

New England Plant Conservation Program

*Ranunculus lapponicus* L.  
Lapland Buttercup

Conservation and Research Plan  
for New England

Prepared by:  
Lisa St. Hilaire  
Ecologist

For:

New England Wild Flower Society  
180 Hemenway Road  
Framingham, MA 01701  
508/877-7630  
e-mail: [conserve@newfs.org](mailto:conserve@newfs.org) • website: [www.newfs.org](http://www.newfs.org)

Approved, Regional Advisory Council, December 2002

## SUMMARY

---

*Ranunculus lapponicus* L., Lapland buttercup, is a member of the Ranunculaceae or buttercup family. It is a circumboreal species found in Eurasia, Greenland, and North America and is considered globally secure (G5). In North America, *R. lapponicus* is at the southern end of its range in Maine (S1, T), Michigan (S1S2), Minnesota (S3), and Wisconsin (S1), and has likely always been relatively rare in these areas. In New England, *R. lapponicus* is only found in northern white-cedar swamps in extreme northern areas of Aroostook County, Maine. There are nine records for *R. lapponicus* in Maine, including two very recent additions. One of these is historic. Four of these occur in the same town, Perham, and three of these four should be combined to one occurrence because they are hydrologically connected. This would give a total of six extant populations and one historic occurrence.

Although other buttercup species have been well studied, there is little information regarding the biology of *R. lapponicus*. We know that it flowers in June and July, flowers have a sweet scent, and that it is a clonal plant, but there is no information regarding pollinators, reproductive allocation, seed dispersal, germination rates, herbivory, or mycorrhizal relationships. Primary threats to Maine populations are from natural processes such as flooding from beaver impoundment and windthrow, as the largest populations are in conservation or state ownership. Logging represents a potential threat at two privately owned occurrences (both smaller populations) and one of the publicly owned occurrences.

The primary conservation objective for *Ranunculus lapponicus* in New England is to maintain plant populations at no fewer than the current number of known occurrences. Other objectives are to secure its existence at occurrences on public land by development of site management plans, to maintain high population numbers at the five (currently, would be three if combined) large sites, and to increase population numbers at the three small sites. Low-priority objectives are seed banking and augmentation.

## 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.

This document should be cited as follows:

St. Hilaire, Lisa. 2003. *Ranunculus lapponicus* (Lapland buttercup) Conservation and Research Plan for New England. New England Wild Flower Society, Framingham, Massachusetts, USA.

© 2003 New England Wild Flower Society

# I. BACKGROUND

---

## INTRODUCTION

*Ranunculus lapponicus* L., Lapland buttercup, is a member of the Ranunculaceae, or buttercup family. This is a large family, and there are 31 species of buttercups in northeastern United States and adjacent Canada (Gleason and Cronquist 1991) and 16 in Maine (Haines and Vining 1998).

*Ranunculus lapponicus* is a circumboreal species found in Eurasia, Greenland, and North America. *Ranunculus lapponicus* is found in all Canadian Provinces, except for Nova Scotia and Prince Edward Island, where it has never been recorded, and Newfoundland Island, where it is historic. In the United States, *Ranunculus lapponicus* is found in Alaska (SR), Maine (S1), Michigan (S1S2), Minnesota (S3), and Wisconsin (S1). Except for Alaska, *R. lapponicus* is at the southern limit of its range in the northern areas of these states. In Maine, *R. lapponicus* is listed as Threatened, and is found only in extreme northern Aroostook County. The *Flora Conservanda* lists *Ranunculus lapponicus* as a Division 2 species, indicating that it is a regionally rare taxon with fewer than 20 occurrences in New England (Brumback and Mehrhoff et al. 1996). There are nine records of *R. lapponicus* in Maine, including one historic record and two new populations observed in the fall of 2002. Four records occur in Perham, and three of these Perham occurrences should be combined because they are part of the same wetland complex. This would leave a total of five extant occurrences and one historic occurrence in Maine. The state ranking of *Ranunculus lapponicus* in Maine was changed from S2 to S1 in October 2002.

*Ranunculus lapponicus* is a clonal plant and reproduces vegetatively. *Ranunculus lapponicus* flowers in June and July, but it is unknown if seed production is apomictic (seed production without fertilization) as in some other *Ranunculus* species, or if it is sexual and outcrossing. *Ranunculus lapponicus* is typically found in wet hollows of northern white-cedar swamps in Maine, often on an elevated surface, such as a rotten log (personal observation). It is generally found in deep shade, though at least one sizeable patch of plants is found near a large blowdown (personal observation). Major threats to the four largest *Ranunculus lapponicus* occurrences in Maine are from natural processes, such as beaver impoundment or windthrow. Logging is a potential threat at the three smaller occurrences, and the large, newly discovered occurrence.

This conservation plan is written in two sections. The first section summarizes available information on the ecology, taxonomy, distribution, and status of *Ranunculus lapponicus*. The second section presents conservation objectives and general conservation actions for

*Ranunculus lapponicus* in New England, specific conservation actions for each occurrence, and a prioritized implementation schedule for these conservation actions.

## **DESCRIPTION**

The following description of *Ranunculus lapponicus* is based primarily on Benson (1940, 1948), Fernald (1950), Gleason and Cronquist (1991), Scott et al. (2000), Whittermore and Parfitt (2002), and personal observation.

*Ranunculus lapponicus* is a relatively small, rhizomatous plant with a creeping ground-level or underground stem. Roots are slender, and the plant roots from rhizome nodes. Scattered simple (rarely forked), glabrous, 0.5-2 dm high flowering scapes are borne at rhizome nodes. Basal leaves are reniform, petioled, 1.1-2.6 cm wide by 1.6-4.3 cm long, and very deeply 3-parted, with each segment coarsely crenate to shallowly lobed. There is typically one basal leaf (occasionally 2) that originates from the rhizome node. There may be a single stem leaf near the base of the scape. The inflorescence is a solitary, axillary, 5-15 mm diameter flower. The receptacle is glabrous, 1-2 mm high, and not noticeably enlarged in fruit. There are three sepals; they are 3-7 mm long by 2-5 mm wide, spreading or reflexed from their base, ovate, greenish yellow to yellow to brownish, scarious, and glabrous. There are 5-10 petals; they are yellow, 4-6 mm long by 2-3 mm wide, oblong to obovate, and unlobed. The nectary scale forms a glabrous pocket at the base of each petal. There are 17-24 stamens. There are 5-15 carpels and subsequent fruits. The fruit is an achene that is oblong to ovoid-fusiform, constricted at the middle, and 2-4.5 mm long by 2-2.2 mm wide, in general slightly longer than the slender hooked style. The style is persistent and forms a beak in the achene that is lanceolate, slender, 1.6-2.4 mm long, and with a sharply curved or hooked tip. There is one seed per achene.

The solitary basal leaf distinguishes *R. lapponicus* from other terrestrial *Ranunculus* species, which typically have several basal leaves (Hinds 2000). Also, the stems are creeping in *R. lapponicus*, whereas in other terrestrial *Ranunculus* species they are more or less erect, though the runners may sometimes be creeping (Hinds 2000). *Ranunculus lapponicus* and *R. ficaria* are the only two yellow-flowered *Ranunculus* species that typically have three sepals, versus the more typical five (Gleason and Cronquist 1991). However, *R. ficaria* occurs in open woods and waste places (Fernald 1950), and it is not included in Maine's Flora (Haines and Vining 1998), so it should not be confused with *R. lapponicus*. The combination of only three sepals and typically one basal leaf should distinguish *R. lapponicus* from any other *Ranunculus* species, including those with which it occurs.

There are 16 *Ranunculus* species in Maine (Haines and Vining 1998). Of these, the following occur in Aroostook County: *R. abortivus*, *R. acris*, *R. aquatilis* var. *diffusus*, *R. flammula*, *R. gmelinii*, *R. hispidus* var. *caricetorum* (= *R. septentrionalis*), *R. lapponicus*, *R. pensylvanicus*, and *R. recurvatus* (Campbell et al. 1995, Haines and Vining 1998).

*Ranunculus acris* and *R. hispidus* var. *caricetorum* occur in areas where *R. lapponicus* grows (Richard Clark, TNC steward, personal communication). *Ranunculus pensylvanicus* is a species of stream banks, bogs, moist clearings, and depressions in woodlands (Whittermore and Parfitt 2002). Though not recorded on species lists with *R. lapponicus*, *R. pensylvanicus* may be found in similar habitat. An abbreviated key (from Haines and Vining 1998) is presented to distinguish *Ranunculus* species that may be found in northern white-cedar swamp habitat in Maine.

- 1a. Sepals 3 (4); flowering stems with 1 (2) basal leaves; achenes with a prominent, corky appendage prolonged distally to the seed.....*Ranunculus lapponicus*
- 1b. Sepals 5; flowers borne on leafy stems, at least arising from a tuft of leaves; achenes not prolonged beyond the seed body.....2
  - 2a. Leaves with flattened, winged, sometimes ill-defined petiolules, therefore these leaves lobed but not divided; petals 7.0-15.0 mm long, exceeding the length of the sepals; receptacle glabrous.....*Ranunculus acris*
  - 2b. At least the larger leaves with definite, unwinged petiolules, therefore these leaves are compound .....3
    - 3a. Petals 2.0-5.0 mm long; anthers to 1.0 mm long..... *Ranunculus pensylvanicus*
    - 3b. Petals 5.0-15.0 mm long; anthers 1.2 mm or longer; leaf blades more or less palmately divided, about as wide as long; stems decumbent to creeping, sometimes rooting at the nodes..... *Ranunculus hispidus* var. *caricetorum*

Leaves of *Ranunculus lapponicus* are somewhat similar in size and appearance to leaves of *Coptis trifolia* (goldthread). *Coptis trifolia* is a white-flowered member of the Buttercup family and also occurs in northern white-cedar swamps in Maine (Fernald 1950, Gleason and Cronquist 1991, Haines and Vining 1998). Leaves of *Coptis trifolia* are evergreen, whereas leaves of *Ranunculus lapponicus* are deciduous (Fernald 1950). In general, leaves of *C. trifolia* are coarser, thicker, harder, and a darker green than those of *R. lapponicus*, while leaves of *R. lapponicus* are always a lighter and fresher green (Clark, personal communication). Additionally, leaves of *C. trifolia* are more sharply toothed, the teeth are mostly mucronate, and the lateral leaflets are unequalateral and broadly rounded on the lower side (Fernald 1950, Gleason and Cronquist 1991).

**TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY**

*Ranunculus lapponicus* was first described in 1753, in *Species Plantarum* 1: 553, as *Ranunculus Lapponicus* (MOBOT 2002). *Coptidium lapponicum* (L.) Gandog. and

*Anemone nudicaulis* A. Gray are synonyms for *R. lapponicus* (Benson 1942, 1948, Scott et al. 2000, IPNI 2002, MOBOT 2002). *Anemone nudicaulis* A. Gray was published in 1886, in the *Botanical Gazette* 11: 17 (Benson 1942, 1948). Coulter and Fisher (1893: 299) indicate that *Anemone nudicaulis* Gray is “imperfectly known,” and that N. L. Britton determined it is actually *Ranunculus lapponicus* L. *Ranunculus lapponicus* is known in French as Renoncule de Lapponie (Whittemore and Parfitt 2002).

The type specimen of *Ranunculus lapponicus* was collected in “habitat in Alpibus Lapponicus” (Benson 1942: 385). The type specimen of *Anemone nudicaulis* is from bogs and banks near the water in the Lake Superior region, Sand Bay, Minnesota, near 48° latitude, dated August 8, 1870, collected by a member of the U. S. Steamer Search, and sent to A. Gray (Benson 1942). The type specimen of *Ranunculus lapponicus* is actually a lectotype, a specimen selected from the original material to serve as the nomenclatural type because the holotype was not designated at the time of publication or was designated so long ago that it is missing (Benson 1954).

Hybridization is infrequently reported for *Ranunculus* species (Mitchell and Dean 1982), though apomixis and interspecific hybridization can occur in some Old World groups of Ranunculaceae (Whittemore and Parfitt 2002). *Ranunculus lapponicus* hybridizes with *R. pallasii*, a low arctic species, to form the sterile hybrid *R. x spitzbergensis*, named for the island of Spitzbergen (a territory of Norway in the high Arctic) where it was first described (Benson 1948, Cody et al. 1988). This hybrid is known from five areas in northern Canada, but neither *R. pallasii* nor *R. x spitzbergensis* occur in New England, nor are they likely to.

The genus *Ranunculus* is divided into subgenera. *Ranunculus lapponicus* is the only member of the subgenus Coptidium (Benson 1940). Benson (1940) uses the sepal characteristic to separate the subgenera of *Ranunculus*. Only the subgenera Coptidium (*R. lapponicus*), Pallasiantha (*R. pallasii*), and Ficaria (only member is *R. ficaria*) have three sepals, or sometimes two. The subgenus Euranunculus contains the majority of North American *Ranunculus* species, and includes *R. acris* and *R. adoneus*, both discussed in this plan (Benson 1940). The diploid number of *Ranunculus lapponicus* ( $2n$ ) is 16 (Bormann and Beatty 1955, Hinds 2000, Whittemore and Parfitt 2002). Pollen stainability for *Ranunculus lapponicus* is 97% (Cody et al. 1988), indicating high fertility (Quiros et al. 2002, Stoeva et al. 2002).

## **SPECIES BIOLOGY**

There is little published in the literature regarding *Ranunculus lapponicus*, therefore information regarding other terrestrial *Ranunculus* species of cold or temperate climates, but not meadow or field habitat, is presented. The information may or may not be applicable to *R. lapponicus*, but certainly will point to directions for further study.

## ***Flowering and Pollination***

*Ranunculus lapponicus* flowers in June and July across its range (Fernald 1950, Gleason and Cronquist 1991, Whittermore and Parfitt 2002) and in Maine, though flowers may be senescent by July (personal observation). *Ranunculus lapponicus* flowers have a sweet scent (Scott et al. 2000) and are disc-shaped. Disc-shaped flowers present easily accessible pollen and nectar, and may be visited by many insect species (Totland 1994). As a genus, buttercup flowers have abundant pollen but little nectar, and reflect light in the ultraviolet range (Roy 1994).

Pollinators for *Ranunculus lapponicus* are unknown. However, pollinators for an alpine population of *Ranunculus acris* in southwestern Norway were primarily Dipterans, in the Muscidae and Anthomyiidae (Totland 1994). Anthomyiid flies were also the primary pollinators of another alpine buttercup, *Ranunculus inamoenus*, in western Colorado during one study year, but during a previous year Halictid bees were the primary flower visitors (Roy 1994). Though flies were the primary pollinators for alpine *Ranunculus acris*, they carried smaller amounts of pollen than other insect groups (Totland 1994). Relatively few alpine *Ranunculus acris* ovules were fertilized and developed into mature seeds after one fly visit (Totland 1994). Compare this to near total seed set from one bumblebee visit to *Saxifraga oppositifolia* or *Bartsia alpina* in the arctic (Totland 1994 and references therein). Insect visitation increased seed set in *Ranunculus adoneus*, an alpine buttercup (Stanton and Galen 1989 in Roy 1994). The pollinators of *Ranunculus lapponicus* should be determined, and it should be determined if these pollinators also utilize other species.

The between-flower flights of pollinating flies for the alpine population of *R. acris* were quite short, with 95% of them <25 cm, and a maximum distance observed of 60 cm (Totland 1994). Totland (1994) indicated that the short interflower flights and passive seed dispersal in this *R. acris* population could lead to inbreeding depression because most of the genetic exchange in the population occurs between close relatives. This could be an issue for *R. lapponicus*, especially as *R. lapponicus* utilizes vegetative establishment of new plants, which would be genetically identical to the parent plant.

Flowering in *Ranunculus lapponicus* has not been correlated with any environmental variables. However, a study examining climate and flowering of herbs in a Swedish *Carpinus betulus* (hornbeam) forest, found that flowering in another buttercup, *Ranunculus ficaria*, is positively correlated ( $P < .05$ ) with humidity and precipitation of the previous year, especially during August and September ( $P < .01$ ) (Tyler 2001). *Ranunculus ficaria* blooms early in spring, then exists exclusively below ground in summer and autumn (Tyler 2001). *Ranunculus lapponicus* blooms later (June-July, as above), and leaves remain green throughout the growing season and senesce towards fall (Clark, personal communication), but results from the *R. ficaria* study point out that it is worth pursuing the link between flowering and environmental parameters of the previous year.

*Ranunculus lapponicus* grows in an area with low temperatures and short growing seasons, and it is worth investigating if flowers are heliotropic. Flowers of *Ranunculus adoneus* and *Ranunculus acris* in alpine areas are heliotropic (Stanton and Galen 1989, Totland 1996). In cold climates, flower warmth may be a direct reward for pollinators, and/or heliotropism may positively influence pollen germination, growth of the pollen tube, and seed size and production (Patiño et al. 2002). However, in warmer climates, heliotropism may reduce pollen and ovule viability (Patiño et al. 2002). Heliotropism may be important to *Ranunculus lapponicus* in Maine, because it is at the southern edge of its range, though it is unclear if we should expect a positive or negative effect.

### ***Dormancy***

Seeds of *Ranunculus lapponicus*, and at least some other species of *Ranunculus*, exhibit morphophysiological dormancy, meaning that dormancy is controlled by maturity of embryo and hormones (Bliss 1958 in Baskin and Baskin 2001). Length of dormancy for *R. lapponicus* was not indicated, but seeds of *R. adoneus* can remain dormant but viable in the soil for at least two years (Scherff et al. 1994). Vegetative reproduction of *R. adoneus* likely influences the persistence rather than the spread of populations (Scherff et al. 1994). This may or may not be similar for *R. lapponicus*.

### ***Germination and Regeneration***

Germination and establishment rates are unavailable for *R. lapponicus* and it is unknown what portion of reproduction is vegetative and what portion is sexual. Many buttercup species exhibit apomictic seed production (Candace Galen, University of Missouri, personal communication), but it is unknown if *R. lapponicus* is apomictic or sexual and outcrossing.

An important factor in regeneration of any species is the concept of safe sites (Harper 1977) and the regeneration niche (Grubb 1977). Menges (1991) indicates that the number and distribution of safe site/regeneration niche microsites may be more important to plants than the total habitat area. Seedling-environment interactions likely play a role in defining the ecological amplitude of *Ranunculus adoneus*, supporting the idea that the regeneration niche is a main determinant of plant community composition (Galen and Stanton 1999). The same may be true for *R. lapponicus*. For tree and herb seedlings, including *R. adoneus*, favorable germination sites are not necessarily sites most favorable for survival (Harmon and Franklin 1989, Collins 1990, Kellman and Kading 1992, Ohlson and Zackrisson 1992, Smith and Capelle 1992, St. Hilaire and Leopold 1995, Galen and Stanton 1999). This is also likely the case for *R. lapponicus*, but it is an area needing further research.

*Ranunculus lapponicus* is found in scattered hollows of northern white-cedar swamps in Maine, among mosses, sedges, and cedar duff (personal observation). The texture of bryophytes may provide safe germination sites for tree seeds in northern white-cedar swamps (Johnson and Fryer 1992, Ohlson and Zackrisson 1992, St. Hilaire and Leopold 1995). Perhaps the same would be true for *Ranunculus lapponicus* achenes in similar habitats, allowing that other factors needed for germination are also present. Bryophytes are a major feature of the ground layer of northern white-cedar swamps (St. Hilaire and Leopold 1995, Gawler 2001) and may affect *Ranunculus lapponicus* germination and establishment by creating favorable moisture relations (Keizer et al. 1985), transferring or interrupting nutrients (Tamm 1964, Oechel and Sveinbjörnsson 1978, Richardson 1981, Chapin et al. 1987, Longton 1988, Bates and Farmer 1990, Carleton and Read 1991, Longton 1992), forming fungal associations (Pocock and Duckett 1985, Carleton and Read 1991), or releasing growth regulatory compounds (Cox and Westing 1963, Huneck and Meinunger 1990). For tree seedlings in a northern white-cedar swamp, it has been suggested that bryophyte structure and moisture relations may enhance seed germination, though other factors such as nutrient leaching may negatively affect subsequent survival (St. Hilaire and Leopold 1995). Some mosses (*e.g.*, *Sphagnum* species) can overgrow tree seedlings and inhibit their survival (Ohlson and Zackrisson 1992); perhaps the same would be true for *Ranunculus lapponicus* seedlings in some moss microhabitats.

Percent cover and seed mass of *R. adoneus* were lower in late melting snowbed sites (Galen and Stanton 1993). Though timing of snow melt is likely not an issue for *R. lapponicus* in Maine, some *R. lapponicus* patches may remain under water from flooding due to spring high water or beaver activity (personal observation). Several patches of *R. lapponicus* at ME .006 (Perham) were under up to 6 inches of water on June 2, 2002 (personal observation). The plants in these areas appeared healthy, with green, turgid leaves. Richard Clark (personal communication) indicated that one area was flooded from beaver activity in a nearby area of the site, but that the other two areas were flooded due to high spring water levels. It would be interesting to track some measure of fitness, perhaps plant cover and seed mass, at flooded patches and patches that are not flooded.

### ***Seed Dispersal***

Achenes of *R. lapponicus* are green (Clark, personal communication) and presumably photosynthetic. Larger seeds have an establishment advantage, but a dispersal disadvantage over smaller seeds (Galen and Stanton 1993). Photosynthetic achenes can contribute to their own carbon assimilation while the seed fills the achene (Galen and Stanton 1993).

Most plant taxa have highly restricted seed dispersal, and this is true for *R. adoneus* (Scherff et al. 1994 and references therein). *Ranunculus adoneus* relies on passive dispersal mechanisms (Galen and Stanton 1993) and disperses a very short distance from the maternal plant (Scherff et al. 1994). Most seeds disperse between 4 and 16 cm, in the direction of the

prevalent wind patterns (Scherff et al. 1994). During snowmelt, seeds may experience a secondary dispersal, to about 10 cm directly downhill from the maternal plant (Scherff et al. 1994). However, genetic studies of *R. adoneus* indicate that gene flow is widespread, because rare, long-distance dispersal events may have a disproportional effect on the genetic structure of the population (Stanton et al. 1997). Because *R. lapponicus* also has no specialized dispersal mechanism, we can expect it to have a relatively short dispersal distance. Secondary dispersal for *R. lapponicus* is likely related to levels of spring high water due in part to snowmelt, but would not likely cover great distances. Some longer-distance secondary dispersal may occur with achenes grazed by rodents or deer. In addition, the beak of the achene of *R. adoneus* promotes dispersal by small mammals (Galen, personal communication), and the same may be true for *R. lapponicus*.

### ***Genetic Fitness***

Small populations become inbred more rapidly (Barrett and Kohn 1991), while large populations help keep inbreeding low and maintain high allele diversity (Ledig 1986). Because *Ranunculus lapponicus* has small populations and is naturally sparsely distributed in our area, it may have genetic adaptations to such situations (*sensu* Barrett and Kohn 1991). *Ranunculus lapponicus* may have a genetic system to decrease inbreeding as opposed to a species that has recently undergone a sudden population decline (*sensu* Barrett and Kohn 1991).

It is unclear if *R. lapponicus* populations in Maine are large enough to maintain high genetic diversity, especially given that it is a clonal plant, and if intraspecific competition between ramets and genets is an issue (*sensu* van Kleunen et al. 2001). Populations of low genetic diversity are susceptible to stresses such as disease and climate change (Ledig 1986). However, there are few documented examples of natural plant populations where genetic uniformity makes the population more susceptible to disease (Menges 1991), and there is no empirical evidence linking genetic composition to growth and survival of rare plant populations (Schemske et al. 1994).

If *Ranunculus lapponicus* exhibits apomictic seed production as well as vegetative reproduction, then there may be little genetic diversity in a population. Clonal plants compete intraspecifically among genets and ramets (van Kleunen et al. 2001). In the clonal plant *Ranunculus reptans*, increased density caused a shift in reproductive effort, with the allocation to sexual reproduction increased over that of vegetative reproduction (van Kleunen et al. 2001). Intraspecific competition may also affect evolutionary processes such as genetic drift and selection due to effects on effective population size (van Kleunen et al. 2001). Prati and Schmid (2000) found that the variation in sexual reproduction and clonal growth traits of *R. reptans* was maintained by fine-scaled environmental heterogeneity. Intraspecific competition and fine-scaled environmental heterogeneity may be important factors for *R. lapponicus*, especially if they affect life-history traits as in *R. reptans*.

## ***Toxicity and Herbivory***

*Ranunculus lapponicus* is considered toxic when ingested, and may cause contact dermatitis, photosensitization, or photodermatitis (Hinds [2000] considers much of the family mildly to extremely toxic, including some supposed edibles). However, *R. lapponicus* is utilized as a dietary aid prior to consuming other food by starving western Inuit groups (Moerman 1986 in Whittermore and Parfitt 2002).

Though herbivory was not noted on any *Ranunculus lapponicus* plants in Maine, buttercup (as a genus) achenes are eaten in small amounts by several kinds of birds and rodents (Martin et al. 1951). Black-tailed deer browse on whole buttercup plants in very small amounts (Martin et al. 1951); perhaps the same is true for white-tailed deer. *Ranunculus adoneus* typically occurs in snowbeds, but where it occurs in alpine meadows, rodent predation on seedlings can be a significant cause of mortality (Scherff et al. 1994). A European study showed that certain gastropods will feed on *Ranunculus repens*, though not preferentially (Iglesias and Castillejo 1999). Two of these European gastropods are *Arion subfuscus*, dusky slug, and *Deroceras reticulatum*, field slug, which are present in natural habitats in Maine and are serious pests, but it is unlikely that they will graze selectively on *Ranunculus lapponicus*.

## ***Mycorrhizal Relations***

Mycorrhizal relations are unknown for *Ranunculus lapponicus*. Dark septate mycorrhizal fungi, and not vesicular arbuscular mycorrhizal fungi or new roots, may play a role in early season nitrogen uptake by *Ranunculus adoneus* (Mullen et al. 1998), while vesicular arbuscular mycorrhizal fungi are important for phosphorus uptake in *R. adoneus* (Mullen and Schmidt 1993). *Ranunculus adoneus* phosphorus levels were highest in early summer, during flowering and seed production, and declined in July and August, corresponding with flowering and seed dispersal (Mullen and Schmidt 1993). Arbuscules have a short life span and are digested by host cells when they are no longer needed for nutrient transfer (Toth and Miller 1984 in Mullen and Schmidt 1993). One of the two types of vesicular arbuscular mycorrhizal fungi that colonized roots of *R. adoneus* was identified as *Glomus tenue* (Mullen and Schmidt 1993). Mycorrhizal fungi provide an advantage in phosphorus-limited habitats, such as alpine areas and northern white-cedar swamps (Scherff et al. 1994 and references therein).

## **HABITAT/ECOLOGY**

*Ranunculus lapponicus* is found in: low-elevation bogs, arctic-alpine grasslands, and northern coniferous forests (Benson 1942); moss and wet woods (Fernald 1950); cool mossy cedar swamps underlain by calcareous deposits (Hinds 2000); wet soil (Gleason and Cronquist 1991); and boggy places and lakesides in tundra, muskeg, and boreal forest (Whittermore and Parfitt 2002). *Ranunculus lapponicus* can be found at sea level to 900 m elevation (Benson

1955, Whittermore and Parfitt 2002). In the northeastern United States and nationally, *R. lapponicus* is classified as an Obligate Wetland species, meaning that it almost always occurs in wetlands (estimated probability 99%, USDA, NRCS 2001). In Ontario, *R. lapponicus* is typically found in coniferous black spruce swamps on organic substrate (Rosita Ben-Oliel, Ontario Natural Heritage Information Centre, personal communication). In Maine, *R. lapponicus* is typically found among mosses, sedges, and cedar duff in scattered hollows within northern white-cedar swamps (personal observation, confirmed by TNC steward).

The northern white-cedar swamp community is ranked S4 in Maine, and its National Vegetation Classification is *Thuja occidentalis/Mitella nuda/Hylocomium splendens* Saturated Forest (Gawler 2001, NatureServe 2001). The northern white-cedar swamps of Maine are represented by a closed-canopy forest of *Thuja occidentalis* (northern white-cedar), often with *Picea mariana* (black spruce) or *Acer rubrum* (red maple) (Gawler 2001). There is a well-developed herb layer, with small cedar trees and an array of boreal herbs. Hummock-hollow topography carpeted by a lush bryophyte layer is a characteristic feature. This community is typically found in poorly drained basins along streams or small ponds. The substrate is usually shallow peat over mineral soil, with a somewhat acidic to circumneutral pH (Gawler 2001).

Northern white-cedar swamps are generally found in minerotrophic situations, versus other forested peatlands, which tend to be in ombrotrophic situations (Sjörs 1959, Heinselman 1970, Collins et al. 1979, Schwintzer 1981, Kenkel 1987, Crum 1988). Water and nutrients in minerotrophic peatlands are received from groundwater, surface runoff, and precipitation (Moore and Bellamy 1974, Mitch and Gosselink 1986, Crum 1988). Hydrology plays a major role and influences vegetation by influencing groundwater nutrient conditions, pH, and specific conductivity (St. Hilaire 1994). Fens (including forested northern white-cedar swamps) occur in groundwater discharge areas, where the groundwater moves upward, though recharge and discharge volumes are small versus inputs and losses from precipitation, runoff, and evapotranspiration (meaning chemical quality is more important than water quantity) (Siegal 1988). Vascular plants, especially sedges, contribute to the peat formed in northern white-cedar swamps where groundwater is rich in calcium, magnesium, iron, and carbonate (Verhoeven and Arts 1987).

## **THREATS TO TAXON**

Timber harvest (typically for cedar fence posts) and general habitat destruction are the major potential threats to *Ranunculus lapponicus* and other rare species of northern white-cedar swamps (Eastman 1977, Gawler 1983). Pesticide application in adjacent uplands may also be a threat, at least for some Maine populations (as for ME .003 [Chapman]; Jim McGowan, Preserve Design File, MNAP files). Eastman (1977) notes any activity that impedes the lateral flow of groundwater such as filling, dredging, and peat mining is a threat to rare species of northern white-cedar swamps. Stochastic events and natural catastrophe are the

primary threats of populations not already threatened by systematic trends (Shaffer 1987). Stochastic events and natural processes, such as windthrow and flooding, are potential threats, as none of the Maine populations is very large (unless three sites are combined, see site descriptions), and because *R. lapponicus* is at the southern edge of its range in northern Maine.

Climatic warming may lead to competitive exclusion or range contraction in *Ranunculus lapponicus*, as suggested by experiments with alpine *R. acris*. An experimental warming study of alpine *Ranunculus acris* found that seed number and weight and leaf weight were increased with warming (Totland 1999). However, the density of *R. acris* decreased in experimentally warmed open top chambers, possibly because of increased graminoid cover, suggesting that the increased cover of graminoids outweighs the increased reproductive output of *R. acris* (Totland 1999). This may be an issue for *R. lapponicus*, especially as some subpopulations co-occur with sedges (personal observation).

Natural processes such as windthrow, flooding, fire, drainage, drought, and cutting/heavy browse can affect the northern white-cedar swamp community and cause community changes (St. Hilaire 1994). Windthrow of a few trees does not change community structure (Curtis 1946, 1959), but windthrow of many trees may change the community to a rich sedge fen (St. Hilaire 1994). Other means of tree removal, such as clearing, may have the same effect. Flooding may also change community structure and result in a rich shrub fen, rich sedge fen (Schwintzer and Williams 1974, Jeglum 1975), or marsh (Catenhusen 1950, Kenkel 1987). Beavers, roads, railroads, ditches, pipelines, and dams can cause flooding upstream of a peatland or drainage downstream (Stoekeler 1967, Boelter and Close 1974, Jeglum 1975, Jacobson et al. 1991). Drainage and drought can lead to the invasion of pines, balsam fir, and hardwoods, and also to an increased fire frequency (Catenhusen 1950, Christensen et al. 1959, Curtis 1959, Crum 1988). Superficial fires do not affect community structure, but medium-intensity and repeat fires may result in community changes and lead to a rich shrub fen or marsh; deep fires may lead to a quaking aspen community (Catenhusen 1950). Cutting, heavy browse, and fire may lead to a black ash/red maple swamp forest (Gates 1942, Johnston 1990). These community changes are likely not beneficial to *Ranunculus lapponicus*. Flooding from beaver impoundment is a likely threat to *Ranunculus lapponicus* in Maine, and it may soon affect populations at ME .001 (Perham) and ME .006 (Perham). Windthrow is a potential threat to *Ranunculus lapponicus* in Maine. Other threats indicated above, though possible, are less likely. Forest encroachment, a disturbance presumed to be detrimental to some of the other rare plants found in northern white-cedar swamps, would likely favor *Ranunculus lapponicus* (Fen Conservation Network 2002).

**DISTRIBUTION AND STATUS**

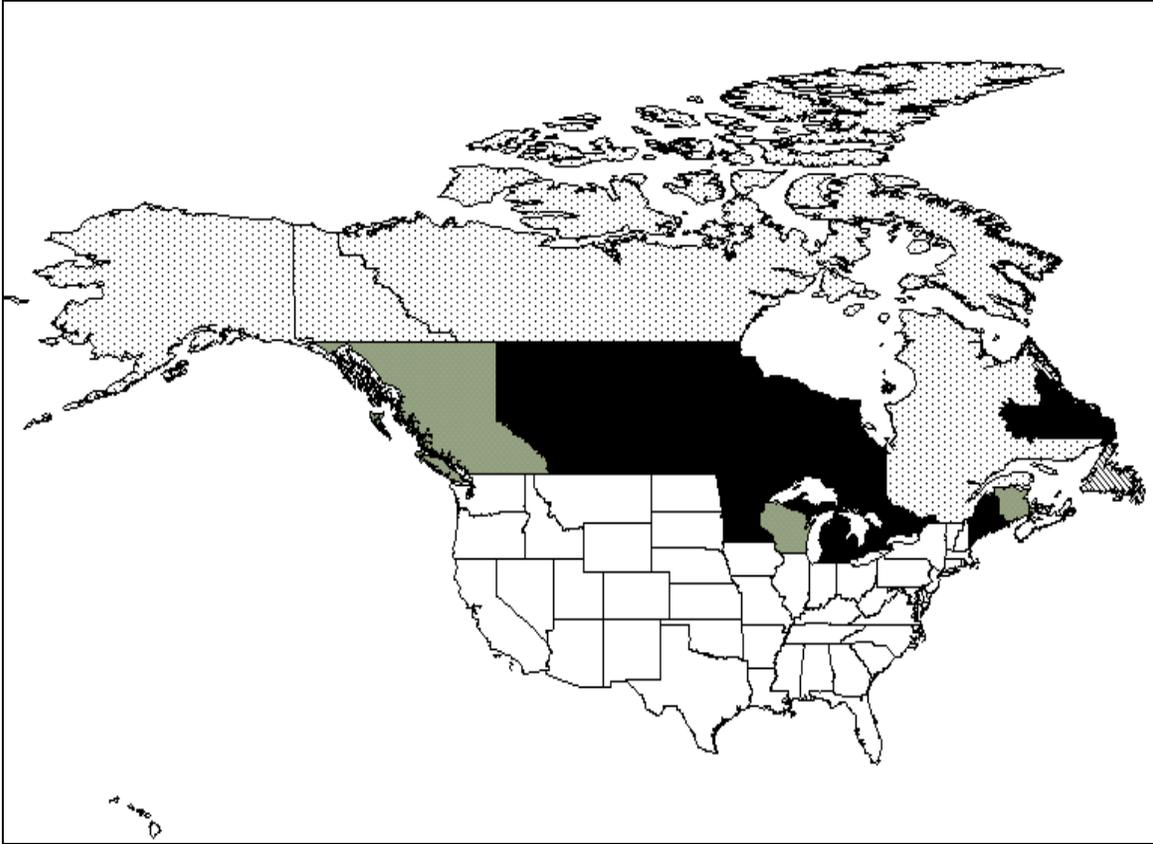
*Ranunculus lapponicus* is apparently globally secure, with a ranking of G5 (NatureServe 2002). *Flora Conservanda* lists *Ranunculus lapponicus* as a Division 2 species, which indicates it is a regionally rare taxon with fewer than 20 occurrences in New England (Brumback and Mehrhoff et al. 1996).

*Ranunculus lapponicus* is a circumboreal species, found in Eurasia, Spitzbergen, Greenland, and North America (Benson 1942, 1948, Fernald 1950, Gleason and Cronquist 1991, Whittermore and Parfitt 2002). It is not found in Iceland (Böcher 1951). In North America, *Ranunculus lapponicus* is found from Alaska to Labrador, south to British Columbia and northern Maine, Michigan, Minnesota, and Wisconsin (Benson 1942, 1848, Fernald 1950, Gleason and Cronquist 1991, Hinds 2000, Whittermore and Parfitt 2002, NatureServe 2002, Figure 1). *Ranunculus lapponicus* is considered a wide-ranging forest species in Canada (Raup 1947).

*Ranunculus lapponicus* is listed as S1, S2, or S3 in six of the sixteen states and provinces in which it occurs, and it is historic in one province. *Ranunculus lapponicus* is apparently secure in the central Canadian provinces. It is widespread and fairly common north of about 48 degrees latitude in Ontario (Ben-Oliel, personal communication). Its status in the remaining six states and provinces where it occurs is largely unknown (Table 1).

<b>Table 1. Occurrence and status of <i>Ranunculus lapponicus</i> in the United States and Canada based on information from Natural Heritage Programs*.</b>			
<b>OCCURS &amp; LISTED (AS S1, S2, OR T &amp; E)</b>	<b>OCCURS &amp; NOT LISTED (AS S1, S2, OR T &amp; E)</b>	<b>OCCURRENCE REPORTED OR UNVERIFIED</b>	<b>HISTORIC (LIKELY EXTIRPATED)</b>
Maine (S1, T)	Labrador (S2S3)	Alaska (SR)	Newfoundland Island (SH)
Michigan (S1S2, T)	Minnesota (S3, SC)	Northwest Territories (SR)	
Wisconsin (S1, E): 2 extant occurrences	Alberta (S4)	Nunavut (SR)	
New Brunswick (S1)	British Columbia (S?)	Quebec (SR)	
	Manitoba (S4S5)	Yukon Territory (SR)	
	Ontario (S5)		
	Saskatchewan (S5?)		

\*This information based on NatureServe, with additional information for Maine from MNAP, for Michigan from [http://michbotclub.org/plants\\_mich/threatened.htm](http://michbotclub.org/plants_mich/threatened.htm), for Wisconsin from [http://www.dnr.state.wi.us/org/land/er/publications/coastal\\_wetlands/Lsuperior/sites/LS13\\_BrueRiverSpillway.htm](http://www.dnr.state.wi.us/org/land/er/publications/coastal_wetlands/Lsuperior/sites/LS13_BrueRiverSpillway.htm), and for Minnesota from [http://www.dnr.state.mn.us/fish\\_and\\_wildlife/endangered\\_species/envasspc.html](http://www.dnr.state.mn.us/fish_and_wildlife/endangered_species/envasspc.html).

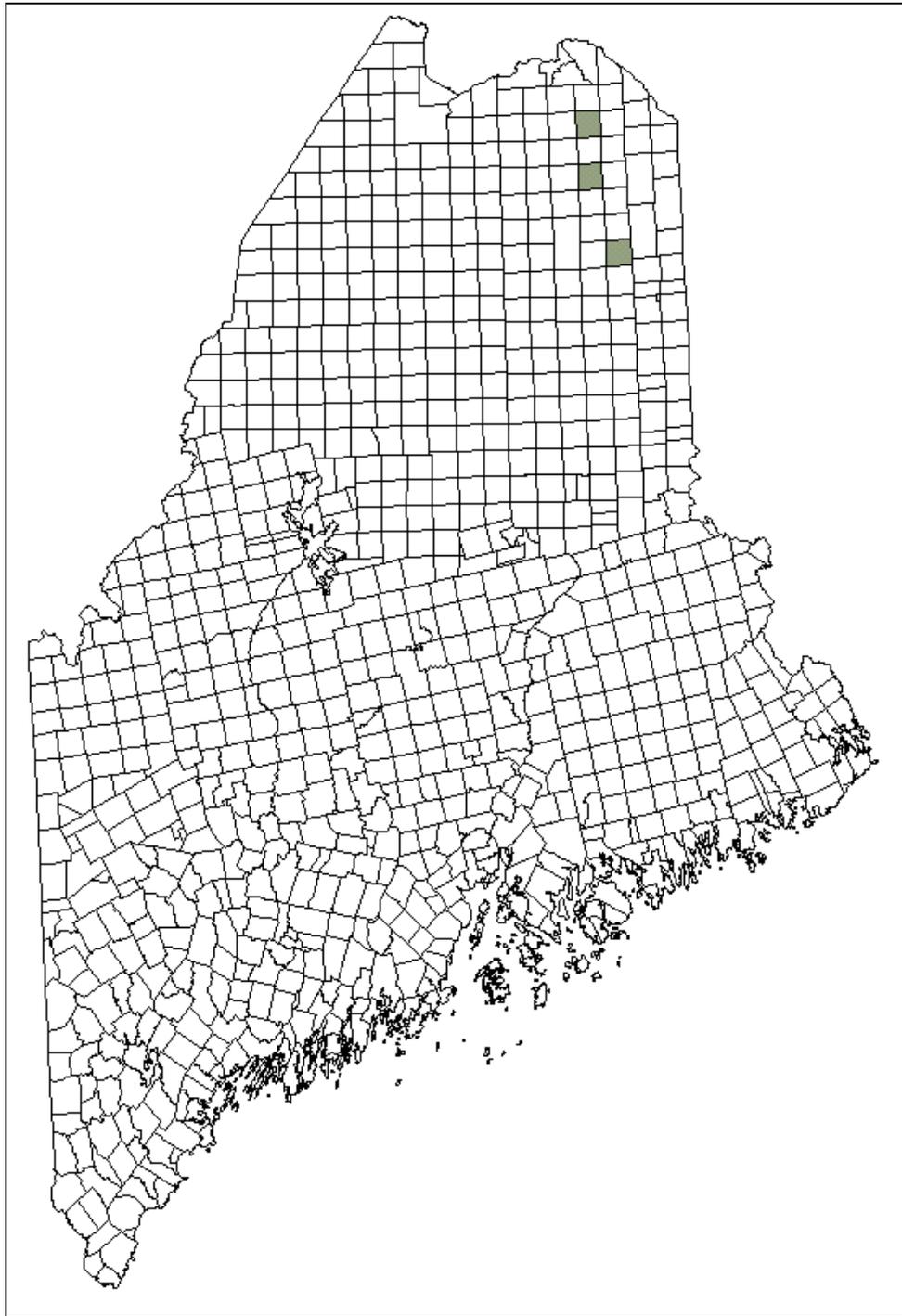


**Figure 1. North American occurrences of *Ranunculus lapponicus*.** States and provinces shaded in gray have one to five (or an unspecified number of) occurrences of the taxon. States and provinces shaded in black have more than five confirmed occurrences. Stippling indicates areas from which the taxon is "reported" ("SR") but not necessarily verified. Diagonal hatching indicates an area from which the taxon is considered historic or extirpated.

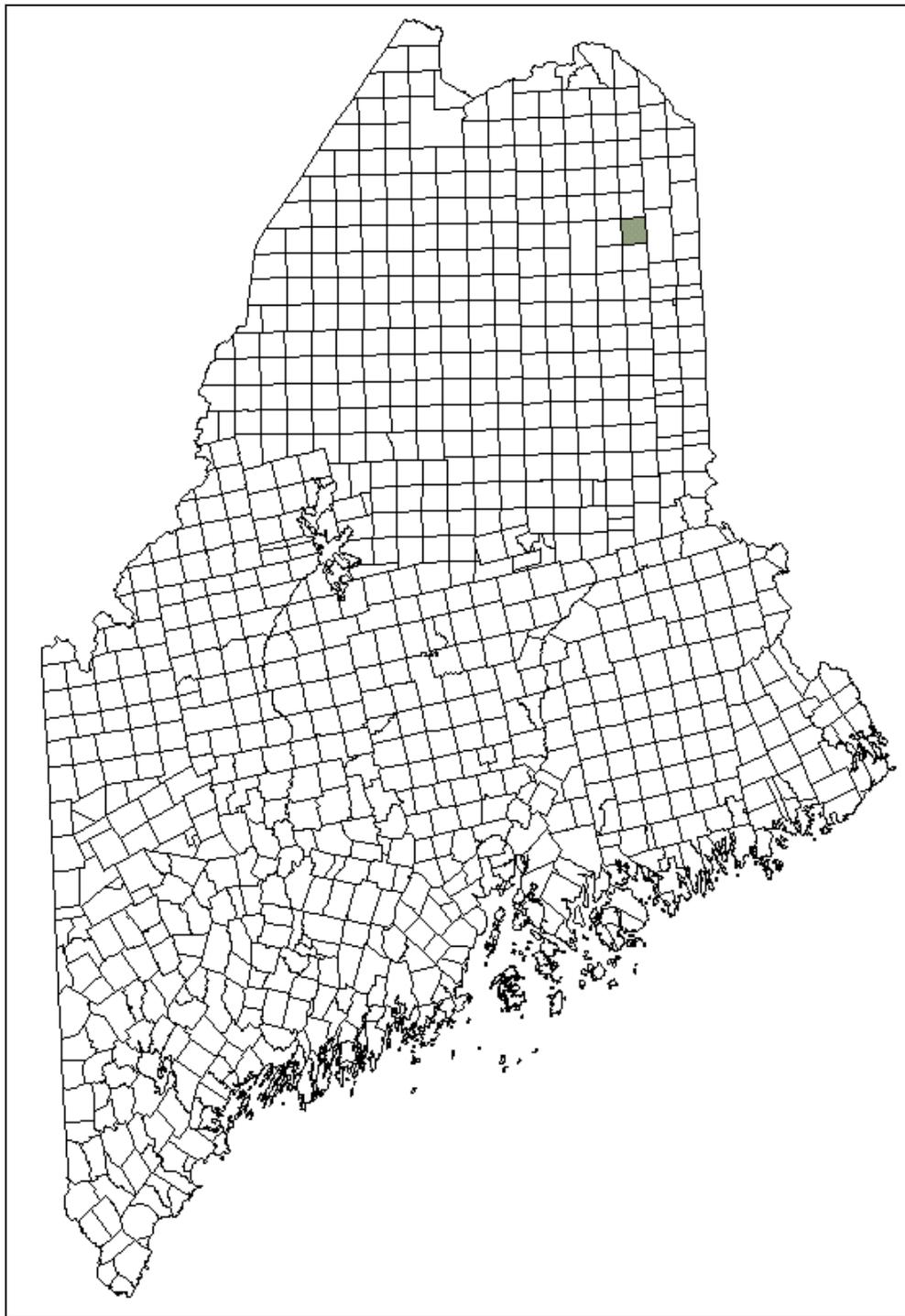
*Status of All New England Occurrences — Current and Historical*

In New England, *Ranunculus lapponicus* currently occurs and historically has only occurred in Maine. In Maine, *R. lapponicus* is ranked S1 by Maine Natural Areas Program and is listed as Threatened, indicating that it is rare, and with further decline could become Endangered. In Maine, an Endangered plant is considered rare and in danger of being lost from the state in the foreseeable future. There is no legal protection based on these designations. In addition to the occurrences listed below, Benson (1948) indicates a collection from Aroostook County, on the Aroostook River, by Chamberlain and Delano # 649, at the Gray Herbarium. New England occurrence records for *Ranunculus lapponicus* are listed in Table 2. A map of extant New England occurrences is shown in Figure 2, the historic occurrence in Figure 3.

<b>Table 2. New England Occurrence Records for <i>Ranunculus lapponicus</i>. Shaded occurrences are considered extant.</b>			
<b>State</b>	<b>EO #</b>	<b>County</b>	<b>Town</b>
ME	.001	Aroostook	Perham
ME	.002	Aroostook	Perham
ME	.003	Aroostook	Chapman
ME	.004	Aroostook	Mapleton
ME	.005	Aroostook	T16 R04 WELS
ME	.006	Aroostook	Perham
ME	.007	Aroostook	Perham
ME	NEW	Aroostook	T16 R12 WELS
ME	NEW	Aroostook	Stockholm



**Figure 2. Extant occurrences of *Ranunculus lapponicus* in New England.** Town boundaries for Maine (the only New England state in which the taxon occurs) are shown. Towns shaded in gray have one to five extant occurrences of the taxon.



**Figure 3. Historic occurrences of *Ranunculus lapponicus* in New England.** Towns shaded in gray have one to five historical records of the taxon.

## II. CONSERVATION

---

### CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

General conservation objectives, in order of priority, for *Ranunculus lapponicus* in New England are to:

- **Determine number** of extant occurrences in New England.
- **Secure existence** of extant occurrences via conservation easement, site design, and habitat preservation.
- **Update occurrence** information.
- **Maintain high population numbers** at the largest sites in Perham, Maine, which currently include ME .001 (approximately 350 individuals) and ME .002, ME .006, and ME .007 (approximately 200, 380, and 380 individuals, respectively). Combining the latter three would leave one very large occurrence, with an estimated population of nearly 1000 individuals. ME NEW (T16 R12, with 295+ individuals) also has a relatively large population.
- **Increase population numbers** at the smaller sites in Maine such that the numbers reflect a similar percentage of habitat occupied as at the larger sites, preferably in the range of several hundreds of individuals.

The five largest occurrences of *Ranunculus lapponicus* in Maine have between 180 and 380 individuals each. These numbers have fluctuated from single numbers to 530 individuals. Some of this variation is due to variable search effort, but some also represents variation in population numbers in different years. Combining ME .002, ME .006, and ME .007 (Perham) would leave one very large population, with The Nature Conservancy population (ME .001 [Perham]) and the privately owned population (ME .008 [T16 R12 WELS]) at about a third of that size.

Site design, protection, and habitat management are the three steps used to conserve viable populations of rare plants in their natural habitats (New England Wildflower Society 1992). In general, these should be the goals at all *R. lapponicus* sites in Maine, especially those on private property. The specific numeric goal for *Ranunculus lapponicus* is that it be maintained at no fewer than the current number of sites in Maine, which would be six extant sites after combination of ME .002, ME .006, and ME .007 (Perham) as indicated above.

Programs that combine approaches of representative display in a botanical garden, establishment of a new population at a distant site, and off-site seed banking are most likely to succeed (Falk 1991). These approaches may be worth pursuing after the initial conservation objectives are met.

General conservation actions for *Ranunculus lapponicus* in New England include:

1. **Surveying likely habitat** in Maine for *Ranunculus lapponicus*, especially east of Route 11, in Aroostook County
2. **Landowner contact and information sharing** to make them aware of the importance of the presence of *Ranunculus lapponicus* on their property
3. **Protection of occurrences on private property** by implementation of conservation easement or other protective measures at each occurrence on private property
4. **Full population count and periodic inventory** of known occurrences
5. **Development of site management plan on BPL property**, currently three occurrences, two of which are Ecological Reserves
6. **Re-evaluation of individual EOR rankings**
7. **Seed banking**
8. **Augmentation**
9. **Research and experimentation** at the large population sites in Maine to better understand species ecology and management needs. Areas of research include: determination of size and percentage of habitat and spatial patterning within habitat utilized by this species at each occurrence; determination of the effects of hydrological change and other disturbances; determination of habitat and microhabitat requirements; determination of vascular, bryophyte, and mycorrhizal associations; determination of pollinators; demographic, reproductive, and genetic studies; and potentially monitoring of pesticide inputs and effects.

### III. LITERATURE CITED

---

- Allen, B. 1999. Checklist of Maine mosses. *Evansia* 16: 28-43.
- Barrett, S. C. H. and J. R. Kohn. 1991. Genetic and evolutionary consequences of small population size in plants: Implications for conservation. Pages 3-30 in D. A. Falk and K. E. Holsinger (Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.
- Baskin, C. C. and J. M. Baskin. 2001. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, San Diego, California, USA, p. 423.
- Bates, J. W. and A. M. Farmer. 1990. An experimental study of calcium acquisition and its effects on the calcifuge moss *Pleurozium schreberi*. *Annals of Botany* 65: 87-96.
- Benson, L. 1940. North American subdivisions of *Ranunculus*. *American Journal of Botany* 27: 799-807.
- Benson, L. 1942. North American Ranunculi-V. *Bulletin of the Torrey Botanical Club* 69: 373-386.
- Benson, L. 1948. A treatise on the North American Ranunculi. *The American Midland Naturalist* 40: 1-261.
- Benson, L. 1954. Supplement to a treatise on the North American Ranunculi. *American Midland Naturalist* 52: 328-369.
- Benson, L. 1955. The Ranunculi of the Alaskan Arctic Coastal Plain and the Brooks Range. *American Midland Naturalist* 53: 242-255.
- Böcher, T. W. 1951. Distributions of plants in the circumpolar area in relation to ecological and historical factors. *Journal of Ecology* 39: 376-395.
- Boelter, D. H. and G. E. Close. 1974. Pipelines in forested wetlands: cross drainage needed to prevent timber damage. *Journal of Forestry* 72: 561-563.
- Bormann, F. H. and A. V. Beatty. 1955. Chromosome studies of plants from the arctic slope of Alaska. I. Ranunculaceae. *Bulletin of the Torrey Botanical Club* 82: 118-120.
- Brown, A. H. D., and J. D. Briggs. 1991. Sampling strategies for genetic variation in *ex situ* collections of endangered plant species. Pages 99-118 in D. A. Falk and K. E. Holsinger

(Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.

Brumbach W. E., L. J. Mehrhoff, R. W. Enser, S. C. Gawler, R. G. Popp, P. Somers, D. D. Sperduto, W. D. Countryman, and C. B. Hellquist. 1996. *Flora Conservanda*: New England. The New England Plant Conservation Program (NEPCoP) list of plants in need of conservation. *Rhodora* 98: 233-361.

Campbell, C. S., H. P. Adams, P. Adams, A. C. Dibble, L. M. Eastman, S. C. Gawler, L. L. Gregory, B. A. Grunden, A. D. Haines, K. Jonson, S. C. Rooney, T. F. Vining, J. E. Weber, and W. A. Wright. 1995. *Checklist of the Vascular Plants of Maine, Third Revision*. Bulletin 13 of the Josselyn Botanical Society of Maine. Bulletin 844 of the Maine Agricultural and Forest Experiment Station, University of Maine, Orono, Maine, USA.

Carleton, T. J. and D. J. Read. 1991. Ectomycorrhizas and nutrient transfer in conifer-feather moss ecosystems. *Canadian Journal of Botany* 69: 778-785.

Carlson, B. D. and J. M. Sweeney. 1999. Threatened and endangered species in forests of Maine: A guide to assist with forestry activities. Cooperatively published by Champion International Corporation; U. S. Fish and Wildlife Service's Old Town, Maine, Field Office; Maine Department of Inland Fisheries and Wildlife; Maine Natural Areas Program; University of Maine, Cooperative Extension.

Catenhusen, J. 1950. Secondary successions on the peat lands of Glacial Lake Wisconsin. *Wisconsin Academy of Sciences, Arts and Letters* 40: 29-48.

Chapin, F. S., W. C. Oechel, K. Van Cleve, and W. Lawrence. 1987. The role of mosses in the phosphorus cycling of an Alaskan black spruce forest. *Oecologia* 74: 310-315.

Christensen, E. M., J. J. Clausen, and J. T. Curtis. 1959. Phytosociology of the lowland forests of northern Wisconsin. *American Midland Naturalist* 62: 232-247.

Cody, W. J., M. Blondeau, and J. Cayouette. 1988. *Ranunculus x spitzbergensis* (Nath.) Hadaè, an addition to the flora of North America. *Rhodora* 90: 27-36.

Collins, S. L. 1990. Habitat relationships and survivorship of tree seedlings in hemlock-hardwood forest. *Canadian Journal of Botany* 68: 790-797.

Collins, S. L., J. L. Vankat, and J. V. Perino. 1979. Potential tree species dynamics in the arbor vitae association of Cedar Bog, a west-central Ohio fen. *Bulletin of the Torrey Botanical Club* 106: 290-298.

- Coulter, J. M. and E. M. Fisher. 1893. New and noteworthy North American plants. *Botanical Gazette* 18: 299-303.
- Cox, R. L. and A. H. Westing. 1963. The effect of peatmoss extract on seed germination. *Proceedings of the Indiana Academy of Science* 73: 113-115.
- Crum, H. A. 1988. *A Focus on Peatlands and Peat Mosses*. University of Michigan Press, Ann Arbor, Michigan, USA.
- Curtis, J. D. 1946. Preliminary observations on northern white-cedar in Maine. *Ecology* 27: 23-36.
- Curtis, J. T. 1959. *The Vegetation of Wisconsin*. The University of Wisconsin Press, Madison, Wisconsin, USA.
- Davy, A. J. and R. L. Jefferies. 1981. Approaches to the monitoring of rare plant populations. Pages 219-232 in H. Synge (Editor). *The Biological Aspects of Rare Plant Conservation*. John Wiley and Sons, London, UK.
- DEP, Department of Environmental Protection, State of Maine. 2002. Natural Resources Protection Act, 38 M.R.S.A. §§480-A to 480-Z, Statute, Bureau of Land and Water Quality, No. DEPLW 284-J2002. Revised April 3, 2002.
- Dixon, P. M. and R. E. Cook 1990. Science, planning, and the recovery of endangered plants. *Endangered Species Update* 6: 9-14.
- Eastman, L. M. 1977. Small round-leaved orchis, *Orchis rotundifolia* Banks ex Pursh, in Maine and its relevance to the Critical Areas Program. Report for the Maine Critical Areas Program, State Planning Office, Augusta, Maine 04333 USA. Planning Report No. 52, September 10, 1977.
- Eberhart, S. A., E. E. Roos, and Le. E. Towill. 1991. Strategies for long-term management of germplasm collections. Pages 135-145 in D. A. Falk and K. E. Holsinger (Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.
- Ewens, W. J., P. J. Brockwell, J. M. Gani, and S. I. Resnick. 1987. Minimum viable population size in the presence of catastrophes. Pages 59-68 in M. E. Soulé (Editor). *Viable Populations for Conservation*. Cambridge University Press, New York, New York, USA.
- Falk, D. A. 1991. Joining biological and economic models for conserving plant genetic diversity. Pages 209-223 in D. A. Falk and K. E. Holsinger (Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.

Falk, D. A., C. I. Millar, and M. Olwell. 1996. The biology of rare plant introduction, introduction to part II. Pages 121-125 in D. A. Falk, C. I. Millar, and M. Olwell (Editors). *Restoring Diversity: Strategies for Reintroduction of Endangered Plants*. Island Press. Washington, D.C., USA

Fen Conservation Network. 2002. "P Bog" Fen Site in Northern Maine. Available at [http://www.leo.lehigh.edu/fen/profiles/p\\_bog/](http://www.leo.lehigh.edu/fen/profiles/p_bog/). (Accessed May 1, 2002).

Fernald, M. L. 1950. *Gray's Manual of Botany, A Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada*, Eight Edition. American Book Company, New York, New York, USA.

Fiedler, P. L. and R. D. Laven. 1996. Selecting reintroduction sites. Pages 157-169 in D. A. Falk, C. I. Millar, and M. Olwell (Editors). *Restoring diversity: Strategies for Reintroduction of Endangered Plants*. Island Press. Washington, D.C., USA.

Galen, C. and M. L. Stanton. 1993. Short-term responses of alpine buttercups to experimental manipulations of growing season length. *Ecology* 74: 1052-1058.

Galen, C. and M. L. Stanton. 1999. Seedling establishment in alpine buttercups under experimental manipulations of growing-season length. *Ecology* 80: 2033-2044.

Gates, F. C. 1942. The bogs of northern lower Michigan. *Ecological Monographs* 12: 213-154.

Gawler, S. 1983. Orchids. Brochure for the Executive Department, Maine State Planning Office Critical Areas Program, Augusta, Maine, USA.

Gawler, S. C. 2001. Natural landscapes of Maine: a classification of vegetated natural communities and ecosystems. Maine Natural Areas Program, Department of Conservation, Augusta, Maine, USA.

Gilpin, M. E. 1987. Spatial structure and population vulnerability. Pages 125-139 in M. E. Soulé (Editor). *Viable Populations for Conservation*. Cambridge University Press, New York, New York, USA.

Gilpin, M. E. and M. E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19-34 in M. E. Soulé (Editor). *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer Associates, Sunderland, Massachusetts, USA.

Gleason, H. A. and A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. Second Edition. The New York Botanical Garden, Bronx, New York, USA.

- Glime, J. M. 1993. *The Elfin World of Mosses and Liverworts of Michigan's Upper Peninsula and Isle Royale*. Isle Royale Natural History Association, Houghton, Michigan, USA.
- Grubb, P. J. 1977. The maintenance of species-richness in plant communities: the importance of the regeneration niche. *Biological Review* 52: 107-145.
- Haines, A. and T. F. Vining. 1998. *Flora of Maine: A Manual for Identification of Native and Naturalized Vascular Plants of Maine*. V. F. Thomas Company, Bar Harbor, Maine, USA.
- Harmon, M. E. and J. F. Franklin. 1989. Tree seedlings on logs in *Picea-Tsuga* forests of Oregon and Washington. *Ecology* 70: 48-59.
- Harper, J. L. 1977. *Population Biology of Plants*. Academic Press, New York, New York, USA.
- Heinselman, M. L. 1970. Landscape evolution, peatland types, and the environment in the Lake Agassiz Peatlands Natural Area, Minnesota. *Ecological Monographs* 40: 235-261.
- Hinds, H. R. 2000. *Flora of New Brunswick, A Manual for Identification of the Vascular Plants of New Brunswick*. Second Edition. Biology Department, University of New Brunswick, Fredericton, New Brunswick, Canada.
- Holsinger, K. E. and L. D. Gottlieb. 1991. Conservation of rare and endangered plants: principles and prospects. Pages 195-208 in D. A. Falk and K. E. Holsinger (Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.
- Hueneke, L. F. 1991. Ecological implications of genetic variation in plant populations. Pages 31-44 in D. A. Falk and K. E. Holsinger (Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.
- Huneck, S. and L. Meinunger. 1990. Plant growth regulatory activities of bryophytes: a contribution to the chemical ecology of mosses and liverworts. Pages 289-198 in H. D. Zinsmeister and R. Mues (Editors). *Bryophytes — Their Chemistry and Chemical Taxonomy*. Phytochemical Society of Europe 29. Clarendon Press, Oxford, UK.
- Iglesias, J. and J. Castillejo. 1999. Field observations on feeding of the land snail *Helix aspersa* Müller. *Journal of Molluscan Studies* 65: 411-423.

IPNI. 2002. International Plant Name Index Query web page. Available at [http://www.ipni.org/ipni/IpniServlet?id=217399-2&query\\_type=by\\_id](http://www.ipni.org/ipni/IpniServlet?id=217399-2&query_type=by_id). (Accessed July 30, 2002, via link at bottom of FNA *Ranunculus lapponicus* web page).

Jacobson, G. L., Jr., H. Almquist-Jacobson, and J. C. Winne. 1991. Conservation of rare plant habitat: insights from the recent history of vegetation and fire at Crystal Fen, northern Maine, USA. *Biological Conservation* 57: 287-314.

Jeglum, J. K. 1975. Vegetation-habitat changes caused by damming a peatland drainageway in northern Ontario. *Canadian Field-Naturalist* 89: 400-412.

Johnson, E. A., and G. I. Fryer. 1992. Physical characterization of seed microsites — movement on the ground. *Journal of Ecology* 80: 823-836.

Johnston, W. F. 1990. *Thuja occidentalis*. Pages 580-589 in R. M. Burns and B. M. Honkala (Editors). *Silvics of North America*, Volume 1. Conifers. USDA Forest Service Agriculture Handbook 654. Washington, D.C., USA.

Keizer, P. J., B. F. van Tooren, and H. J. During. 1985. Effects of bryophytes on seedling emergence and establishment of short-lived forbs in chalk grassland. *Journal of Ecology* 73: 493-504.

Kellman, M. and M. Kading. 1992. Facilitation of tree seedling establishment in a sand dune succession. *Journal of Vegetation Science* 3: 679-688.

Kenkel, N. C. 1987. Trends and interrelationships in boreal wetland vegetation. *Canadian Journal of Botany* 65: 12-22.

Lande, R. and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 in M. E. Soulé (Editor). *Viable Populations for Conservation*. Cambridge University Press, New York, New York, USA.

Ledig, F. T. 1986. Heterozygosity, heterosis, and fitness in outbreeding plants. Pages 77-104 in M. E. Soulé (Editor), *Conservation Biology: The Science of Scarcity and Diversity*. Sinauer Associates, Sunderland, Massachusetts, USA.

Longton, R. E. 1988. *The Biology of Polar Bryophytes and Lichens*. Cambridge University Press, Cambridge, UK.

Longton, R. E. 1992. The role of bryophytes and lichens in terrestrial ecosystems. Pages 32-76 in J. W. Bates and A. M. Farmer (editors). *Bryophytes and Lichens in a Changing Environment*. Clarendon Press, Oxford Science Publications, New York, New York, USA.

Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. *American Wildlife and Plants. A Guide to Wildlife Food Habits: The Use of Trees, Shrubs, Weeds, and Herbs by Birds and Mammals of the United States*. McGraw-Hill Book Company, Inc. New York, New York, USA.

Menges, E. S. 1991. The application of minimum viable population theory to plants. Pages 45-61 in D. A. Falk and K. E. Holsinger (Editors). *Genetics and Conservation of Rare Plants*. Oxford University Press, New York, New York, USA.

Mitch, W. J. and J. G. Gosselink. 1986. *Wetlands*. Van Nostrand Reinhold, New York, New York, USA.

Mitchell, R. S. and J. K. Dean. 1982. *Ranunculaceae (Crowfoot Family) of New York State. Contributions to a Flora of New York State IV*. R. S. Mitchell (Editor). Bulletin No. 446, New York State Museum. The University of the State of New York, The State Education Department, Albany, New York, USA.

MOBOT. 2002. Missouri Botanical Garden web site. Available at <http://mobot.mobot.org/W3T/Search/vast.html>. (Accessed April 26, 2002).

Moore, P. D. and D. J. Bellamy. 1974. *Peatlands*. Springer-Verlag, New York, New York, USA.

Mullen, R. B. and S. K. Schmidt. 1993. Mycorrhizal infection, phosphorus uptake, and phenology in *Ranunculus adoneus*: implications for the functioning of mycorrhizae in alpine systems. *Oecologia* 94: 229-234.

Mullen, R. B., S. K. Schmidt, and C. H. Jaeger III. 1998. Nitrogen uptake during snowmelt by the snow buttercup, *Ranunculus adoneus*. *Arctic and Alpine Research* 30: 121-125.

NatureServe. 2001. NatureServe Explorer: An online encyclopedia of life [web application]. 2001. Version 1.6. Arlington, Virginia, USA: NatureServe. Available at <http://www.natureserve.org/explorer>. (Accessed April 26, 2002).

New England Wild Flower Society. 1992. New England Plant Conservation Program. *Wildflower Notes* 7: 7-79.

Nylander, O. O. 1938. *Castalia tetragona* in Salmon Brook Lake Bog. Free Booters Club of Knowledge, Caribou, Maine, USA (nine page report in MNAP files).

Oechel, W. C. and B. Sveinbjörnsson. 1978. Primary production processes in Arctic bryophytes at Barrow, Alaska. Pages 269-298 in L. L. Tieszen (Editor). *Vegetation and*

*Production Ecology of an Alaskan Arctic Tundra*. Springer-Verlag, New York, New York, USA.

Ohlson, M. and O. Zackrisson. 1992. Tree establishment and microhabitat relationships in north Swedish peatlands. *Canadian Journal of Forest Research* 22: 1869-1877.

Palmer, M. E. 1987. A critical look at rare plant monitoring in the United States. *Biological Conservation* 39: 113-127.

Patiño, S., C. Jeffree, and J. Grace. 2002. The ecological role of orientation in tropical convolvulaceous flowers. *Oecologia* 130: 373-379.

Pocock, K. and J. G. Duckett. 1985. On the occurrence of branched and swollen rhizoids in British hepatics: their relationship with the substratum and associations with fungi. *New Phytologist* 99: 281-304.

Prati, D. and B. Schmid. 2000. Genetic differentiation of life-history traits within populations of the clonal plant *Ranunculus reptans*. *Oikos* 90: 442-456.

Quiros, C., O. Ochoa, and D. Douches. 2002. *L. peruvianum* x *L. pennellii* sexual hybrids. Available at <http://gcrec.ifas.ufl.edu/tgc/newsletters/vol36/v36p31.html>. (Accessed November 16, 2002).

Ramstetter, J. M. 2001. *Triphora trianthophora* (Three-birds Orchid) Conservation and Research Plan. New England Wild Flower Society, Framingham, Massachusetts, USA.

Raup, H. M. 1947. Some natural floristic areas in boreal America. *Ecological Monographs* 17: 221-234.

Richardson, D. H. S. 1981. *The Biology of Mosses*. John Wiley and Sons, New York, New York, USA.

Roy, B. A. 1994. The effects of pathogen-induced pseudoflowers and buttercups on each other's insect visitation. *Ecology* 75: 352-358.

St. Hilaire, L. R. 1994. Ecological model for northern white-cedar and rich shrub fen communities at Bonaparte Swamp. Internal report prepared for The Nature Conservancy, Central and Western Chapter, Rochester, New York, USA.

St. Hilaire, L. R. and D. J. Leopold. 1995. Conifer seedling distribution in relation to microsite conditions in a central New York forested minerotrophic peatland. *Canadian Journal of Forest Resources* 25: 261-269.

Schemske, D. W., B. C. Husband, M. H. Ruckelshaus, C. Goodwillie, I. M. Parker, and J. G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. *Ecology* 73: 584-606.

Scherff, E. J., C. Galen, and M. L. Stanton. 1994. Seed dispersal, seedling survival and habitat affinity in a snowbed plant: limits to the distribution of the snow buttercup, *Ranunculus adoneus*. *Oikos* 69: 405-413.

Schwintzer, C. R. 1981. Vegetation and nutrient status of northern Michigan bogs and conifer swamps with a comparison to fens. *Canadian Journal of Botany* 59: 842-853.

Schwintzer, C. R. and G. Williams. 1974. Vegetation changes in a small Michigan bog from 1917-1972. *American Midland Naturalist* 92: 447-459.

Scott, P. J., S. G. Aiken, R. L. Boles, and M. J. Dallwitz. 2000 onwards. *Ranunculaceae of the Canadian Arctic Archipelago: Descriptions, Illustrations, Identification, and Information Retrieval. Version: 6<sup>th</sup> November 2000*. Available at <http://www.mun.ca/biology/delta/arcticf/ran/www/rnmla.htm>. (Accessed May 1, 2002).

Shaffer, M. 1987. Minimum viable populations: coping with uncertainty. Pages 69-86 in M. E. Soulé (Editor). *Viable Populations for Conservation*. Cambridge University Press, New York, New York, USA.

Siegal, D. I. 1988. Evaluating cumulative effects of disturbance on the hydrologic function of bogs, fens, and mires. *Environmental Management* 12: 621-626.

Sjörs, H. 1959. Bogs and fens in the Hudson Bay Lowlands. *Arctic* 12: 2-19.

Smith, M. and J. Capelle. 1992. Effects of soil surface microtopography and litter cover on germination, growth, and biomass production of chicory (*Chicorium intybus* L.). *American Midland Naturalist* 128: 246-253.

Stanton, M. L. and C. Galen. 1997. Life on the edge: adaptation versus environmentally mediated gene flow in the snow buttercup, *Ranunculus adoneus*. *American Naturalist* 150: 143-178.

Stanton, M. L., C. Galen, and J. Shore. 1997. Population structure along a steep environmental gradient: consequences of flowering time and habitat variation in the snow buttercup, *Ranunculus adoneus*. *Evolution* 51: 79-94.

Stoekeler, J. H. 1967. *Wetland Road Crossings: Drainage Problems and Timber Damage*. USDA Forest Service Research Note NC-27. North Central Forest Experiment Station, St. Paul, Minnesota, USA.

- Stoeva, P, Z. Valcova, and M. Petrova. 2002. Study of the cytoplasmic male sterility in tomato. Available at <http://www.geocities.com/PicketFence/Garden/9151/proj14.html>. (Accessed November 16, 2002).
- Tamm, C. O. 1964. Growth of *Hylocomium splendens* in relation to tree canopy. *Bryologist* 67: 423-426.
- Totland, Ø. 1994. Intra-seasonal variation in pollination intensity and seed set in an alpine population of *Ranunculus acris* in southwestern Norway. *Ecography* 17: 159-165.
- Totland, Ø. 1999. Effects of temperature on performance and phenotypic selection on plant traits in alpine *Ranunculus acris*. *Oecologia* 120: 242-251.
- Tyler, G. 2001. Relationships between climate and flowering of eight herbs in a Swedish deciduous forest. *Annals of Botany* 87: 623-630.
- USDA. 1964. *Soil Survey, Aroostook County, Northeastern Part*. Soil Conservation Service, Washington, D.C., USA.
- USDA, NRCS. 2001. USDA, Natural Resources Conservation Service. The PLANTS Database, Version 3.1. Available at <http://plants.usda.gov>. National Plant Data Center, Baton Rouge, LA 70874-4490, USA. (Accessed April 26, 2002).
- Van Kleunen, M. Fischer, and B. Schmid. 2001. Effects of intraspecific competition on size variation and reproductive allocation in a clonal plant. *Oikos* 94: 515-524.
- Verhoeven, J. T. and H. H. M. Arts. 1987. Nutrient dynamics in small mesotrophic fens surrounded by cultivated land. II. N and P accumulation in plant biomass in relationship to the release of inorganic N and P in the peat soil. *Oecologia* 72: 557-561.
- Whittemore, A. T. and B. D. Parfitt. 2002. Ranunculaceae. *Flora of North America North of Mexico, Volume 3*, on-line version. Available at [http://hua.huh.harvard.edu/cgi-bin/Flora/flora.pl?FLORA\\_ID=12395](http://hua.huh.harvard.edu/cgi-bin/Flora/flora.pl?FLORA_ID=12395). (Accessed July 30, 2002).
- Zeedyk, W. D., R. E. Farmer, Jr., B. MacBryde, and G. S. Baker. 1978. Endangered plant species and wildland management. *Journal of Forestry* 76: 31-36.

## **Appendix 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 been made for more than 20 years. An X rank is utilized for sites that are known to be extirpated. Not all EOs have received such ranks in all states, and ranks are not necessarily consistent among states as yet.