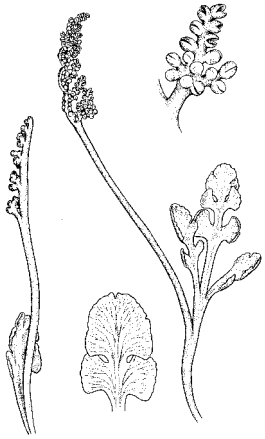
Conservation Assessment

For

Least Moonwort (Botrychium simplex)



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USDA Forest Service, Eastern Region
2003

Prepared by Steve Chadde & Greg Kudray
For USDA Forest Service, Region 9
Requisition no. 43-54A7-0-0036 / Project no. Ottawa-00-06

This Conservation Assessment was prepared to compile the published and unpublished information and serves as a Conservation Assessment for the Eastern Region of the Forest Service. It does not represent a management decision by the U.S. Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if you have information that will assist in conserving the subject community, please contact the Eastern Region of the Forest Service - Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203.

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EXECUTIVE SUMMARY

Botrychium simplex is a small moonwort found in many areas of the world including eastern North America, the Great Lakes region, and the Rocky Mountains. It is one of the more common moonworts, and a number of subspecies and varieties have been named. It is found in a variety of open and forested habitats. Some sites have been disturbed in the past, such as roadsides, tailings pond, and old fields, but a wide range of relatively undisturbed forests (including northern hardwood forests, jack pine barrens, and cedar swamps) are also common habitats. Most details about the biology of *B. simplex* are generalized from studies of other moonwort species. Much of the life-cycle occurs underground. Populations of aboveground sporophytes fluctuate and individual plants may not appear every year, complicating attempts to adequately inventory the population. A population study in a prairie environment reported aboveground plants appeared in less than half of the years monitored; drought combined with fire also caused a population decline. Like other moonworts, *B. simplex* is dependent on a mycorrhizal relationship; thus any concerns about species conservation must include consideration of this relationship. No information is available on managing habitat to maintain the species. Potential threats are not well understood; disturbance may stimulate plant establishment in some habitats. Natural plant succession may be a threat in open habitats, but no information is available on the response of *B. simplex* to site changes. Since the species is small and populations fluctuate, continued inventory efforts are necessary to better refine population demographics, range, and habitat. Much basic research on *B. simplex* biology is lacking.

INTRODUCTION/OBJECTIVES

One of the conservation practices of the USDA Forest Service is designation of Regional Forester's sensitive species. The Eastern Region (R9) of the Forest Service updated its Sensitive Species list on February 29, 2000. Part of that process included identification of priority species for Conservation Assessments and Strategies. A group of *Botrychium* species (Ophioglossaceae; Adder's-Tongue Family) was one of those priorities.

The objectives of this document are to:

1. Provide an overview of current scientific knowledge for *Botrychium simplex*.
2. Provide a summary of the distribution and status of *Botrychium simplex,* both rangewide and within the Eastern Region of the USDA Forest Service.
3. Provide the available background information needed to prepare a subsequent Conservation Strategy.

In North America, the genus *Botrychium,* family Ophioglossaceae, is comprised of three subgenera (Lellinger 1985, Wagner and Wagner 1993). One subgenus, *Osmundopteris,* is only represented in our area by *B. virginianum*, the rattlesnake fern, which is common around the world (Wagner 1998). The subgenus *Sceptridium* are the grapeferns, medium sized and decidedly evergreen plants (Lellinger 1985). Subgenus *Botrychium,* the moonworts, includes numerous species of often rare, local, and very small plants that are difficult to find and identify.

North America is a center of diversity for moonworts (Wagner and Wagner 1994) and the upper Great Lakes Region, along with the northwestern U.S. and nearby Canada, are two of the richest areas (Wagner and Wagner 1990a, Wagner 1998). Twenty-three species of North American moonworts are now recognized (Wagner and Wagner 1994) compared to the traditional interpretation of only six (Clausen 1938). The problems in distinguishing moonwort species are considerable (Wagner and Wagner 1990a), including the habit of different species of moonworts growing at one site, the natural variation in form due to microhabitat variability, their small size, and the difficulty of making good herbarium specimens. However, decades of work, primarily by the late Dr. Herb Wagner and associates, have clarified the taxonomy of the group, habitat preferences, and the ranges of individual species. Several rare species of subgenus *Botrychium* are now recognized in the Upper Great Lakes region.

Botrychium simplex is a small perennial fern, growing to only several inches tall. It is widely distributed around the world and also in disjunct distributions in eastern and western North America. *B. simplex* is considered one of the most common moonwort species (Wagner and Wagner 1986, Wagner 1991) and grows in a wide variety of open and forested habitats. It is also one of the most variable of all moonworts in appearance, with different forms determined by site conditions (Hagenah 1966, Wagner and Wagner 1993) or perhaps by genetic differences. There may be further species or subspecies differentiation in the future (Wagner and Wagner 1993) for what is currently classified within a single *B. simplex* complex.

NOMENCLATURE AND TAXONOMY

- Scientific Name: *Botrychium simplex* E. Hitchc.
- Synonymy: *Botrychium simplex* E. Hitchc. ssp. *typicum* Clausen; *Botrychium simplex* E. Hitchc. var. *compositum* (Lasch) Milde; *Botrychium simplex* E. Hitchc. var. *laxifolium* (Clausen) Fern.; *Botrychium simplex* E. Hitchc. var. *tenebrosum* (A.A. Eat.) Clausen; *Botrychium tenebrosum* A.A. Eat.
- Family: Ophioglossaceae; Adder's-Tongue Family
- common names: Least Moonwort; Little Grapefern; botryche simple

DESCRIPTION OF SPECIES

General description and identification notes

Botrychium simplex is a stout and rather fleshy perennial fern, growing 4-12 inches (10-30 cm) tall (Wagner and Wagner 1993, Rook 2001). There is a single erect frond divided into a sterile (trophophore) and a fertile (sporophore) segment. The single leaf is pale green, resembling a daisy leaf in shape; about 1 inch (2.5 cm) long, twice-cut, and erect. The stalk is pale green, slender, succulent, fragile, and about 4 inches (10 cm) long. The fertile frond rises above the leaf with erect, branched clusters of prominent yellow spore cases.

The many environmental and juvenile stages of *B. simplex* have resulted in the naming of

numerous, mostly taxonomically insignificant, infraspecific taxa, although the western variety may merit separation as a distinct subspecies or species (Wagner and Wagner 1993). Eastern North American populations of *B. simplex* can be distinguished from western populations as follows*:* sporophore 1-4 times length of trophophore, arising from well-developed common stalk from below middle to near top, well above leaf sheath; trophophore non-ternate or if subternate, lateral pinnae smaller than central pinnae and simple to merely lobed (rarely pinnate); pinnae usually adnate to rachis, rounded and ovate to spatulate, segment sides at angles mostly less than 90°; trophophore tip undivided; texture papery to herbaceous.

The eastern, typical *B. simplex* has a common woodland and swamp shade form (sometimes termed *B. tenebrosum* A. A. Eaton) that appears to be a persistent juvenile (Wagner and Wagner 1993). Plants are small and extremely slender, and the trophophore is simple, rudimentary, and attached near the top of an elongated common stalk (Wagner and Wagner 1993). Many intermediates between this and more typical forms exist. The variation appears to be the result of different growing conditions (Wagner and Wagner 1993).

A key to all *Botrychium* is provided in Wagner and Wagner (1993), but the difficulty of accurately identifying subtly different species of *Botrychium* often requires an expert. The treatment in Volume 2 of the Flora of North America (Wagner and Wagner 1993) is the most current published guide to all but the most recently described species (for example, since the release of Volume 2, a new species, *Botrychium linear*e, has been described by Wagner and Wagner [1994]). Lellinger (1985) includes descriptions and color photographs of many moonwort species. Cody and Britton (1989) provide descriptions and distribution maps of *Botrychium* species known to that time in Canada.

Technical description

Trophophore stalk 0-3 cm long, 0-1.5 times length of trophophore rachis; blade dull to bright green to whitish green, linear to ovate-oblong to oblong to fully triangular with pinnae arranged ternately, simple to 2 (-3)-pinnate, to 7 x 0.2 cm, fleshy to thin, papery or herbaceous. Pinnae or well-developed lobes to 7 pairs, spreading to ascending, approximate to widely separated, distance between first and second pinnae frequently greater than between second and third pairs, basal pinna pair commonly much larger and more complex than adjacent pair, cuneate to fan-shaped, strongly asymmetric, undivided to divided to tip, basiscopic margins ± perpendicular to rachis, acroscopic margins strongly ascending, basal pinnae often divided into 2 unequal parts, margins usually entire or shallowly sinuate, apex rounded, undivided and boat-shaped to strongly divided and plane, venation pinnate or like ribs of fan, with midrib. Sporophores mainly 1-pinnate, 1-8 times length of trophophores. 2n = 90 (after Wagner and Wagner 1993).

LIFE HISTORY

B. simplex belongs to subgenus *Botrychium* (moonworts) within the genus *Botrychium*. In North America there are also subgenus *Osmundopteris* (rattlesnake fern) and subgenus *Sceptridium* (grapeferns) (Lellinger 1985, Wagner and Wagner 1993). The life-cycle of all three subgenera is similar (Lesica and Ahlenslager 1996). Moonworts are generally smaller than rattlesnake ferns and grapeferns. Plants have both a trophophore (vegetative segment) and a sporophore (fertile segment). Grapefern trophophores are present during the winter, while moonwort and rattlesnake fern leaves die back by winter.

Like all ferns, moonworts are characterized by alternation of generations between sporophytes and gametophytes. The sporophyte, the diploid (2N) generation of the plant, begins its life after fertilization of an egg by a sperm within the archegonium of the gametophyte. Embryology of moonwort species has been little studied due to the difficulty of obtaining suitable material (Gifford and Foster 1989, Mason and Farrar 1989). Early morphological studies (e.g., Campbell 1922) described a diversity of patterns of embryo development among moonworts. For example, *Botrychium simplex* has a relatively large cotyledon and rapid development, perhaps capable of maturing a small aboveground fertile frond in its first year, while *B. lunaria* has a relatively small cotyledon, and may take as much as seven years to produce an emergent frond.

The following information is from research with a variety of *Botrychium* species. Reproduction in *B. simplex* has not been fully researched and there may be life history details specific to *B. simplex* that do not follow these general patterns for the genus. Lack of specific information on the life history of *B. simplex* is a significant management concern.

Vegetative reproduction was not thought to occur in *Botrychium* (Wagner et al. 1985), but Farrar and Johnson-Groh (1990) have documented underground gemmae in a few species of moonwort. They speculated that asexual reproduction may have evolved as an adaptation to the dry habitat that some of these moonwort species were found in. They also examined *B. simplex*, but found no evidence of gemma production, indicating that the primary mode of reproduction is sexually through spore production.

The spore cases of *Botrychium* are among the largest of all known ferns and appear like clusters of tiny grapes (hence the name *Botrychium*, from *botrus*, Greek for grapes) (Wagner 1998). The number of spores per case is probably the highest known for vascular plants, numbering in the thousands (Wagner 1998). Except for *B. mormo*, the sporangial opening to release the spores in most *Botrychium* is over 90° between the two sides of the gap (Wagner 1998). The spores have been measured to disperse by wind about one meter (Hoefferle 1999), but may typically travel much less, perhaps only a few centimeters (Casson et al. 1998). Peck et al. (1990) found that *B. virginianum* spores landed within 3 meters of the source if the plant was above the herbaceous layer, but much less when the sporophore was within the herbaceous layer. While most spores could be expected to land near the parent, some may travel considerable distances (Wagner and Smith 1993, Briggs and Walters 1997).

The succulent nature of the plant, the questionable spore dispersal mechanism, and the very thick spore walls that could help that spores to pass through an animal's gut, have suggested

to some that herbivores such as small mammals may be involved in dispersal (Wagner 1998, Wagner et al. 1985, Wagner and Wagner 1993). The sporangia may also simply rot in the ground, thereby dispersing their spores (NatureServe 2001). It is uncertain how long *Botrychium* spores remain viable (Lesica and Ahlenslager 1996).

After the spores are released, they infiltrate into the soil and may germinate. Infiltration and subsequent germination may take up to 5 years, although some may germinate immediately (Casson et al. 1998). Spore germination requires darkness, (Whittier 1972, 1973; Wagner et al. 1985), a requirement that is not surprising in view of the subterranean habitat of the gametophyte and the need for the resultant gametophyte to be infected by an endophytic fungus in an obligate association (Whittier 1973). Details of this host/fungus interaction are provided in Schmid and Oberwinkler (1994). It has been suggested that *Botrychium* gametophytes may even delay growth until they are infected with the fungus (Campbell 1911; Whittier 1973, 1996). Essentially the *Botrychium* gametophyte becomes a parasite of the mycorrhizal fungus (Casson et al. 1998, Whittier 2000).

All *Botrychium* species are believed to be obligately dependent on mycorrhizal relationships in both the gametophyte (Bower 1926, Campbell 1922, Gifford and Foster 1989, Scagel et al. 1966, Schmid and Oberwinkler 1994) and sporophyte generations (Bower 1926, Gifford and Foster 1989, Wagner and Wagner 1981). The gametophyte is subterranean and achlorophyllous, depending on an endophytic fungus for carbohydrate nutrition, while the roots of the sporophyte lack root hairs and probably depend on the fungus for absorption of water and minerals (Gifford and Foster 1989). *Botrychium* gametophytes were formerly considered saprophytic (Bower 1926), but are now thought to obtain carbohydrates fixed by neighboring plants and transported by shared mycorrhizal fungi (Camacho 1996); they are thus better classified as myco-heterotrophic (Leake 1994).

A fungal associate is present within the plant at the earliest stages of development of the gametophyte and sporophyte (Bower 1926). There are no reports of successful completion of the lifecycle by *Botrychium* species without fungal infection, however, the degree of infection may vary between species and age of plants (Bower 1926, Campbell 1922). Little is known about the mycorrhizal fungi associated with *Botrychium* species other than their presence within the gametophyte and roots of the sporophyte (Camacho 1996). *Botrychium* mycorrhizae have been described as the vesicular-arbuscular (VAM) type by Berch and Kendrick (1982) and Schmid and Oberwinkler (1994).

The mycotrophic condition is important to the ecology of *Botrychium* species in several ways. Nutrition supplied through a fungal symbiont may allow the ferns to withstand repeated herbivory, prolonged dormancy, or growth in dense shade (Kelly 1994, Montgomery 1990). The fungal/fern relationship has implications for the occurrence of genus communities, the distribution of the species across the landscape, and associations with particular vascular plants. Mycorrhizal links may explain the often observed close associations between certain moonworts and strawberries (*Fragaria* spp.; Zika 1992, 1994) and between grapeferns *(Botrychium* subgenus *Sceptridiu*m) and Rosaceous fruit trees (Lellinger 1985). Due to the occurrence of heterotrophic life-stages, moonworts share many of the morphological and habitat characteristics of myco-heterotrophic plants such as

orchids (reviewed by Leake 1994) and in many respects behave much like mushrooms (Zika 1994).

Gametophytes and young sporophytes may exist underground for many years before an aboveground plant develops (Campbell 1911, Muller 1993). Mortality may be high during this period (Peck et al. 1990). The gametophyte produces male and female gametangia; fertilization of eggs occurs via free-swimming sperm under wet conditions (Lesica and Ahlenslager 1996). Most fertilizations are likely due to inbreeding, since the antheridia and archegonia are nearby and enzyme electrophoresis indicates a lack of genetic variability (McCauley et al. 1985, Soltis and Soltis 1986, Farrar and Wendel 1996, Farrar 1998). However, there is no reason that cross-fertilization should not occur (Wagner et al. 1985), especially in consideration of the existence of interspecific hybrids (Wagner et al. 1985, Wagner 1998). McCauley et al. (1985) calculated that *B. dissectum* outcrosses about 5% of the time. Extremely high levels of inbreeding were also found in *B. virginianum* although there was evidence for some outcrossing (Soltis and Soltis 1986).

Sporophytes develop on the gametophyte, forming roots and a single leaf each season from a short rhizome (Foster and Gifford 1974). Root development occurs before any leaf development (Casson et al. 1998), and the roots must also be colonized by the mycorrhizal fungi for a nutrient source (Farrar and Johnson-Groh 1990, Wagner 1998, Johnson-Groh 1998). The fungus involved is believed to be a vesicular arbuscular mycorrhizae (Berch and Kendrick 1982), which penetrates inside the plant cells of both the roots and the gametophytes in the case of *Botrychium* spp. The fungus may be transferring carbohydrates from other photosynthesizing plants in the vicinity, possibly species of herbaceous flowering plants (Farrar 1998). The species of mycorrhizae fungus involved with *Botrychium* is unknown (Casson et al. 2000). In a comparison of ferns and mycorrhizae colonization, the two *Botrychium* species surveyed had more extensively colonized roots than 37 other species of ferns (Berch and Kendrick 1982).

When the sporophyte eventually emerges, a sterile leafy blade (trophophore) and a fertile segment (sporophore) will develop. *Botrychium* plants may go dormant some years and not produce an aerial sporophyte (Wagner and Wagner 1981, Muller 1993). For example, *B. mormo* plants apparently do not produce aboveground sporophytes more than two consecutive years and there may be gaps as long as 6 years, although 1–3 years is more typical (Johnson-Groh 1998, Tans and Watermolen 1997). Johnson-Groh and Farrar (1996a) reported that *B. simplex* plants appeared aboveground in less than half of the years that were monitored. Species of *Botrychium*, with the exception of *B. mormo*, will not produce more than one sporophyte from a gametophyte within one growing season (Casson et al. 1998).

Several factors likely determine the size of the plant and how many spores it is capable of producing (Casson et al. 1998). These include the health of the plant and the associated fungi, climatic conditions, plant age, predators, and other factors. In discussing *B. mormo*, Casson et al. (1998) estimated that about 5–10 percent of aboveground plants would develop into larger plants with 20–50 sporangia (spore-bearing tissues) each.

B. simplex leaves appear in midspring to early fall (Wagner and Wagner 1993). In open droughty areas, plants appear and mature earlier, while woodland plants emerge and persist later into the season (Hagenah 1966). In Minnesota, least moonwort is reported to emerge in June and senesce by early August, making mid-June through July the best time to search for the species (Chippewa Rare Plants Field Guide 1996). The loss of plants to herbivory, fire, and collection did not affect the return of moonworts in later years (Johnson-Groh and Farrar 1996a, b). *Botrychium* may depend little on photosynthesis, and mycorrhizae alone may supply a significant amount of the plant's nutrients and energy (Johnson-Groh 1999, Casson 2000). However, it has been suggested that that photosynthesis may be important and that indiscriminate collecting could threaten *Botrychium* populations (USDA Forest Service, Eastern Region 1999).

Numerous hybrids between different species of moonworts have been found (Wagner et al. 1985; Wagner 1991, 1993; Wagner and Wagner 1988). The hybrids possess abortive spores and are intermediate in characteristics between the presumed parents (Wagner 1993). Wagner (1991) detailed a hybrid between *B. simplex* and *B. matricariifolium* from Quebec and also mentions two localities in Michigan. He provided a key to separate the hybrids. A suspected *B. simplex* hybrid with *B. lunaria* has also been reported (Wagner and Wagner 1988).

All 23 taxa of moonworts have chromosome numbers based on 45; half the members are tetraploids, and one is a hexaploid (Wagner 1993). Chromosome number has been useful in recognizing the distinctness of a new species; additionally, some species may have arisen through allopolyploids of interspecific hybrids (Wagner 1993). Farrar and Wendel (1996a, b) applied enzyme electrophoresis to the genetic relationships of eastern moonworts, including *B. simplex,* and suggested some relationships for moonwort species and hybrids. They subdivided *B. simplex* into three genetically divergent varieties with genetic differences between them approaching that of species (Farrar and Wendel 1996a). Wagner and Wagner (1993) also suggested that the western species may be distinct, meriting subspecies or even species status. However, Hauk and Haufler (1999) found genetic similarities between eastern and western *B. simplex* plants.

HABITAT

Lellinger (1985) described the North American habitat of *B. simplex* as meadows, barrens, and woods; plants were usually in subacid soil. In the eastern United States, Gleason and Cronquist (1991) listed the habitat as open marshy places, meadows, and the edge of woodland ponds. Wagner and Wagner (1993) listed the habitat for eastern *B. simplex* as upland fields.

In Michigan, Hagenah (1966) listed typical habitats as jack pine barrens, highway shoulders, old fields, sandy borrow pits, and along the highwater mark of seasonal ponds in low, sandy woodlands.

In Minnesota, *B. simplex* was found in a wide variety of habitats including northern hardwood forests of sugar maple and basswood, rich black ash and cedar swamps, jack pine

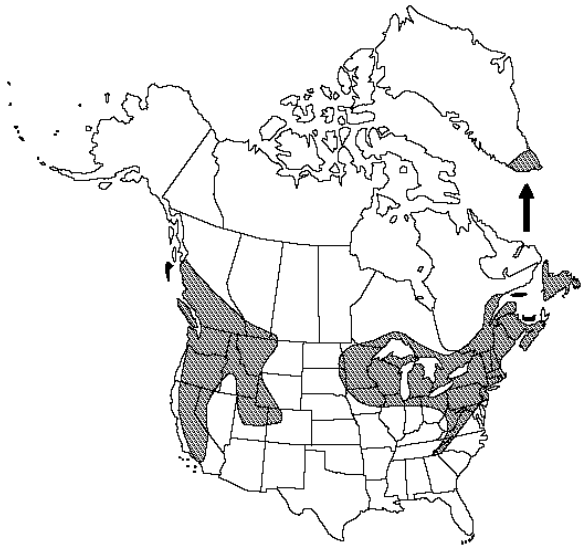
woods, prairies, and disturbed areas such as borrow pits, tailings ponds and road shoulders (Appendix A). Also in Minnesota, Rook (2001) listed habitats as dry or more often damp, partially shaded areas in coniferous forests, or rich deciduous woods on slopes. Lynden Gerdes has found this species at the base of black ash trees, usually growing in a carpet of mosses.

On the Chippewa National Forest in Minnesota, 4 locations of *Botrychium simplex* are reported (Ian Shackleford, Chippewa NF, pers. comm. September 2000). Habitats included a depression in an open area dominated by reed canary-grass, an open field with non-native grasses, and two northern hardwood stands.

In northern Wisconsin, the Chequamegon-Nicolet National Forest reported a wide range of habitat types associated with *B. simplex*, ranging from old fields and barrens to pine and hardwood forests (Appendix A). Common plant associates included jack pine and red pine, sugar maple, basswood and *Carex pensylvanica*. The species is found on glacial till and outwash on a wide variety of landforms, including pitted-outwash to drumlin ridges. Soils are sands, sandy loams, and loams, with low to moderate organic content. Plants are found in open to filtered light conditions and in dry to moist moisture regimes.

DISTRIBUTION, ABUNDANCE, AND STATUS

Botrychium simplex and *B. matricariifolium* are the most common moonworts in eastern North America (Wagner 1991). *B. simplex* is circumboreal and reported as common in Europe (Wagner and Wagner 1986 Gleason and Cronquist 1991). *B. simplex* is listed as "frequent" by Lellinger (1985). State and provincial conservation status rankings are listed below (see Appendix C for ranking definitions).



North American range of *Botrychium simpex* (Wagner and Wagner 1993).

The species is not listed as endangered, threatened, or special concern in Michigan or

Wisconsin. It is listed as a species of special concern in Minnesota.

United States
Alaska (SR), California (SR), Colorado (S1), Connecticut (SH), Delaware (SR), District of Columbia (SR), Idaho (S1), Illinois (S1), Indiana (S1), Iowa (S2), Maine (SR), Maryland (SH), Massachusetts (SR), Michigan (S?), Minnesota (S3), Mississippi (SR), Montana (SU), Nevada (SR), New Hampshire (SR), New Jersey (S?), New Mexico (SR), New York (SR), North Carolina (S1), North Dakota (SU), Ohio (SH), Oregon (S4), Pennsylvania (S5), Rhode Island (S1), South Dakota (SU), Utah (S1), Vermont (SR), Virginia (S1), Washington (S3), West Virginia (S?), Wisconsin (S?), Wyoming (S2).

Canada
Alberta (S1S2), British Columbia (S1?), New Brunswick (SR), Newfoundland (S2), Newfoundland Island (Newfoundland) (SR), Northwest Territories (SR), Nova Scotia (S2S3), Ontario (S4?), Prince Edward Island (S1), Quebec (SR), Saskatchewan (S1).

Global Heritage Status Rank: G5 (20 May 1998)
Rounded Global Heritage Status Rank: G5

United States
National Conservation Status Rank: N5 (17 Dec. 1994)

Canada
National Conservation Status Rank: N? (08 Aug. 1993)

EO SUMMARY

GREAT LAKES STATES – NUMBER OF ELEMENT OCCURRENCES

State	No. of EOs	Status	Comments
Minnesota	70	S3	State special concern
Wisconsin	unknown	S?	Not tracked
Michigan	unknown	S?	Not tracked
Total	na		

GREAT LAKE STATES and NATIONAL FORESTS - SUMMARY OF ELEMENT OCCURRENCES

National Forest	No. of EOs
Minnesota	70
Chippewa National Forest	4
Superior National Forest	4
Michigan	na

Ottawa National Forest	na
Hiawatha National Forest	na
Huron-Manistee National Forest	na
Wisconsin	na
Chequamegon-Nicolet National Forest	na
Total State EOs	70 (MN only)
Total National Forest EOs	8 (MN only)
NF as % of EOs (MN only)	11%

POPULATION BIOLOGY AND VIABILITY

Little information is available about the population biology of *B. simplex*. Monitoring of a *B. simplex* population over several years in the presence of fire confirmed the variable nature of the plants' appearance aboveground (Johnson-Groh and Farrar 1996a). On average, less than half of the plants produced aboveground leaves in any given year. The total number of plants and plant size showed no difference between burned and unburned sites in most years. However, fires occurring during or after a drought resulted in population decline, suggesting that plants are killed or severely weakened by this combination of factors (Johnson-Groh and Farrar 1996a).

Population studies on other species of moonworts have also shown that there can be considerable annual variation in the number of aboveground plants at a given site (Johnson-Groh 1999). Typically, populations fluctuated independently among plots at any given site, with some populations increasing while others decreased (Johnson-Groh 1999). These variations reflected microsite differences such as soil moisture, herbivory, or mycorrhizae (Johnson-Groh 1999), although populations of moonworts often fluctuate wildly from year-to-year without any apparent cause, and individual plants may not emerge every year (Muller 1993; Johnson-Groh and Farrar 1996a; Johnson-Groh 1998, 1999).

Botrychium probably appear or disappear, at least in part, due to the health of associated mycorrhizae fungi because of their obligate relationship with the fungi (Johnson-Groh 1998). Johnson-Groh (1999) concluded that mycorrhizae were the most important limiting factor for *Botrychium* establishment, distribution, and abundance. Environmental factors that may affect mycorrhizae, such as reductions in water availability, are also likely to have significant impacts on moonworts, whereas the repeated removal of leaf tissue may have little effect (Johnson-Groh 1999). Standard assumptions about the population biology of other, more 'typical' plants may be irrelevant to *Botrychium* because of this obligate relationship (Johnson-Groh 1999).

Since there is considerable variation in the numbers of aboveground sporophytes, a field measurement of only sporophytes does not completely indicate population numbers. Johnson-Groh (1998) developed a method to extract *Botrychium* gametophytes and belowground sporophytes from soil samples. Up to 7000 gametophytes and 250 non-

emergent sporophytes per square meter of soil have been recovered, although an unknown number of these may be from the common *B. virginianum* (Johnson-Groh 1998). In another report Johnson-Groh et al. (2000) found gametophyte populations ranging up to 2000 gametophytes/m^2 for some moonwort species; other moonwort species had a much lower density. Bierhorst (1958) reported finding 20 to 50 gametophytes of *B. dissectum* beneath each surface square foot with a predominance of younger gametophytes versus older ones with attached sporophytes. These findings suggest that a finding even a single emergent sporophyte may indicate a self-sustaining population at that site (Casson et al. 1998).

A spore bank that consists of all ungerminated spores, including unopened sporangia, is present within the litter, duff, and soil (Casson et al. 1998). The spores persist in the soil for several years and, along with underground gametophytes and developing sporophytes, form a highly buffered population that can rebound from unfavorable years (Johnson-Groh et al. 1998, Johnson-Groh 1999). However, events that destroy the sporophytes may have an effect several years later (Johnson-Groh 1999). These underground stages have been compared to seed banks in angiosperms and could play an important role in population dynamics (Kalisz and McPeek 1992).

A population model for *Botrychium mormo* has been developed by a working group within the Population and Habitat Viability Assessment effort (Berlin et al. 1998) and Johnson-Groh et al. (1998). This model uses a variety of input variables such as number of spores in the soil, number of soil gametophytes, frequency of catastrophes, etc. They concluded that populations subjected to increased levels of annual environmental variation are at greater risk of population decline and extinction, although a single catastrophic year has relatively little effect on simulated populations. The population is likely more stable than would be predicted from monitoring only aboveground plants due to the large proportion of the population in underground stages. *B. simplex* may respond similarly.

Many species of *Botrychium* are associated with light to moderate disturbances (Lellinger 1985, Wagner and Wagner 1993a, Lesica and Ahlenslager 1996). As *B. simplex* is often found in open and disturbed areas, it may have a metapopulation structure whereby local populations are founded then go extinct as succession proceeds toward a closed climax community (Menges and Gawler 1986, Parsons and Browne 1982). The high variability in aboveground plant numbers found in some moonworts suggests a high probability of local extinction (Johnson-Groh et al. 1998). This kind of species may then depend on a regime of natural disturbances that creates a shifting mosaic of seral communities (Pickett and Thompson 1978).

Most moonworts, including *B. simplex,* are highly variable due to genetic differences and the effects of habitats (Wagner and Wagner 1990b). *B. simplex* is an especially variable moonwort with very different forms depending on environmental influences (Hagenah 1966, Wagner and Wagner 1993). The disjunct eastern and western populations may merit separate species or subspecies status (Wagner and Wagner 1993). However, one genetic study found similarities between the western and eastern populations (Hauk and Haufler 1999). An enzyme electrophoresis study of eastern *B. simplex* populations reported three genetically divergent varieties with the genetic distances between them approaching that of

the species-level (Farrar and Wendel 1996a).

POTENTIAL THREATS AND MONITORING

Threats to *B. simplex* are not well understood but a serious underlying threat is the lack of information available on the species. The only well-documented threat resulting in a population decline was drought combined with fire (Johnson-Groh and Farrar 1996a). Because *B. simplex* often occurs in disturbed sites, threats may include natural plant succession and potentially the same human activities that have also apparently resulted in suitable habitat. Since *B. simplex* is also found in forested areas that have not been recently disturbed, forestry activities may affect existing populations negatively, although no research has been reported. Some threats will have their direct effect on the aboveground sporophyte and may be less serious, since the belowground part of the life-cycle is so important (see Sections C and F above).

Simple removal of leaf tissue may be inconsequential to the ability of moonworts to survive, although removing sporulating individuals may eventually have an effect (Johnson-Groh 1999). Wagner and Wagner (1993a) also stated that taking many samples will have little effect on the population as long as the underground shoots and roots are left intact. However, Hoefferle (1999) reported that if the aboveground plant was removed after spore release, the trophophore the following year was significantly smaller in size. Removal before sporulation had no effect. (It should be noted that this was a one-year study and weather conditions could have had a significant impact). Longer-term studies have indicated that the removal of leaves has no effect on subsequent leaf size or vigor (Johnson-Groh and Farrar 1996a, b). However, it has been suggested that that photosynthesis may be important and that indiscriminate collecting could threaten *Botrychium* populations (USDA Forest Service, Eastern Region 1999); thus leaf removal may have negative impacts on a population.

In a French study (Muller 1992), drought-like conditions resulted in wilting a sporophyte of a species of *Botrychium* prior to sporulation. The work of Johnson-Groh (1999) also emphasized the importance of water-relations to moonworts and their supporting mycorrhizae. Mycorrhizae are the most limiting factor for *Botrychium* establishment, distribution, and abundance (Johnson-Groh 1999); therefore adverse impacts to the mycorrhizae may be expected to also have deleterious effects on *Botrychium*.

Large decreases in mycorrhizal fungi have occurred following earthworm invasion in deciduous hardwood forests (Nielsen and Hole 1963, 1964; Cothrel et al. 1997; Nixon 1995). A similar effect may occur in the habitats favored by *B. simplex*, which include northern hardwood forests. Since most mycorrhizal activity occurs in the interface between the O and A horizons (Read 1994), the concurrent action of exotic earthworms in the same area may have significant effects. The exotic earthworms have their largest impact on the organic surface layer present in some soils (Langmaid 1964). However, the disturbed areas often favored by *B. simplex* likely would have less organic material; typical earthworm activity cycling organic material may not be a serious threat to *B. simplex* habitat there. Since *B. simplex* occurs with some regularity in forested environments that could be

impacted by worms, habitat could be negatively affected.

STEWARDSHIP OVERVIEW AND POPULATION VIABILITY CONCERNS

Often it is difficult to determine what factor or combination of factors is impacting *Botrychium* populations (USDA Forest Service, Eastern Region 1999). Populations are inherently variable (Johnson-Groh 1999) but maintaining the health of the mycorrhizae seems to be an underlying necessity. Moisture relations are critical, as activities that dry the habitat may have deleterious effects on the population. *B. simplex* occurs in a wide variety of habitats, therefore a variety of techniques may be necessary to encourage the establishment and maintenance of the species. A variety of disturbed and relatively undisturbed habitats have been reported; identifying a specific disturbance regime favorable to the species may be difficult.

Since *B. simplex* often exists in a habitat that is early successional due to disturbance (such as fields, tailings piles, roadsides, etc.), it may be prone to local extinctions. Maintaining viable populations may rely on a shifting mosaic of suitable habitats opening up for colonization (see Section F). Species protection efforts must account for the immediate area surrounding *B. simplex* populations to ensure that an adequate buffer is present to protect the population from potential threats. A buffer also allows for expansion of the population.

RESEARCH AND MONITORING REQUIREMENTS

Like all *Botrychium*, *B. simplex* is small, inconspicuous, and fairly difficult to find. The fluctuating population also creates difficulties; plants may go dormant some years and not appear aboveground. There are probably undiscovered sites for *B. simplex*, inventories for the plant should continue. While some research data have been developed about population fluctuations for certain species of *Botrychium* (Johnson-Groh 1999), and one study of a *B. simplex* population in a prairie environment has occurred (Johnson-Groh and Farrar 1996a), much information about *B. simplex* population biology is lacking.

Almost no information is available on *B. simplex* life history in relation to disturbance and colonization of new sites. While its habitat is generally considered to be open areas, it also occurs in forested habitats. The specific habitat requirements of *B. simplex* and the sensitivity of this species to disturbance need to be determined. Succession toward closed-canopy conditions may be a threat, but it is unclear how *B. simplex* reacts to site changes over time. Long-term monitoring is necessary to determine life history characteristics, population stability, and dynamics over time.

Life history information for moonworts is mostly generalized from studies on various species within the group. Specific information on *B. simplex* life history is needed including its important relationship with mycorrhizal fungi and its belowground ecology in general. Data on spore dispersal are also lacking.

Exotic earthworms are a serious threat to some moonwort species, particularly *B. mormo* (Sather et al. 1998). It is unknown if exotic earthworms threaten *B. simplex* populations or habitats.

Berlin et al. (1998) make a number of specific research and monitoring recommendations for the moonwort, *B. mormo*. Many of their suggestions apply to other *Botrychium* species also, and that source should be consulted for detailed recommendations about *Botrychium* monitoring and research. There are also a number of specific suggestions about habitat and population monitoring for *B. rugulosum* that generally apply to most rare *Botrychium* spp. at www.natureserve.org (NatureServe 2001).

In small populations, individual counts of the entire group should be made. In large populations, a representative sample of the population should be monitored through a randomized, permanent plot methodology. Individuals within each plot should be mapped as an aid to tracking, possibly providing detailed information pertaining to life span, dormancy, recruitment, etc.

Habitat monitoring is also a need for the species. Correlations between changes in habitat and reproductive success can give strong recommendations toward future management activities. Such monitoring will also indicate the appropriate time to initiate management activities. Perhaps the easiest and most effective way of monitoring habitat would be through permanent photo-points. Although photo-points may not provide the detailed information pertaining to species composition within a given site, rough changes in habitat should be observable. Photo-point analysis of canopy cover, and shrub and ground layer competition with respect to population trends would provide useful information for possible management procedures. Other more time-intensive procedures designed to statistically track changes in composition of the ground-layer associates at each site may be installed and monitored along with the methodology designed to track population trends, as discussed above.

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UNITED STATES
Michigan: http://www.dnr.state.mi.us/wildlife/heritage/mnfi/
Minnesota: http://www.dnr.state.mn.us/ecological_services/nhnrp/index.html
Wisconsin: http://www.dnr.state.wi.us/org/land/er/nhi/nhi.htm
Illinois: http://dnr.state.il.us/
Indiana: http://www.ai.org/dnr/naturepr/index.htm
Iowa: http://www.state.ia.us/dnr/organiza/ppd/nai.htm
Ohio: http://www.dnr.state.oh.us/odnr/dnap/dnap.html
North Dakota: http://www.abi.org/nhp/us/nd/index.html

CANADA
Ontario: http://www.mnr.gov.on.ca/MNR/nhic/nhic.html
Quebec: http://www.menv.gouv.qc.ca/biodiversite/centre.htm

APPENDICES

APPENDIX A. *Botrychium simplex* Element Occurrence Records

The following information was obtained from natural heritage programs in Michigan, Minnesota, Wisconsin, and adjacent states (U.S.) and provinces (Canada). National Forests within the Great Lakes region also provided survey data on species occurrences within each Forest.

Element occurrence summary:
Michigan (not tracked)
Minnesota 70
Wisconsin (not tracked)

MICHIGAN

Location: Michigan
Ownership: Ottawa National Forest
Abundance: Not listed
Habitat: *Botrychium simplex* occurs in hardwoods, e.g. sugar maple-yellow birch-basswood types, richer sites. Shady and moist conditions.
Comments: 2 specimens in the Ottawa NF herbarium. Sue Trull, Forest Botanist reported that "we do not specifically track this species and have very little information on its distribution or abundance on the Forest. I think this taxon is probably less common than many of the other *Botrychium*."
Source of information: Survey form from the Ottawa N.F.

Location: Michigan
Ownership: Hiawatha National Forest
Abundance: Not listed
Habitat: Not listed
Comments: "We do not survey for this species."
Source of information: Survey form from the Hiawatha N.F.

MINNESOTA

Location: Minnesota, Aitkin County
Ownership: State
Abundance: Not listed
Habitat: Ash swale along savanna portage trail. With *Botrychium matricariifolium, Carex pedunculata, Trientalis borealis, Uvularia sessilifolia, Athyrium filix-femina.*
Comments: 1996.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: Private
Abundance: Not listed

Habitat: Growing near the base of a very small steep hill. Plants occur in a disturbed, mixed woodland thicket with *Acer saccharum* and *Fraxinus pensylvanica*. Associated with *Botrychium simplex, Ulmus americana, Dirca palustris, Thalictrum dioicum.*
Comments: 1996.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: State
Abundance: Approx. 6 plants observed
Habitat: Black ash swamp. At bases of *Fraxinus nigra* on north side of trunk, hidden in bryophytes. Associated spp. include *Rubus pubescens, Ranunculus abortivus,* and *Carex intumescens.*
Comments: verified by W.H. Wagner 9/97.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: County
Abundance: Approx. 20 plants observed
Habitat: Mixed hardwood forest primarily of maple-basswood and northern red oak. In leaf trough/moist depression, mostly along sides and upper slopes of micro-topography. Associated species include *B. lanceolatum* var. *angustisegmentum* (nearby), and *B. matricariifolium.*
Comments: verified by W.H. Wagner 9/97.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: County
Abundance: Approx. 24 plants observed
Habitat: Maple-basswood-ash forest. Leafy depression with little to no vegetation. Plants from midway to 3/4 way up the side of depression. Associated spp. include a few *Dryopteris carthusiana* and *Arisaema triphyllum.*
Comments: verified by W.H. Wagner 9/97.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: Unknown
Abundance: Approx. 75 - 100 plants observed
Habitat: On large upland island in wetland complex. Hollow depression of leaf litter and sparse vegetation in maple-basswood-ash forest. Some hollows with *Osmunda* overgrowth, *Uvularia sessilifolia, Onoclea sensibilis,* etc.
Comments: 1997. (verified by W.H. Wagner 9/97).
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: State and con-con land
Abundance: Several plants observed

Habitat: Growing in a black ash swamp that borders a large black spruce swamp. Several shoots on just one slightly raised hummock. With *Carex leptonervia, Carex pedunculata* and *Carex rosea*.
Comments: 1997.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: County
Abundance: Ten shoots in cluster and 4 shoots seen about 100m away in same habitat
Habitat: Growing in a rare, lowland forest dominated by *Thuja occidentalis* and *Acer saccharum*. In shade under *Acer*, sparse woody understory. With *Asarum canadense, Uvularia sessilifolia, Botrychium virginianum, Carex pedunculata* and *Mitella diphylla*. Adjacent upland forest recently thinned.
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: County
Abundance: 2 clusters (total 9 shoots)
Habitat: Growing in a mature white cedar swamp on raised woody hummocks. Stand is 30 x 60m, very shady and situated between black ash swamp (wetter) and brushy, balsam fir/trembling aspen zone that borders the extensive wetland system. *Athyrium filix-femina* common, but *B. simplex* associated with *Carex pedunculata* and small herbs.
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: State
Abundance: Not listed
Habitat: Rare along an ecotone between northern hardwood forest and black ash swamp. Interrupted canopy of *Fraxinus nigra, Tilia americana, Acer rubrum* with a near-continuous subcanopy of *Acer saccharum*. Associates: *Clintonia borealis, Maianthemum canadensis, Aralia nudicaulis, Fragaria virginiana*. Silty clay loam over sand.
Comments: 1999.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: State and con-con land
Abundance: 15-20 plants
Habitat: In a maple-basswood forest occupying the lower portion of a glacial beach ridge. Assoc.: *Athyrium filix-femina, Carpinus caroliniana, Sanicula marilandica, Festuca obtusa*. Fine sand. Humus 7 cm thick. Mixed with a few *B. lanceolatum* and “hundreds” of plants of *B. matricariifolium.*
Comments: 1999.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Aitkin County
Ownership: Unknown
Abundance: 15-20 plants
Habitat: In a hardwood forest dominated by *Acer saccharum* and *Tilia americana*. Associated with *Botrychium multifidum, B. lanceolatum.*
Comments: 1996. Verified by W.H. Wagner 6/1998
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Anoka County
Ownership: Univ. of MN
Abundance: Not listed
Habitat: In an old field.
Comments: 1996. Verified by W.H. Wagner 10/1997
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cass County
Ownership: Unknown
Abundance: 4 plants
Habitat: In white cedar swamp with *Coptis groenlandica, Rubus pubescens, Ribes triste, Carex leptalea, Mitella nuda, Cicuta maculata.*
Comments: 1996. Verified by W.H. Wagner 10/1996
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cass County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a deciduous forest dominated by *Acer saccharum*. Associated with *Botrychium minganense, B. matricariifolium, B. pallidum, B. multifidum, B. virginianum.* Growing close to the lakeshore on a small plateau above the lake.
Comments: 1993.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cass County
Ownership: Chippewa National Forest
Abundance: 2 plants
Habitat: Plants are growing on uphill side of a w-facing slope at the base of a large red pine. Habitat is a maple-basswood stand with paper birch and some red pine. Associated spp: hazel, wild lily-of-the-valley, large-leaf aster and poison ivy.
Comments: 1997. (verified by W.H. Wagner 10/97).
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cass County
Ownership: Tribal Reservation
Abundance: Not listed
Habitat: Numerous stems located in and around edges of slight depression in weedy, sandy area being experimentally treated for leafy spurge

Comments: 1995.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Clay County
Ownership: Private
Abundance: Not listed
Habitat: In glacial till prairie
Comments: 1988.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Clay County
Ownership: Unknown
Abundance: Not listed
Habitat: In glacial till prairie growing with *Stipa spartea*.
Comments: 1988. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Clearwater County
Ownership: State
Abundance: Not listed
Habitat: In jack pine forest near gravel pit.
Comments: 1927. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: USFS
Abundance: 1 plant
Habitat: In brushy edge of old log landing. Associated spp: *Danthonia spicata, Apocynum androesamifolium, Fragaria virginiana, Anaphalis margaritacea, Aster ciliolatus, A. macrophyllus, Solidago* spp., *Botrychium dissectum* var. *obliquum, B. multifidum, Vaccinium angustifolium, Corylus cornuta.*
Comments: 1997.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: Unknown
Abundance: 1 plant
Habitat: Located along trail among *Aster macrophyllus*.
Comments: 1944.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: Unknown
Abundance: Not listed
Habitat: On moist, spring side of marly ditch along road.
Comments: 1948.

Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: Unknown
Abundance: Several plants observed
Habitat: Plants observed just off pavement. Several plants obs. with *Fragaria*, grasses and *Hieracium*. Plants were yellow, past prime. No other *Botrychium* spp. observed.
Comments: 1998. Verified by Wagner.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: Unknown
Abundance: Several plants observed
Habitat: Plants observed just off pavement. Several plants obs with *Fragaria,* grasses and *Hieracium*. Plants were yellow, past prime. No other *Botrychium* spp. observed.
Comments: 1998. Verified by Wagner.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: State
Abundance: 1983: About 12 plants observed, 1985: 15 – 20 plants
Habitat: 1983: in gravelly soil in sparsely vegetated ditch. 1985: 15-20 plants observed by c. Anderson along cliff edge at Lake Superior. Site has scrubby vegetation and scattered white spruce; ground cover is grasses, mosses and lichens
Comments: 1985.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: Unknown
Abundance: Not listed
Habitat: In old, mesic opening/meadow near lakeshore. With *Populus balsamifera, Thalictrum dasycarpum, Urtica dioica.*
Comments: 1999. Verified by W. H. Wagner.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: Unknown
Abundance: Not listed
Habitat: In old roadside embankment/ditch/borrow pit. Area is open with only a few shrubs. Associated spp include *B. pallidum, B. michiganense B. matricariifolium, Fragaria, Achillea, Hieracium, Trifolium.*
Comments: 1999.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Cook County
Ownership: USFS

Abundance: Not listed
Habitat: Located on e-facing cliff feature. At immediate base of rock cliff and forested talus, seepy soils. With *Galium triflorum, Thuja, Goodyera.*
Comments: 1999. Young plant, positive id difficult to make.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Hubbard County
Ownership: Unknown
Abundance: Not listed
Habitat: Located on dry road bank, jack pine forest. Sandy soil.
Comments: 1974. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Itasca County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a partially forested 30 acre tailings pond in a mine dump area. Associated with *Populus balsamifera, Botrychium multifidum, B. matricariifolium, Fragaria virginiana*.
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Itasca County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a 160 acre, minimally stabilized tailings pond in a mine spoil associated with *Populus balsamifera, Malaxis unifolia, Fragaria virginiana, Botrychium matricariifolium, B. multifidum*.
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Itasca County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond in a mine spoil area. Associated with *Populus balsamifera, Carex aurea, Achillea millefolium, Populus grandidentata, Botrychium matricariifolium.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Itasca County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond. Associated with *Populus balsamifera, Betula papyrifera, Equisetum hyemale, Prunella vulgaris, Botrychium pallidum.*
Comments: 1998.

Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Kanabee County
Ownership: State
Abundance: 4 plants
Habitat: In a mesic maple-basswood forest with a continuous canopy. Nearly level ground moraine topography. Associated spp.: *Aralia nudicaulis, Geranium maculatum, Milium effusum, Festuca obtusa, Uvularia sessilifolia*. Silt over clay with gravel. Mull humus.
Comments: 1999.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Kittson County
Ownership: State
Abundance: Not listed
Habitat: Growing on flat or slightly undulating prairie. Associated species: *Poa pratensis, Andropogon, Stipa, Schizachyrium, Artemisia, Solidago, Euphorbia, Botrychium campestre, B. gallicomontanum.*
Comments: 1997.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Kittson County
Ownership: State
Abundance: Not listed
Habitat: Growing on flat or slightly undulating prairie. Associated spp: *Poa pratensis, Andropogon, Populus tremuloides, Botrychium matricariifolium, Lithospermum.*
Comments: 1997.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Lake County
Ownership: Unknown
Abundance: Not listed
Habitat: On a leveled log landing at base of north-facing, sandy, jackpine covered slope. Sandy, rocky soil. Associated with *Hieracium aurantiacum, Fragaria americana, Antennaria neglecta, Botrychium matricariifolium.*
Comments: 1995.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Lake County
Ownership: Unknown
Abundance: Approx. 12 plants
Habitat: On s-facing, open, upper bank of railroad r-o-w with *Botrychium multifidum.*
Comments: 1999. Verified by W.H. Wagner.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Lake County
Ownership: Superior National Forest

Abundance: Not listed
Habitat: Old "wildlife" opening with *Pinus strobus, P. resinosa* saplings, *Fragaria virginiana, Oryzopsis asperifolia, Danthonia spicata, Rubus strigosus, Botrychium dissectum* var. *dissectum, B. dissectum* var. *obliquum, B. multifidum, B. rugulosum, B. matricariifolium.*
Source of information: Survey form from the Superior N.F.

Location: Minnesota, Lake County
Ownership: Not listed
Abundance: 24 estimated
Habitat: Along old railroad grade in a disturbed railroad opening. The RR tracks were removed around 10 years ago. Sandy, gravel substrate with *Hieracium, Silene antirhina, Danthonia spicata*. Plants appeared to be localized and were not observed in similar habitat locals at the site.
Source of information: Survey form from the Superior N.F.

Location: Minnesota, Marshall County
Ownership: State
Abundance: Not listed
Habitat: Growing on flat or slightly undulating prairie. Associated species: *Poa pratensis, Andropogon, Stipa, Prunus americana, Lithospermum, Botrychium campestre.*
Comments: 1997. Verified by D. Farrar.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Mille lacs County
Ownership: State
Abundance: Uncommon
Habitat: Growing on somewhat poorly drained sandy loam. Local topography almost level within a larger undulating terminal moraine landscape. Uncommon in a wet-mesic forest under a near-continuous canopy of *Quercus macrocarpa* and *Acer rubrum.* Subcanopy dominated by *Acer saccharum, Amphicarpaea bracteata, Uvularia sessilifolia, Streptopus roseus* and *Carex pensylvanica* common below.
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Mille lacs County
Ownership: Unknown
Abundance: 25–30 plants
Habitat: Growing in mesic hardwood forest near the base of a slope next to lowland hardwood forest
Comments: 1998. Area searched at least 200 x 30m, only 5 other locations found (total of 25-30 shoots), all within a 20 x 30m area.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Mille lacs County
Ownership: State

Abundance: 2 plants
Habitat: At the base of a 1-2 degree nw-slope in an ecotone between northern hardwood forest and black ash swamp. Thick, spongy duff layer. Canopy includes *Quercus rubra, Tilia americana, Acer saccharum* Assoc.*: Botrychium virginianum, B. lanceolatum, B. matricariifolium, Carex pedunculata, Uvularia sessilifolia*. Undulating end-moraine topography.
Comments: 1999. Area searched at least 200 x 30m, only 5 other locations found (total of 25-30 shoots), all within a 20 x 30m area.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Mille lacs County
Ownership: State
Abundance: 15 plants
Habitat: Plants growing in a narrow band of lowland hardwood forest with a canopy of *Tilia amer, Acer rubr,* and *Acer sacc*. Community lies between mesic northern hardwood forest and black ash swamp on rather level ground moraine topography. Assoc.: *Aralia nudicaulis, Geranium maculatum, Sanicula marilandica, Carex woodii, C. pedunculata.* Duff layer 2-3cm thick.
Comments: 1999
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Norman County
Ownership: Unknown
Abundance: Not listed
Habitat: On glacial till prairie growing with *Stipa spartea.*
Comments: 1988
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: 100 plants observed, most extremely small, few spore capsules.
Habitat: Plants growing in a deciduous forest dominated by *Acer saccharum*. Associated with *Ostrya virginiana, Streptopus roseus, Lycopodium lucidulum, Athyrium filix-femina, Aster macrophyllus. Botrychium matricariifolium, B. lanceolatum,* and *B. multifidum* present.
Comments: 1993
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants growing in a mossy, upland stand dominated by *Pinus banksiana*. Associated with *Botrychium dissectum, B. rugulosum, B. multifidum, B. matricariifolium.*
Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Not listed
Habitat: This specimen is *Botrychium simplex* var. t*enebrosum*. Plants occur in a deciduous forest dominated by *Acer saccharum* and *Quercus rubra*. Associated with *Amphicarpaea bracteata, Hepatica americana, Solidago flexicaulis, Monotropa uniflora, Aster macrophyllus. Botrychium dissectum, B. multifidum* and *B. virginianum* present.
Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Infrequent
Habitat: Plants occur in a deciduous forest dominated by Acer saccharum. Associated with *Ostrya virginiana, Cornus alternifolia, Botrychium lanceolatum* ssp. *angustisegmentum, B. matricariifolium.* Growing in bare leaf litter between herbs.
Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Not listed
Habitat: Large specimen very visible. Plants occur in a moist area in a deciduous forest dominated by *Acer saccharum.* Associated with *Ostrya virginiana, Cornus alternifolia, Aralia racemosa, Allium tricoccum, Streptopus roseus.* Observed in bare, moist leaf litter in between herbs.
Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: 200+ plants observed in a 50 x 10 meter area.
Habitat: Plants occur in a deciduous forest dominated by *Acer saccharum*. Associated with *Ostrya virginiana, Cornus alternifolia, Clintonia borealis, Viola pubescens, Anemone quinquefolia*.
Comments: 1993. Extreme size variations in extensive population. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a low area with *Fraxinus nigra* and *Acer saccharum*. Associated with *Osmunda claytoniana, Monotropa hypopithys, Streptopus roseus, Anemone quinquefolia, Athyrium filix-femina. Botrychium lanceolatum* and *B. matricariifolium* present.

Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a deciduous forest with *Acer saccharum* and *Ostrya virginiana*. Associated with *Cornus alternifolia, Viola pubescens, Asarum canadense, Botrychium virginianum, Betula alleghaniensis*. Growing in a moist area of tree tip-ups.
Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a deciduous forest dominated by *Acer saccharum* and *Quercus rubra*. Associated with *Acer rubrum, Athyrium filix-femina, Lycopus uniflorus, Scutellaria galericulata, Nemopanthus mucronatus*. Growing in a moist area at the base of a gentle slope.
Comments: 1993. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Pine County
Ownership: State
Abundance: Not listed
Habitat: Jack pine woods along river.
Comments: 1918. Verified by W.H. Wagner 10/97
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Superior National Forest
Abundance: 20 estimated
Habitat: Along west side of railroad grade. In a small patch of grass and sedge.
Source of information: Survey form from the Superior N.F.

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: A few plants
Habitat: A few plants under *Alnus* in a thicket bordering a bog.
Comments: 1936. Verified by W.H. Wagner 10/97.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: 1 plant
Habitat: In a colony of *Oenothera pumila* in moist mossy soil.

Comments: 1943. Verified by W.H. Wagner 10/97.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants growing in middle of old logging road.
Comments: 1992. Verified by W.H. Wagner 10/97.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond. Associated with *Populus balsamifera, Carex aurea, Malaxis unifolia, Ophioglossum pusillum, Fragaria virginiana.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a stabilized tailings pond associated with *Populus tremuloides, Picea mariana, Carex aurea, Ledum groenlandicum, Vaccinium angustifolium.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond. Associated with *Populus balsamifera, Hieracium aurantiacum, Vaccinium angustifolium, Picea mariana, Alnus incana.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond. Associated with *Populus balsamifera, Equisetum arvense, Alnus incana, Rumex acetosa, Hieracium aurantiacum.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond of a mine spoil area with pioneering aspen and jack

pine. Associated with *Botrychium multifidum, B. matricariifolium, Fragaria virginiana, Achillea millefolium.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: Unknown
Abundance: Not listed
Habitat: Plants occur in a tailings pond in an old mine spoil area with pioneering aspen and jack pine. Associated with *Achillea millefolium, Botrychium multifidum, Antennaria neglecta, Aster ciliolatus, Fragaria virginiana.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: USFS
Abundance: About 40 fronds, many under 1/2 inch in height
Habitat: located in roadbank with some brush (alder, willow, hazel). Plants recently emerged from soil, in part shade. Associated spp: *Fragaria virginiana, Bromus inermis, Carex umbellata, Chrysanthemum leucanthemum, Hieracium piloselloides, Achillea millefolium, Solidago gigantea, Taraxacum officinale, Salix* spp*., Alnus incana, Corylus cornuta.*
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, St. Louis County
Ownership: USFS
Abundance: 7 plants
Habitat: Located on trail overgrown with brush (black alder, pussy willow, beaked hazel, some young quaking aspen and balsam fir). Directly across from road in grassy/ brushy ditch between road and railroad grade. In full sun to part shade. In May, plants recently emerged from soil, plants senescing by July. Associated spp: *Fragaria virginiana, Danthonia spicata, Luzula acuminata, Hieracium aurantiacum*. Four other species of *Botrychium* found at same location.
Comments: 1998.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

Location: Minnesota, Washington County
Ownership: Unknown
Abundance: Not listed
Habitat: Located near lake on border of swamp
Comments: 1905.
Source of information: Minnesota Natural Heritage Program Element Occurrence Record

WISCONSIN

Location: Wisconsin
Ownership: Chequamegon-Nicolet N.F.
Abundance: Multiple sites with limited data.
Habitat: Wide range of habitat types, from old field and barrens habitat to pine and hardwood forests. Plant associates include jack and red pine, sugar maple, basswood and *Carex pensylvanica*. The species is found on glacial till and outwash on a wide variety of landforms from pitted-outwash to drumlin ridges. Soils are sand, sandy loam, and loam with low to moderate organic content. Plants are found in open to filtered light conditions and dry to moist regimes.
Comments: *B. simplex* is not listed as a species of concern by the state of Wisconsin and is not tracked by the Chequamegon-Nicolet Forest as it is reported as common.
Source of information: Survey form from the Chequamegon-Nicolet Forest

OTHER MIDWESTERN STATES

ILLINOIS

Location: Illinois, Cook County
Ownership: Private
Abundance: Not listed
Habitat: Not listed
Comments: 1976.
Source of information: Illinois Natural Heritage Program Element Occurrence Record

Location: Illinois, Lee County
Ownership: Not listed
Abundance: < 10 plants
Habitat: Not listed
Comments: 1971.
Source of information: Illinois Natural Heritage Program Element Occurrence Record

Location: Illinois, Winnebago County
Ownership: Not listed
Abundance: Unknown
Habitat: Not listed
Comments: 1993.
Source of information: Illinois Natural Heritage Program Element Occurrence Record

Location: Illinois, Winnebago County
Ownership: Not listed
Abundance: Unknown
Habitat: Not listed
Comments: 1993.
Source of information: Illinois Natural Heritage Program Element Occurrence Record

Location: Illinois, Lee and Winnebago County

Ownership: Private
Abundance: Unknown
Habitat: Not listed
Comments: Three in-state specimens listed, one from Lee County which may be the above record and two from Winnebago County that do not correspond with element occurrence records.
Source of information: Specimens in the herbarium of the Illinois Natural History Survey.

INDIANA

Location: Indiana, De Kalb County
Ownership: Private
Abundance: 51-100 solitary plants in leaf and fruit.
Habitat: Growing in moss on decaying logs adjacent to buttonbush swamp.
Comments: 1986.
Source of information: Indiana Natural Heritage Program Element Occurrence Record

Location: Indiana, Tippecanoe County
Ownership: Private
Abundance: 101-1000 plants in leaf covering 10-100 sq. yd. area.
Habitat: Associated species: *B. virginianum, B. dissectum,* and *B. matricariifolium*; abundant in regrowth of young red maple on an upland flat.
Comments: 1987.
Source of information: Indiana Natural Heritage Program Element Occurrence Record

Location: Indiana, Portage County
Ownership: Private
Abundance: 1-3 sporulating individuals in a 1 sq. yd area.
Habitat: Mesic sand substrate area with filtered light. south aspect of a swale 0-10 degree upper slope.
Comments: 1990.
Source of information: Indiana Natural Heritage Program Element Occurrence Record

OHIO

Location: Ohio, Highland County
Ownership: Unknown
Abundance: Not listed
Habitat: Clay soil, woods, lower ravine slope.
Comments: 1961
Source of information: Ohio Natural Heritage Program Element Occurrence Record

Location: Ohio, Lucas County
Ownership: Unknown
Abundance: Not listed
Habitat: In sand dunes area, oak openings.

Comments: 1984
Source of information: Ohio Natural Heritage Program Element Occurrence Record

Location: Ohio, Ashtabula, Erie, and Geauga Counties
Ownership: Unknown
Abundance: Not listed
Habitat: Not listed
Comments: Pre-1960 collections
Source of information: Ohio Natural Heritage Program Element Occurrence Record

APPENDIX B. *Botrychium* Status And Threats Summary

Three tables are presented below. Table 1 summarizes the state, national, and global status of each *Botrychium* taxon. Table 2 summarizes range, population, and habitat features. Table 3 ranks the degree of threat to populations of each taxon from various factors. The assigned rankings are intended as general guidelines based on information presented in each conservation assessment. For many taxa, detailed ecological information is lacking.

Table 1. *Botrychium* status.

Key
Status:

- E = state endangered
- T = state threatened
- SC = state special concern
- S1 = state rankings (see Appendix B)
- absent = taxon not known from state
- not listed = taxon not tracked by state natural heritage program.
- Global/National – worldwide or United States ranking provided by NatureServe (2001, see Appendix B. for definitions).

	Range	Habitat Amplitude	Pop Trend	Habitat Integrity	Vulnerability
B. campestre	wide, disjunct	intermediate	unknown	fair	medium
B. dissectum	wide	broad	increasing	fair	low
B. hesperium (B. michiganense)	endemic	intermediate	stable	fair	medium
B. lanceolatum var. *angustisegmentum*	wide	intermediate	increasing	fair	low
B. lunaria	wide	broad	stable	fair	medium
B. minganense	high	medium	medium	low	medium
B. mormo	endemic	narrow	decreasing	fair	high
B. oneidense	wide	intermediate	unknown	fair	medium
B. pallidum	narrow	broad	stable	fair	low
B. pseudopinnatum	endemic	narrow	unknown	poor	high
B. rugulosum	narrow	intermediate	stable	fair	low
B. simplex	wide	broad	increasing	good	low
B. spathulatum	narrow	intermediate	unknown	fair	medium

Status:	Minnesota	Michigan	Wisconsin	Global/National
B. campestre	SC (S3)	T (S2)	E (S1)	G3/N3
B. dissectum	(not listed) SU	(not listed) S?	(not listed) SR	G5/N5
B. hesperium (B. michiganense)	(not listed)	T (S1S2)	(absent)	G3/N2
B. lanceolatum	T (SR)	(not listed) S4	(not listed) S3	G5/N4
B. lunaria	T (S2)	(not listed) S?	E (S1)	G5/N4?
B. minganense	SC (S3)	(not listed) S?	SC (S2)	G4/N?
B. mormo	SC (S3)	T (S1S2)	E (S2)	G3/N3
B. oneidense	E (S1)	(not listed) S?	SC (S2)	G4Q/N4
B. pallidum	E (S1)	SC (S3)	(absent)	G2G3/N2N3
B. pseudopinnatum	(not listed) S?	(absent)	(not listed)	G1/N1
B. rugulosum	T (S2)	(not listed) S3	SC (S2)	G3/N3
B. simplex	SC (S3)	(not listed) S?	(not listed) S?	G5/N5
B. spathulatum	(not listed) S?	(not listed) S3	SC (S1)	G3/N3

Table 2. *Botrychium* range, population, and habitat features.

Key

- range: wide (occurs across much of North America), narrow (e.g. Lake States), endemic (restricted to Lake States), disjunct (separated from main population).
- amplitude: broad (tolerates a variety of habitats and conditions), intermediate, narrow (very specific requirements).
- estimated population trend: increasing, stable, decreasing, unknown (insufficient information to estimate trend).
- habitat integrity: good (most habitats/sites protected, not commonly impacted by management), fair, poor (most sites degraded, unoccupied habitat subject to numerous impacts), unknown.
- vulnerability: high (populations generally not resilient or are intolerant of habitat changes), medium, low (populations resilient and/or resistant to change), unknown.

Table 3. Major threats to *Botrychium*.

	Threat					
	Exotic Earthworms	**Exotic Plants**	**Canopy Thinning**	**Succession To Closed Canopy**	**Disturbance**	
					Major	**Minor**
B. campestre	low	medium	low	high	medium	low
B. dissectum	medium	medium	medium	low	high	medium
B. hesperium (B. michiganense)	medium (forested sites) low (other sites)	medium-high	low	low-medium	medium	low
B. lanceolatum var. *angustisegmentum*	high	medium	medium	low	medium	low
B. lunaria	low	medium	low	medium	medium	low
B. minganense						
B. mormo	high	low	high	low	high	medium
B. oneidense	high	medium	medium-high	low	high	medium-high
B. pallidum	low	high	low	high	medium	low
B.pseudopinnatum	low	high	low	high	medium	low
B. rugulosum	low	medium	low	high	high	medium
B. simplex	medium	medium	low	medium	medium	low
B. spathulatum	low	high	low	high	medium	low

Key
High, medium, or low are used to indicate the estimated degree of impact of a specific threat to a *Botrychium* population.

APPENDIX C. Global, National, And Subnational Conservation Status Ranks (From NATURESERVE, www.natureserve.org).

NatureServe reports the relative imperilment, or conservation status, of plants, animals, and ecological communities (elements) on a global, national, and subnational (state/provincial) level. Based on the conservation status ranking system developed by The Nature Conservancy and the Natural Heritage Network, conservation status ranks are assigned, reviewed, and revised according to standard criteria. Assessing the conservation status of species and ecological communities is the cornerstone of Natural Heritage work. It allows Natural Heritage programs and their cooperators to target the most at-risk elements for inventory, protection, management, and research.

Global, National, and Subnational Conservation Status Ranks

An element is assigned one global rank (called a G-rank), which applies across its entire range; a national rank (N-rank) for each nation in its range; and a subnational rank (S-rank) for each state, province, or other subnational jurisdiction in its range (e.g. Yukon Territory). In general, Association for Biodiversity Information (ABI) scientists assign global, U.S., and Canadian national ranks. ABI scientists receive guidance from subnational data centers, especially for endemic elements, and from experts on particular taxonomic groups. Local data centers assign subnational ranks for elements in their respective jurisdictions and contribute information for national and global ranks. New information provided by field surveys, monitoring activities, consultation, and literature review, improves accuracy and keeps ranks current. Including an annual data exchange with local data centers, ABI's central databases are updated continually with revisions, corrections, and information on ranked elements.

What the Ranks Mean

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, in other words, 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). Other codes, rank

variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty. See the lists of conservation status rank definitions for complete descriptions of ranks and qualifiers.

Rank Definitions

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 is in conservation priority.) On the other hand, it is possible for an element to be 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 which should receive priority for research and conservation in a jurisdiction. Highest priority should be given to elements that are most vulnerable to extinction—that is, those ranked G1, G2, or G3. And, according to the rules of ranking, these must have equally high or higher national and subnational ranks. Elements vulnerable to national or subnational extirpation (ranks N1, N2, N3, or S1, S2, S3) with global ranks of G4 or G5 should be considered next.

Assessment Criteria

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 ABI 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, which function as guidelines rather than arithmetic rules. The ranker's overall knowledge of the element allows him or her to weigh each factor in relation to the others and to consider all pertinent information for a particular element. The factors considered in ranking species and communities are similar, but the relative weight given to the factors differs.

For species elements, the following factors are considered in assigning a rank:
total number and condition of occurrences
population size
range extent and area of occupancy
short- and long-term trends in the foregoing factors
threats
fragility.

Secondary factors include the geographic range over which the element occurs, threats to occurrences, and viability of the occurrences. However, it is often necessary to establish preliminary ranks for communities when information on these factors is not complete. This is particularly true for communities that have not been well described. In practice, a preliminary assessment of a community's range-wide global rank is often based on the following:
geographic range over which the element occurs
long-term trend of the element across this range
short-term trend (i.e., threats)
degree of site/environmental specificity exhibited by the element
rarity across the range as indicated by subnational ranks assigned by Heritage data centers.

Global Heritage Status Rank Definitions

Rank	Definition
GX	Presumed Extinct—Believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
GH	Possibly Extinct (species)—Known from only historical occurrences, but may nevertheless still be extant; further searching needed.
G1	Critically Imperiled—Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).
G2	Imperiled—Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
G3	Vulnerable—Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4	Apparently Secure—Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
G5	Secure—Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

National (N) and Subnational* (S) Heritage Status Rank Definitions
* Subnational indicates jurisdictions at the state or provincial level (e.g. California, Ontario).

Rank	Definition
NX SX	Presumed Extirpated—Element is believed to be extirpated from the nation or subnation*. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
NH SH	Possibly Extirpated (Historical)—Element occurred historically in the nation or subnation*, and there is some expectation that it may be rediscovered. Its presence may not have been verified in the past 20 years. An element would become NH or SH without such a 20-year delay if the only known occurrences in a nation or subnation were destroyed or if it had been extensively and unsuccessfully looked for. Upon verification of an extant occurrence, NH or SH-ranked elements would typically receive an N1 or S1 rank. The NH or SH rank should be reserved for elements for which some effort has been made to relocate occurrences, rather than simply using this rank for all elements not known from verified extant occurrences.
N1 S1	Critically Imperiled—Critically imperiled in the nation or subnation* because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000).
N2 S2	Imperiled—Imperiled in the nation or subnation* because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
N3 S3	Vulnerable—Vulnerable in the nation or subnation* either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
N4 S4	Apparently Secure—Uncommon but not rare, and usually widespread in the nation or subnation*. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals.
N5 S5	Secure—Common, widespread, and abundant in the nation or subnation*. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.
N? S?	Unranked—Nation or subnation* rank not yet assessed.

APPENDIX D. CONTRACTOR QUALIFICATIONS AND EXPERIENCE

The conservation assessment was prepared by Steve W. Chadde and Dr. Greg Kudray. Mr. Chadde holds an M.S. degree in Plant Ecology from Montana State University and a B.S. degree in Agriculture from the University of Wyoming. He has conducted numerous botanical and ecological surveys and research studies in both the Great Lakes (Michigan, Minnesota, Wisconsin) and Rocky Mountain regions. Mr. Chadde's primary areas of expertise are endangered, threatened, and sensitive plant surveys, plant community characterization studies, natural areas evaluations, and wetlands inventory, delineation, and mapping. Dr. Kudray holds a Ph.D. in Wetland Ecology from Michigan Technological University. He has extensive experience in ecosystem characterization and mapping, vegetation inventory and monitoring, and forest analysis. Additional information for each author is provided below.

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Statement of Qualifications – Steve W. Chadde

Recent Experience

Consulting Botanist
Ottawa National Forest, Lake Superior Land Co., Central Lake Superior Watershed Partnership, U.P. Engineers and Architects, Michigan (partial list only).
Conducted field surveys for endangered, threatened, and rare plant species, and various wetland and other ecological studies.

Botanist, USDA Forest Service
Ottawa National Forest and Hiawatha National Forest, Michigan
Conducted field surveys for endangered, threatened, and rare plant species on national forest lands in Michigan's Upper Peninsula.

Biologist, US Geological Survey
Great Lakes Science Center, Ann Arbor, Michigan
Vegetation scientist for a large wetland restoration project at Seney National Wildlife Refuge in Michigan's Upper Peninsula.

Natural Areas Ecologist, USDA Forest Service/The Nature Conservancy
Northern Region USDA Forest Service, Missoula, Montana
Responsible for identifying and establishing research natural areas (RNAs) and botanical areas on national forests in northern Idaho, Montana, and North and South Dakota. Performed field surveys and baseline inventories of wetlands and natural areas. Conducted field surveys for rare plants and plant communities.

Education

Michigan Technological University—Coursework in the Scientific and Technical Communication program.
Michigan Technological University—Coursework in the Scientific and Technical Communication program.
M.S. Range Ecology— Montana State University, 1985
B.S. Agriculture (Honors)—University of Wyoming, 1983

Publications

Chadde, Steve. 2000. Natural Features Survey, Lake Superior Shoreline, Marquette County, Michigan. Contract report prepared for Central Lake Superior Watershed Partnership, Marquette.
Chadde, Steve. 1999. A Forester's Field Guide to the Endangered and Threatened Plants of Michigan's Upper Peninsula. Contract report prepared for Mead Corporation, Champion International Corporation, and Shelter Bay Forests.
Chadde, Steve. 1998. A Great Lakes Wetland Flora - A Complete, Illustrated Guide to the Aquatic and Wetland Plants of the Upper Midwest. PocketFlora Press, Calumet, MI. 584 p.
Chadde, Steve, and others. 1998. Peatlands on National Forests of the Northern Rocky Mountains: Ecology and Conservation. USDA Forest Service, Rocky Mountain Research Station General Technical Report RMRS-GTR-11. Ogden, UT.
Chadde, Steve. 1996. Plants of the Copper Country - An Illustrated Guide to the Vascular Plants of Houghton and Keweenaw Counties, Michigan, and Isle Royale National Park. PocketFlora Press, Calumet, MI. 112 p.
Chadde, Steve. 1996. Plants of Pictured Rocks National Lakeshore – A Complete, Illustrated Guide to the Plant's of America's First National Lakeshore. PocketFlora Press, Calumet, MI. 103 p.
Chadde, Steve. 1995. Ecological Evaluation - Findlayson Property, Chippewa County, Michigan. Contract report prepared for Michigan Chapter, The Nature Conservancy.
Chadde, Steve. 1995. Research Natural Areas of the Northern Region: Status and Needs Assessment. USDA Forest Service, Northern Region, Missoula, MT. 164 p.
Rabe, Fred, and Steve Chadde. 1995. Aquatic Features of Research Natural Areas of the

Kootenai and Flathead National Forests, Montana. USDA Forest Service, Northern Region, Missoula, MT. 66 p. plus appendices.
Rabe, Fred, and Steve Chadde. 1994. Classification of Aquatic and Semiaquatic Wetland Natural Areas in Idaho and Western Montana. Natural Areas Journal 14(3): 175-187.
Statement of Qualifications – Dr. Greg Kudray

Recent Experience

Ecological Inventory and Analysis, Chassell, MI. Established company in June 1999 to conduct ecological consulting work for individuals, corporations, and government agencies. Contracted with the Hiawatha National Forest to do ecosystem mapping, the correlation of ecosystem types to soil types, and the training of Hiawatha personnel in ecosystem inventory and mapping. Contracted with the USGS to do wetland vegetation monitoring in the Seney National Wildlife Refuge. Other experience includes teaching wetland plant workshops, evaluation and mapping of exotic plant infestions, vegetation inventory, bryophyte identification, and aquatic plant monitoring. Six seasonal employees in 1999.

Michigan Technological University, Department of Forestry and Wood Products, Houghton, MI. Employed as a research scientist with primary responsibilities involving ecosystem classification and mapping with related database management and data analysis for the Hiawatha National Forest. Wetland mapping was based on a key and field guide developed during my doctoral research and continually refined through multivariate data analysis. In this position I trained and supervised a seasonal crew of biologists (8 in 1996, 9 in 1995, 3 in 1994) to conduct field mapping integrating vegetation, soil, and hydrological data. I also trained and coordinated four employees from the USDA Natural Resources Conservation Service (former USDA Soil Conservation Service) during the 1995 season and USDA Forest Service personnel throughout the project. Accomplishments include the fine-scale mapping of approximately 300,000 acres in the western half of the Hiawatha National Forest and the development of a database with detailed soil characterizations, hydrological data, and vascular and bryophyte plant information from 4000 plot records. In addition to this work I was an instructor in the 1994 Wetland Ecology course (FW 451), taught a 2 day Clear Lake Conference wetlands plant workshop, and also taught the wetland ecology section during a USFS silvicultural certification workshop offered by our department. (1994 to Nov. 1996)

Michigan Department of Natural Resources, Forest Management Division, Baraga Field Office. Assistant area forester supervising two forest technicians. Primarily responsible for the operations inventory and timber sale programs on the 135,000 acre Baraga area state forest. Conducted and supervised stand exam, type mapping, timber volume estimates, stumpage appraisal, and timber sale contract compliance. Other duties included Commercial Forest Act administration, insect surveys, wildfire suppression, road layout, and forest regeneration activities. Overall performance appraisal rating term for 1989 was "exceptional". Received 1989 DNR District One award for overall excellence. (1984 to 1990)

EDUCATION

Michigan Technological University, Houghton, Michigan. Ph.D. in Wetland Ecology. 1999. Research project involved the development of a ecosystem classification system for the wetlands of the Hiawatha National Forest. Attended University of Michigan Biological Station 1991 summer session with classes in Bryology and Aquatic Plants. Other areas of specialization include soil science, hydrology, forest and landscape ecology, vegetation science, statistics, and remote sensing/GIS applications in land management. Overall GPA of 4.0. (1990 to 1994, Nov. 1996 to June 1999). Published book chapter on the relationship of peatland types and vegetation to water chemistry, other publications in review.

Michigan State University, East Lansing, Michigan. MS specializing in Forest Genetics. 1979. Masters thesis was an evaluation of a spruce hybrid breeding program. Work as a research assistant included controlled pollinations, greenhouse propagation, and plantation establishment. Initiated a computerized record keeping system for a breeding arboretum. Published scientific article based on my research. Overall GPA of 3.6. (1977 to 1979)

Michigan State University, East Lansing, Michigan. BS in Forestry. 1976.
Graduated with high honor including Honors College membership. Also a member of Alpha Zeta, Beta Beta Beta, and Phi Kappa Phi honorary societies. Overall GPA of 3.8. (1972 to 1976)