plants at the site were heavily encrusted with marl so the plants probably had already died back at the time of sampling in early August.

The other sites are lower in numbers but are known to fluctuate year to year. This is a phenomenon regularly observed despite the fact that the plants produce turions. Because of this natural variability, known and historic sites should be visited at least once every six years. Sites with extensive weed problems should be monitored biannually for six years to note any changes in the populations. It is important to record the change in densities over a number of years to determine if the population is growing and to determine if there is any correlation of population growth with factors that might affect growing conditions.

It would be ideal, but very difficult, to control invasive species while leaving *P. strictifolius* undisturbed. Typical control methods used are herbicide applications, harvesting, benthic barriers, and hand-pulling; the preferred method depends on the conditions at the site. Control should only be attempted after a thorough study of the water body. All state regulations and permitting must be followed. Yearly monitoring of the invasive weeds is needed to make sure they are not encroaching on the *P. strictifolius.* It is important to educate the public concerning ways to prevent introduction of invasive species in the lakes and ponds with *Potamogeton strictifolius*. Boaters and fisherman should receive educational literature when fishing licenses and boat registrations are issued.

Nutrient runoff in the lakes and ponds where *P. strictifolius* occurs should be controlled to prevent eutrophication. This can be accomplished by educating the public to make sure septic systems at shoreline homes are functioning correctly and by reducing the use of lawn fertilizer. The establishment and maintenance of vegetated buffer zones around the lakes will help to reduce runoff from agricultural lands and lawns.

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APPENDICES

1. Unverified *Potamogeton* Sites

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

1. Unverified *Potamogeton strictifolius* Sites in Vermont			
Town	**County**	**Years reported and reported by:**	**Comments**
Bristol	Addison	1986, Vermont Department of Environmental Conservation (VT DEC)	Sampled by Hellquist in 1992, no plants found
Leicester	Addison	1990, VT DEC	Private access through camp. No one available for permission in 2000
Bennington, Shaftsbury	Bennington	1993, 1994, 1996, VT DEC	
Colchester	Chittenden	1988, VT DEC	Resample
North Hero	Grand Isle	1991, VT DEC	Resample
North Hero	Grand Isle	1899, Ezra Brainerd	Historic
Craftsbury	Orleans	1972, 1986, VT DEC	
Benson	Rutland	1969, Frank Seymour 26893, VT	Site has been sampled many times since 1969 without being relocated
Castleton, Fairhaven	Rutland	1990, VT DEC	
Hubbardton	Rutland	1990, VT DEC	
Hubbardton	Rutland	1991, 1993, VT DEC	Resample
Poultney/Wells	Rutland	1999, VT WPA	Resample
Orwell/Benson	Rutland	1991, VT WPA	Hellquist identified specimen as *P. pusillus*
Calais, East Montpelier	Washington	1986, VT DEC	Hellquist sampled in 2000, plants not found,
Plymouth	Windsor	1985, VT DEC	Surveyed 2000, no plants found
Sharon	Windsor	1988, VT DEC	Resample

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 group—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 observation have been made for more than 20 years. An X rank is utilized for sites that are 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.