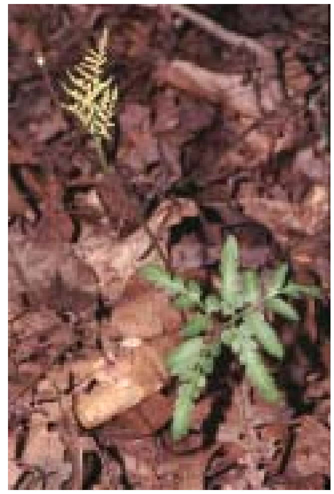
Conservation Assessment
For
Cut-leaf Grapefern (Botrychium dissectum)

Botrychium dissectum var. obliquum (left), var. dissectum (right).Photo © Steve Mortensen.



Botrychium dissectum var. *obliquum*. *Photo © Steve Mortensen.*

USDA Forest Service, Eastern Region
2001

Prepared by
Steve Chadde & Greg Kudray
Requisition no. 43-54A7-0-0036 /
Project no. Ottawa-00-06

This Conservation Assessment was prepared to compile the published and unpublished information on the subject species or community. 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 taxon, please contact the Eastern Region of the Forest Service Threatened and Endangered Species Program at 310 Wisconsin Avenue, Milwaukee, Wisconsin 53203.

Table of Contents

EXECUTIVE SUMMARY

Botrychium dissectum (cut-leaf grapefern) is a small evergreen fern within *Botrychium* subgenus *Sceptridium* (grapeferns) of the Ophioglossaceae (Adder's-Tongue Family). The species occurs across much of eastern North America, extending from Nova Scotia to Minnesota, south to Florida and Texas. It is not uncommon across much of its range. In the Great Lakes region, the species is not listed as endangered, threatened or special concern by the Minnesota, Wisconsin, or Michigan natural heritage programs. Therefore, population and habitat data for specific sites are not available. The species is variable in its appearance, and two varieties are included in this assessment: *B. dissectum* var. *dissectum*, and *B. dissectum* var. *obliquum*. The varietial distinction is based solely on the nature of the leaf blade divisions; in var. *dissectum*, the blade is very finely dissected, in var. *obliquum*, the blade is shallowly divided. However, it is common to find intermediates between the two varieties. Habitat preferences are variable, ranging from grassy openings and roadsides, to dry, mesic, or wet forests. Sites are often somewhat disturbed by human activities. Much of the life-cycle occurs underground, and numbers of aboveground sporophytes fluctuate from year-to-year. Like other species of *Botrychium*, *B. dissectum* is dependent on a mycorrhizal relationship; thus concerns about species conservation should consider this relationship.

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 *B. dissectum* (both var. *dissectum* and var. *obliquum*).
2. Provide a summary of the distribution and status of *B. dissectum*, 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). Subgenus *Sceptridium*, the grapeferns, encompasses plants (including *B. dissectum*) which are medium-sized and decidedly evergreen (Lellinger 1985). Subgenus *Osmundopteris* is only represented in our area by *B. virginianum*, the rattlesnake fern, which is common over much of the world (Wagner 1998). Subgenus *Botrychium*, the moonworts, are 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 1990, Wagner 1998). In North America, thirty species of *Botrychium* are recognized (Wagner and Wagner 1993). Worldwide, it is estimated that 30-50 species exist.

The problems in distinguishing valid moonwort species are considerable (Wagner and Wagner 1990), including the tendency for different species of *Botrychium* to occur together at one site, variation in appearance caused by microhabitat differences, small size, and the difficulty of preserving good herbarium specimens. However, decades of work, primarily by the late Dr. Herb Wagner and his associates, have clarified the taxonomy of the group, their habitat preferences, and the ranges of individual species. Several rare species within subgenus *Botrychium* are now recognized in the Upper Great Lakes region.

NOMENCLATURE AND TAXONOMY

- Scientific Name: *Botrychium dissectum* Spreng.
- *B. dissectum* Spreng. var. *dissectum*
- *B. dissectum* Spreng. var. *obliquum* (Muhl. Ex. Willd.) Clute
- Family: Ophioglossaceae (Adder's-Tongue Family)
- Common Names: Cut-leaf grapefern, dissected grapefern, bronze fern, botryche découpé.
- Synonymy (*Botrychium dissectum* var. *dissectum*): *B. lunarioides* var. *dissectum*; *B. ternatum* var. *dissectum*; *B. obliquum* var. *dissectum*; *B. dissectum* var. *typicum*.
- Synonymy (*Botrychium dissectum* var. *obliquum*): *Botrychium obliquum*; *B. lunarioides* var. *obliquum*; *B. ternatum* var. *obliquum*.

DESCRIPTION OF SPECIES

Botrychium dissectum is an evergreen perennial to 30 cm tall; the common stalk at the plant base is 4-5 cm long. The blade is three-parted, 8-14 cm long and 8-15 cm wide, somewhat leathery and typically turning bronze-colored in fall. The fertile spike is 2-3 times pinnate, on a stalk to 20 cm long; sporangia are globe-shaped, to 1 mm diameter; spores yellowish, and maturing in late September-October. The roots are fleshy (from Lellinger 1985, Cody and Britton 1989, Wagner and Wagner 1993, Mohlenbrock 1999).

B. dissectum var. *dissectum* may be distinguished from var. *obliquum* by the nature of the leaf blade divisions. In var. *dissectum*, the blade is very finely dissected; in var. *obliquum*, the blade is shallowly divided (see illustrations). However, the distinction is not always clear. For example, Mohlenbrock (1999) reported that in northeastern Illinois, specimens are often intermediate between the two varieties. As *B. dissectum* is an extremely variable species (Wagner 1960), some authors do not separate the two varieties.

A key to identify plants within the *Botrychium* subgenus *Sceptridium* (grapeferns, which includes *B. dissectum*, *B. multifidum*, *B. oneidense*, and *B. rugulosum*) is provided in works by Wagner and Wagner (1993, 1982). Lellinger (1985) includes descriptions and color photographs of many grapefern species. Cody and Britton (1989) provide descriptions and distribution maps of *Botrychium* species known to that time in Canada.

Technical description

Trophophore stalk 3–15 cm tall, 1.5–2.5 times length of trophophore rachis; blade shiny green, often bronze in winter, plane to convex, 3–4 times pinnate, to 20 × 30cm long, leathery. Pinnae to 10 pairs, approximate to remote, slightly ascending, distance between first and second pinnae not or slightly more than between second and third pairs, undivided except in proximal 2/3–3/4. Pinnules usually obliquely angular trowel-shaped to widely trowel-shaped to obliquely round-lanceolate to ovate and pointed, margins denticulate to lacerate to coarsely cut halfway or wholly into linear-divergent segments in some populations; venation pinnate. Sporophores 2–3 times pinnate, 1.5–2.5 times length of trophophore. 2n =90 (after Wagner and Wagner 1993).

B. dissectum is a highly variable species, even within the same population. Less divided plants are sometimes confused with *B. oneidense*. In Florida and along the Gulf Coast, the extremely lacerate form of *B. dissectum* is absent, and the blade segments are usually strongly angular, trowel-shaped, and dentate. In eastern Kentucky and central Tennessee, plants have narrowly linear, somewhat blunt-tipped segments with a whitish central line above the veins. This variant may deserve recognition as a distinct species (Wagner and Wagner 1993). The fronds of *B. dissectum* turn a distinctive bronze or reddish color in the fall.

LIFE HISTORY

B. dissectum belongs to subgenus *Sceptridium* (grapeferns) within the genus *Botrychium*. In North America there are also subgenera *Osmundopteris* (represented by a single species in North America, *B. virginianum* or rattlesnake fern) and *Botrychium* (moonworts) (Lellinger 1985, Wagner and Wagner 1993). The life-cycle of all three subgenera is similar (Lesica and Ahlenslager 1996). The 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. Leaves of *B. dissectum* often turn a bronze color in autumn.

Like all ferns, grapeferns 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 *Botrychium* 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 *Botrychium*. 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 spore cases of *Botrychium* are among the largest of all known ferns and appear like clusters of tiny grapes (creating 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* species 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 potentially travel much less, perhaps only a few centimeters (Casson et al. 1998). Peck et al. (1990) found that *B. virginianum* spores landed within 3 m 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 plant, 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 (Wagner 1998) that could help the spores to pass through an animal's gut, have suggested to some that herbivores, such as small mammals, may be involved in dispersal (Wagner et al. 1985, Wagner and Wagner 1993). The sporangia may also simply rot in the ground, thereby dispersing their spores, but it is uncertain how long *Botrychium* spores remain viable (Lesica and Ahlenslager 1996).

Spore germination and gametophyte growth in *B. dissectum* were studied by Whittier (1972, 1973). After the spores are released, it is necessary for them to be covered by soil before germination can occur (Whittier 1972, 1973; Wagner et al. 1985). Infiltration into the soil and subsequent germination may take up to 5 years (Casson et al. 1998). That spore germination requires darkness is not surprising in view of the subterranean habitat of the gametophyte (or prothallus) 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, Whittier 1996). Essentially the *Botrychium* gametophyte becomes a parasite of the mycorrhizal fungus (Casson et al. 1998, Whittier 2000).

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, probably 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 the 37 other species of ferns (Berch and Kendrick 1982).

When the sporophyte eventually emerges, a sterile leafy blade (trophophore) and a fertile segment (sporophore) develop. *Botrychium* plants may go dormant some years and not produce an aerial sporophyte (Wagner and Wagner 1981, Muller 1993). In the case of *B. mormo*, plants do not produce aboveground sporophytes more than two consecutive years (Johnson-Groh 1998) and there may be gaps as long as 6 years, although 1–3 years is more typical (Johnson-Groh 1998, Tans and Watermolen 1997). *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. Montgomery (1990) reported that the leaves of many *B. dissectum* plants were eaten in the spring and fall. In discussing *B. mormo*, Casson et al. (1998) estimated that about 5–10% of aboveground plants will develop into larger plants with 20 to 50 sporangia (spore-bearing tissues) each.

B. dissectum plants emerge from the ground in late spring (Wagner and Wagner 1993). In general, *Botrychium* spp. may depend little on photosynthesis for their survival, and mycorrhizae alone may supply a significant amount of the plant's nutrients and energy (Johnson-Groh 1999, Casson et al. 2000).

Available information indicates that members of subgenus *Sceptridium* (grapeferns) are long-lived, relative to the shorter-lived subgenus *Botrychium* (moonworts) (Montgomery 1990, Muller 1993, Kelly 1994, Lesica and Ahlenslager 1996). Estimated half-life times for various grapeferns were 43.2 years (Montgomery 1990) and 11.2 years (Kelly 1994), while moonwort half-lives were 1.3 years (Muller 1993) and 3 years or less (Lesica and Ahlenslager 1996).

Numerous hybrids between different species of *Botrychium* have been found (Wagner et al. 1985, Wagner 1991, Wagner 1993). Hybrids possess abortive spores and are intermediate in characteristics between the presumed parents (Wagner 1993). All taxa have chromosome numbers based on 45 (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 (1996) have applied enzyme electrophoresis to the genetic relationships of eastern moonworts and have also suggested some relationships for moonwort species and hybrids.

HABITAT

Botrychium dissectum occurs in habitats ranging from open grasslands to deep shaded woods (Wagner and Wagner 1993). Lellinger (1985) described the habitat as "moist to rather dry woods, swamps, and pastures or old fields, commonly under somewhat disturbed conditions." In Canada, habitats are described as sterile hilltops, dry pastures, dry woodlands, and grassy banks (Cody and Britton 1989).

In Michigan, *B. dissectum* is reported from low woods, swamp margins, thickets, and old pastures, especially where soils are sandy (Billington 1952). On the Ottawa National Forest in Michigan, the species is reported from rich mesic hardwood forests dominated by sugar maple, yellow birch, and basswood, and in soil along shaded roadsides (Ottawa NF *Botrychium* survey form 2000).

In northern Wisconsin, *B. dissectum* is found in a wide variety of habitats including old fields and barrens, and rich sugar maple forests. (Chequamegon-Nicolet NF *Botrychium* survey form 2000).

In Minnesota, two specimens from the Chippewa National Forest have been deposited in the Univ. of Minnesota Bell Herbarium (www.wildflowers.umn.edu). Habitats associated with each specimen are listed as mesic hardwood forests of sugar maple and basswood. Associated herbaceous species include *Athyrium filix-femina*, *Dryopteris carthusiana*, *Scutellaria lateriflora*, *Uvularia grandiflora*, and *Streptopus roseus.*

In Missouri, both var. *dissectum* and var. *obliquum* are reported from rich, wooded ravines, low wet woods, and open oak-hickory woods (Key 1982).

Montgomery (1990) reported large *B. dissectum* populations in old fields and second-growth woodlands of black oak (*Quercus velutina*), red maple (*Acer rubrum*), and American ash (*Fraxinus americana*) from his study area in Pennsylvania.

DISTRIBUTION, ABUNDANCE, AND STATUS

Botrychium dissectum is a fairly common grapefern across much of its range, and the species was described by Lellinger (1985) as "abundant." It is not listed as endangered, threatened, or special concern by natural heritage programs in Michigan, Minnesota, or Wisconsin, so only limited population and habitat data are available.

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

The species occurs across eastern North America, extending from Nova Scotia to Wisconsin and eastern Minnesota, south to Florida, Jamaica, and Texas. *Botrychium dissectum* var. *dissectum* ranges from Nova Scotia to Ontario and Minnesota, south to Missouri and Florida (Mohlenbrock 1999). *Botrychium dissectum* var. *obliquum* ranges from Nova Scotia to Ontario and Michigan, south to Oklahoma and Georgia; Jamaica (Mohlenbrock 1999).

In Illinois, Mohlenbrock (1999) reported *B. dissectum* var. *obliquum* to be somewhat more common than var. *dissectum*, and noted that the two varieties were often growing together.

Global and state rankings were obtained from NatureServe (www.natureserve.org), a comprehensive online database of information on plants, plant communities, and animals. Conservation status ranks are defined in Appendix A.

Global Conservation Status Rank: G5
United States: National Conservation Status Rank: N5
Canada: National Conservation Status Rank: N?

Distribution and Conservation Status in the United States

Alabama (SR), Arizona (SH), Arkansas (S4), Connecticut (SR), Delaware (SR), District of Columbia (S?), Florida (S?), Georgia (SR), Illinois (S3S4), Indiana (SR), Iowa (S3), Kansas (S?), Kentucky (S?), Louisiana (SR), Maine (SR), Maryland (SR), Massachusetts (SR), Michigan (S?), Minnesota (SU), Mississippi (SR), Missouri (S4), Nebraska (S?), New Hampshire (SR), New Jersey (SR), New York (SR), North Carolina (S5), Ohio (SR), Oklahoma (SR), Pennsylvania (S?), Rhode Island (S2), South Carolina (SR), Tennessee (SR), Texas (SU), Vermont (SR), Virginia (SR), West Virginia (S?), Wisconsin (SR)

Distribution and Conservation Status in Canada
New Brunswick (S3), Nova Scotia (S3), Ontario (S5), Prince Edward Island (S1), Quebec (SR)

EO SUMMARY

GREAT LAKES STATES – NUMBER OF ELEMENT OCCURRENCES

State	No. of EOs	State Rank	Status	Comments
Minnesota	na	SU	none	Not tracked in state
Wisconsin	na	SR	none	Not tracked in state
Michigan	na	S?	none	Not tracked in state
Total	na			

POPULATION BIOLOGY AND VIABILITY

Apart from the spore germination and gametophyte studies of Whittier (1972, 1973), little information is available about the population biology of *B. dissectum.* Population studies on species of moonworts (*Botrychium* subgenus *Botrychium*) have shown that there can be considerable annual variation in the number of aboveground plants at a given site (Johnson-Groh 1999). Populations fluctuated independently among plots at any given site, and some populations increased while others decreased (Johnson-Groh 1999). These variations reflect microsite differences such as soil moisture, herbivory, or mycorrhizae (Johnson-Groh 1999), although populations of moonworts, including *B. dissectum*, are known to fluctuate wildly without any apparent cause (Montgomery 1990, Johnson-Groh 1999). Individual plants may not emerge every year (Muller 1993, Johnson-Groh 1998).

Botrychium probably appear or disappear, to a large extent, in accordance with mycorrhizal health (Johnson-Groh 1998) due to their obligate relationship with the fungi. Johnson-Groh (1999) concluded that mycorrhizae are the most limiting factor for *Botrychium* establishment, distribution and abundance. Environmental factors that may affect mycorrhizae, such as reductions in water availability, likely have significant impacts on species of *Botrychium*, whereas the repeated removal of leaf tissue may have little effect (Johnson-Groh 1999). Wagner and Wagner (1993) also concluded that taking many samples will have little effect on a population as long as the underground shoots and roots are left intact. 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 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. She recovered up to 7000 gametophytes and 250 non-emergent sporophytes per square meter of soil, although an unknown number of these may be the common *B. virginianum* (Johnson-Groh 1998). In another report, Johnson-Groh et al. (2000) found gametophyte populations ranging up to 2000 gametophytes per square meter for some moonwort species. Bierhorst (1958) reported finding 20 to 50 gametophytes of *B. lanceolatum* beneath each surface square foot with a predominance of younger gametophytes versus older ones with attached sporophytes. These findings suggest that a single emergent sporophyte may indicate a self-sustaining population at a particular 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 likely play an important role in *Botrychium* 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 (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. dissectum* may respond similarly.

Many species of *Botrychium*, including *B. dissectum*, are associated with light to moderate disturbances (Lellinger 1985, Wagner and Wagner 1993). Given that spores need darkness to germinate (Whittier 1973), activities that disturb the soil surface and result in burial of spores may be beneficial to establishment.

POTENTIAL THREATS AND MONITORING

Threats to *B. dissectum* include exotic earthworms, invasion of sites by garlic mustard (*Alliaria petiolaria*) and possibly other exotic plant species, herbivory, timber harvesting, road building, and land use changes that affect drainage (USDA Forest Service 2000).

Some of these 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 (1993) 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) concluded that if the aboveground plant was removed after spore release, the trophophore the following year was significantly smaller. 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 had little effect on subsequent leaf-size or plant vigor (Johnson-Groh and Farrar 1996a, b). Collection by herbalists due to the plant's perceived medicinal powers may also pose a threat (USDA Forest Service, Eastern Region 1999).

Montgomery (1990) monitored several *B. dissectum* populations in Pennsylvania over a ten-year period. He reported high levels of herbivory to aboveground plants and found that plants eaten in autumn for three or more consecutive years were able to produce new leaves the following spring. He concluded that the plant's fleshy rhizome stored food and that the mychorrhizae contributed to the plant's nutrient needs.

In a French study (Muller 1992), drought-like conditions wilted *Botrychium* sporophytes before sporulation occurred. The work of Johnson-Groh (1999) also emphasized the importance of water relations to moonworts and their supporting mycorrhizae. Mycorrhizae are likely the most limiting factor for *Botrychium* establishment, distribution, and abundance (Johnson-Groh 1999); therefore anything negatively affecting mycorrhizae may 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). 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). The potential of the threat to *B. dissectum* and its habitat is uncertain, but since the species sometimes occurs in these habitats, there may be significant adverse impacts, similar to those reported for *B. mormo* (Sather et al. 1998).

Threat from exotic earthworms

Native earthworms were eliminated from the Lake States during the last ice age. Natural recolonization from the unglaciated south has been extremely slow, for example, less than 100 miles in the several thousand years since the glacial retreat (James 1990, Berlinger 2000, Conover 2000). European earthworms were introduced into North America with European settlement and then spread through the use of earthworms for fishing bait, gardening, and inadvertent human transport (Kalisz and Wood 1995, Berlinger 2000). Logging machinery and other forest vehicles can transport cocoons and hatchlings, thereby dispersing earthworms widely into forests (Marinissen and van den Bosch 1992, Dymond et al. 1997). More remote forests in our region still lack earthworms, but as humans move through the landscape the probability of colonization increases (Casson et al. 2000).

Worms have been considered to have a very positive influence on soil structure, litter decomposition, and mineralization and cycling of nutrients (review in Lee 1985), but since regional ecosystems have evolved in the absence of earthworms (James 1990), their recent introduction is having serious consequences.

One of the earliest studies of non-native earthworms in forested habitats documented a disappearance of the organic surface O horizon, an increase in the depth and character of the A layer, and a decrease in the B horizon (Langmaid 1964). Another study stated that worms "eliminated the forest floor" (Groffman et al. 2000). Alban and Berry (1994) provided the first detailed documentation of earthworm effects in Minnesota forest soils where earthworms dramatically reduced the litter and duff layers, eliminated the E-layer, and increased the A horizon. Worms also can make the soil more permeable to water (Peterson and Dixon 1971), potentially altering water relations, especially near the soil surface.

Leaf litter can be completely broken down in as little as 4 weeks by worms (Knollenberg et al. 1985), whereas in a natural forest system it has been estimated that it might take 3–5 years for decomposition (Mortensen and Mortensen 1998). Earthworms introduced to mine spoil banks have had dramatic effects on the litter layer, burying or consuming 5 metric tons of leaf litter/ha within 2 years (Vimmerstedd and Finney 1973).

The evidence suggests that the several species of exotic earthworms now colonizing the Lake States region will have considerable impact on native plants including *Botrychium*. Within this genus, the most studied species has been *B. mormo*. A comparison of 6 plots with earthworms compared to 6 plots without worms (a relatively small sample size) on the Chippewa National Forest found that 70% of the plant species were adversely affected by worms, and 25 species (50% of all the species present in the undisturbed plots and including *B. mormo*) were apparently eliminated by the worms (Almendinger 1998). Others have also reported decreased diversity in the herbaceous layer (Nielsen and Hole 1963, 1964; Nixon 1995, Cothrel et al. 1997). It has been suggested that European earthworms may be incompatible with the survival of many North American hardwood undergrowth species (Hale et al. 1999), although some species have been noticed to increase in numbers after worm invasion (Almendinger 1998, Berlinger 2000).

In an ongoing *B. mormo* monitoring effort on the Chippewa National Forest (Johnson-Groh 1999), plots impacted by worms exhibited significant negative effects on *B. mormo* populations. However, she cautioned that, while the worms likely had fatally affected the plants, other, 'worm-free' populations also showed decreases during that dry period. She also observed that it is normal for moonwort populations to fluctuate widely and that population declines may be due to a population exceeding the carrying capacity of a site. Another monitoring study in the same area also observed negative effects on soil properties and a dramatic reduction in the *B. mormo* population following exotic earthworm invasion (Casson et al. 2000).

The loss of the soil organic layer may affect *Botrychium* through their obligate association with mycorrhizal fungi. The fungi may perish with the loss of the forest floor (Nixon 1995) or may also be eaten by sowbugs, which, in at least one instance seem to be invading sites with exotic earthworms (Wolff et al. 1997).

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. Also critical are moisture relations, as activities that dry the habitat may have deleterious effects on the population.

RESEARCH AND MONITORING REQUIREMENTS

Berlin et al. (1998) make a number of specific research and monitoring recommendations for *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* species at www.natureserve.org (NatureServe 2001).

B. dissectum monitoring over a period of ten years was conducted by Montgomery (1990) in Pennsylvania. He determined survivorship and predation patterns by marking and measuring individual plants.

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

Perhaps the easiest and most effective way of monitoring habitat would be through the use of 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.

LITERATURE CITED AND REFERENCES

Alban, D. H. and E. C. Berry. 1994. Effects of earthworm invasion on morphology, carbon, and nitrogen of a forest soil. Applied Soil Ecology 1:243-249.

Almendinger, J. 1998. Unpublished. Frequency of vascular plants with regard to significant earthworm activity. Minnesota Department of Natural Resources. Grand Rapids, Minnesota.

Berch, S. M. and B. Kendrick. 1982. Vesicular-arbuscular mycorrhizae of southern Ontario ferns and fern-allies. Mycologia 74: 769-776.

Berlin, N., P. Miller, J. Borovansky, U. S. Seal, and O. Byers (eds.). 1998. Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.

Berlinger, N. 2000. A bad case of worms. Minneapolis-St. Paul Star Tribune. 21 August 2000. page A-l.

Bierhorst, D. W. 1958. Observations on the gametophytes of *Botrychium virginianum* and *B. dissectum*. Amer. J. of Bot. 45: 1-9.

Billington, C. 1952. Ferns of Michigan.Cranbrook Institute of Science, Bull. No. 32. Bloomfield Hills, MI.

Bower, F. O. 1926. The ferns (Filicales), volume 2. Cambridge University Press. 344 pp.

Briggs, D. and S. M. Walters. 1997. Plant variation and evolution. Cambridge University Press. New York.

Brzeskiewicz, M. 1999. Conservation Assessment for *Botrychium rugulosum* (St. Lawrence grapefern). USDA Forest Service, Region 9.

Camacho, F. J. 1996. Mycorrhizal fungi of *Botrychium* genus communities in Montana. Unpublished proposal to the Montana Natural Heritage Program. Oregon State University, Corvallis, OR. 6 pp.

Campbell, D. H. 1911. The eusporangiate. Carnegie Inst. Wash. Publ. No. 140.

Campbell, D. H. 1922. The gametophyte and embryo of *Botrychium simplex*, Hitchcock. Annals of Botany 36:441-456.

Casson, J., J. Dobberpuhl, D. Farrar, A. Hoefferle, C. Johnson-Groh, H. Peters, H. Wagner, F. Wagner, C. Westfield, and P. Miller. 1998. Population life history and viability working group report. In: Berlin, N., P. Miller, J. Borovansky, U. S. Seal, and O. Byers (eds.). Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.

Casson, J., I. Shackleford, L. Parker, and J. Schultz. 2000. Conservation Strategy for the Goblin fern, *Botrychium mormo* W. H. Wagner. USDA Forest Service–Eastern Region 27 October, 2000 draft.

Clausen, R. T. 1938. A monograph of the Ophioglossaceae. Memoirs of the Torrey Botanical Club 19(2): 1-177.

Clausen, R.T. 1946. Nomenclatural and distributional notes on *Botrychium lanceolatum*. American Fern Journal. pp. 44-47.

Cody, W. J., and D. M. Britton. 1989. Ferns and Fern Allies of Canada. Research Branch Agriculture Canada Public. 1829/E.

Conover, A. 2000. Foreign worm alert. Smithsonian, August 2000. Smithsonian Institution.

Cothrel, S. R., J. P. Vimmerstedt, and D. A. Kost. 1997. *In situ* recycling of urban deciduous litter. Soil Biol. Biochem. 29: 3/4: 295-298.

Dix, W.L. 1945. Observed characteristics of *Botrychium multifidum* var. *oneidense*. American Fern Journal 35: 37-39.

Dymond, P., S. Scheu, and D. Parkinson. 1997. Density and distribution of *Dendrobaena octaodra* (Lumbricidae) in aspen and pine forests in the Canadian Rocky Mountains (Alberta). Soil Biol. Biochem. 29:3/4: 265-273.

Farrar, D. R. 1998. Population genetics of moonwort populations. In: Berlin, N., P. Miller, J. Borovansky, U. S. Seal, and O. Byers (eds.). Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.

Farrar, D. R. and C. L. Johnson-Groh. 1990. Subterranean sporophytic gemmae in moonwort ferns, *Botrychium* subgenus *Botrychium*. American Journal of Botany 77: 1168-1175.

Farrar, D. R. and J. F. Wendel. 1996. On the origins and relationships of the *Botrychium matricariifolium* complex in eastern North America. (Abstract). Am. J. Botany 83(Suppl.): 125.

Foster, A. S., and E. M. Gifford. 1974. Comparative morphology of vascular plants. W. H. Freeman, San Francisco.

Gifford, E. M. and A. S. Foster. 1989. Morphology and evolution of vascular plants, third edition. W. H. Freeman and Co., New York, NY. 626 pp.

Groffman, P. M., P. J. Bohlen, T. J. Fahey, and M. C. Fisk. 2000. Invasion of north temperate forest soils by exotic earthworms. Research Report. Institute of Ecosystem Studies. www.ecostudies.org/research/reportstgrofrep2.html

Hale, C., L. Frelich, and P. Reich. 1999. Unpublished. Research proposal concerning earthworms and population dynamics and diversity of native plant species. University of Minnesota. St. Paul, Minnesota.

Hoefferle, A.M. 1999. Impacts of aerial leaf removal on leaf size of the daisy leaf moonwort (*Botrychium matricariifolium*) and the triangle moonwort (*Botrychium lanceolatum* var. *angustisegmentum*) in the subsequent year (master’s thesis). Houghton, (MI): Michigan Technological University. 42 pp.

James, S. W. 1990. Oligochaeta: Megascolecidae and other earthworms from southern and Midwestern North America. p. 370-386. In: Dinal, D. L. (ed.) *Soil Biology Guide*. John Wiley and Sons, New York.

Johnson-Groh, C. 1998. Population demographics, underground ecology and phenology of *Botrychium mormo.* In: Berlin, N., P. Miller, J. Borovansky, U. S. Seal, and O. Byers (eds.). Population and Habitat Viability Assessment Workshop for the Goblin Fern (*Botrychium mormo*): Final Report. CBSG, Apple Valley, MN.

Johnson-Groh, C. 1999. Population ecology of *Botrychium* (moonworts), status report on Minnesota *Botrychium* permanent plot monitoring. Dept. of Biology, Gustavus Adolphus College, St. Peter, MN.

Johnson-Groh, C. L., D. R. Farrar. 1996a. Effects of leaf loss on moonwort ferns, *Botrychium* subgenus *Botrychium*. Am. J. Botany 83(Supple.): 127.

Johnson-Groh, C. L., D. R. Farrar. 1996b. The effects of fire on prairie moonworts (*Botrychium* subgenus *Botrychium).* Am. J. Botany 83(Supple.): 134.

Johnson-Groh, C. L., D. R. Farrar, P. Miller. 1998. [Abstract] Modeling extinction probabilities for moonwort (*Botrychium*) populations. Amer. J. Bot. Supplement 85: 95.

Kalisz, S., and M. A. McPeek. 1992. Demography of an age-structured annual: resampled projection matrices, elasticity analysis, and seed bank effects. Ecology 73: 1082–1093.

Kalisz, P. J. and H. B. Wood. 1995. Native and exotic earthworms in wildland ecosystems. In: Hendrix, P. F. 1995. Earthworm ecology and biogeography. Lewis Publishers. Boca Raton, Florida.

Kartesz, J. T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. In: Kartesz, J.T., and C.A. Meacham. Synthesis of the North American Flora, Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Kelly, D. 1994. Demography and conservation of *Botrychium australe*, a peculiar sparse mycorrhizal fern. N.Z. J. Bot. 32: 393-400.

Key, J.S. 1982. Field Guide to Missouri Ferns. Missouri Dept. of Conservation. Jefferson City, MO.

Knollenberg, W. G., R. W. Merrift, and D. L. Lawson. 1985. Consumption of leaf litter by *Lumbricus terrestris* (Oligochaeta) on a Michigan Woodland Floodplain. American Midland Naturalist 113: 1-6.

Langmaid, K. K. 1964. Some effects of earthworm invasion in virgin podzols. Canadian Journal of Soil Science 44: 34-37.

Leake, J. R. 1994. The biology of myco-heterotrophic plants. New Phytologist 127: 171-216.

Lee, K. E. 1985. Earthworms, Their Ecology and Relationship with Soils and Land Use. Academic Press.

Lellinger, D.B. 1985. A Field Manual of the Ferns and Fern-allies of the United States and Canada. Smithsonian Institution Press, Washington D.C.

Lesica, P., and K. Ahlenslager. 1996. Demography and life history of three sympatric species of *Botrychium* subg. *Botrychium* in Waterton Lakes National Park, Alberta. Can J. Bot. 74: 538-543.

Marinissen, J. C. Y., and F. van den Bosch. 1992 Colonization of new habitats by earthworms. Oecologia 91: 371-376.

McCauley D. E., Whittier D. P., Reilly L. M. 1985. Inbreeding and the rate of self-fertilization in a grapefern, *Botrychium dissectum*. Amer. J. Bot. 72: 1978-1981.

Mohlenbrock, R.H. 1999. The Illustrated Flora of Illinois: Ferns (second ed.). Southern Illinois Univ. Press, Carbondale, IL.

Montgomery, J. D. 1990. Survivorship and predation changes in five populations of *Botrychium dissectum* in eastern Pennsylvania. Am. Fern J. 80: 173-182.

Mortensen, S. and C. Mortensen. 1998. A new angle on earthworms. The Minnesota Volunteer, Jul-Aug., 1998. Minn. Dept. Nat. Res., St. Paul, MN.

Muller S. 1992. The impact of drought in spring on the sporulation of *Botrychium matricariifolium* (Retz) A. Br. in the Bitcherland (Northern Vosges, France). Acta. Oecol. 13:335-43.

Muller, S. 1993. Population dynamics in *Botrychium matricariifolium* in Bitcherland (Northern Vosges Mountains, France). Belg. J. Bot. 126: 13-19.

NatureServe: An online encyclopedia of life [web application]. 2001. Version 1.0. Arlington (VA): Association for Biodiversity Information. Available: http://www.natureserve.org/. (Accessed: January 21, 2001).

Nielsen, G. A. and F. D. Hole. 1963. A study of the natural processes of incorporation of organic matter into soil in the University of Wisconsin Arboretum. Wisconsin Academy of Sciences, Arts and Letters 52: 213-227.

Nielsen, G.A. and F. D. Hole. 1964. Earthworms and the development of coprogeneous A1 horizons on forest soils of Wisconsin. Soil Science Society of America Proceedings 28: 426-430.

Nixon, W. 1995. As the worm turns. American Forests. Autumn 1995: 34-36.

Ostlie W. 1990. Element Stewardship Abstract for American Ternate Grapefern. Minneapolis MN: The Nature Conservancy.

Parsons, R. F., and J. H. Browne. 1982. Causes of plant species rarity in semi-arid southern Australia. Biol. Conserv. 24: 183-192.

Peck, J. H., C. J. Peck, and D. F. Farrar. 1990. Influence of life history attributes on formation of local and distant fern populations. Am. Fern J. 80: 126-142.

Peterson, A. E., and R.M. Dixon. 1971. Water movement in large soil pores: validity and utility of the channel concept, College of Agr. and Life Sci., Univ. of Wisconsin Res. Rep. 75.

Read, D. J. 1994. Plant-microbe mutualisms and community structure. In: Schulze, E.D. and H.A. Mooney (eds.) Biodiversity and ecosystem function, Springer-Verlag, New York.

Sather, N., C. Kjos, C. Mortensen, J. Gallagher, S. Mortensen, C. Leibl, B. Wolff, S. Trull, and O. Byers. Threats and Risk Working Group Report. 1998. In: Berlin, N., P. Miller, J. Borovansky, U. S. Seal, and O. Byers (eds.). Population and Habitat Viability Assessment

Workshop for the Goblin Fern *(Botrychium mormo):* Final Report. CBSG, Apple Valley, MN.

Scagel, R. F., R. J. Bandoni, G. L. Rouse, W. B. Schofield, J. R. Stein, and T. M. Taylor. 1966. An evolutionary survey of the plant kingdom. Wadsworth Publishing Co., Belmont, CA. 658 pp.

Schmid, E., and F. Oberwinkler. 1994. Light and electron microscopy of the host-fungus interaction in the achlorophyllous gametophyte of *Botrychium lunaria.* Can. J. Bot. 72: 182-188.

Soltis, D. E., and P. S. Soltis. 1986. Electrophoretic evidence for inbreeding in the fern *Botrychium virginianum* (Ophioglossaceae). Amer. J. Bot. 73: 588-592.

Tans, W. E. and D. X. Watermolen. 1997. Distribution, current population status, growth and habitat of goblin fern *(Botrychium mormo)* in Wisconsin. Wisconsin Endangered Resources Report #115. Bureau of Endangered Resources, Wisconsin Department of Natural Resources. Madison, Wisconsin.

Taylor, C. W. 1984. Arkansas Ferns and Fern Allies. Milwaukee Public Museum, WI.

USDA Forest Service, Eastern Region. 1999. Draft Species Data Collection Forms prepared under contract for population viability analyses on the Wisconsin and Minnesota National Forests. Unpublished reports, Eastern Region, Milwaukee, WI.

USDA Forest Service. 2000. Population Viability Assessment Database. USDA Forest Service, Eastern Region, Milwaukee, WI.

Vimmerstedt, J. P. and J. H. Finney. 1973. Impact of earthworm introduction on litter burial and nutrient distribution in Ohio strip-mine spoil banks. Soil Sci. Soc. Am. Proc., 37: 388-391.

Wagner, W. H. 1960. Periodicity and pigmentation in *Botrychium* subg. *Sceptridium* in the northeastern United States. Bull. Torrey Club 87 (5): 303-325.

Wagner, H. 1991. New examples of the moonwort hybrid, *Botrychium matricariifolium* x *simplex* (Ophioglossaceae). Can. Field Nat. 105(1): 91-94.

Wagner F. S. 1993. Chromosomes of North America grapeferns and moonworts (Ophioglossaceae*: Botrychium*). Contr. Univ. Michigan Herb. 19: 83-92.

Wagner, W. H. 1998. A Background for the Study of Moonworts. In: Berlin, N., P. Miller, J. Borovansky, U.S. Seal, and O. Byers (eds.). Population and Habitat Viability Assessment Workshop for the Goblin Fern *(Botrychium mormo):* Final Report. CBSG, Apple Valley, MN.

Wagner, W. H., and A. R. Smith. 1993. In: Flora of North America North of Mexico, Volume 1. Flora of North America Editorial Committee (ed.). Oxford University Press. New York.

Wagner, W. H., and F. S. Wagner. 1981. New species of moonworts, *Botrychium* subg. *Botrychium* (Ophioglossaceae), from North America. American Fern Journal 71(l): 26.

Wagner, W. H., and F. S. Wagner. 1982. *Botrychium rugulosum* (Ophioglossaceae), a newly recognized species of evergreen grapefern in the Great Lakes area of North America. Contr. Univ. Mich. Herb. 15: 315-324.

Wagner, W. H., and F. S. Wagner. 1983. Genus communities as a systematic tool in the study of new world *Botrychium* (Ophioglossaceae). Taxon 32(1): 51-63.

Wagner, W. H., and F. S. Wagner. 1988. Detecting *Botrychium* hybrids in the Lake Superior region. Mich. Botanist 27: 75-80.

Wagner, W. H. and F. S. Wagner. 1993. Ophioglossaceae. In: Flora of North America, Vol. 2, Flora of North America Editorial Committee (ed.). Oxford University Press, NY.

Wagner, W. H., and F. S. Wagner. 1994. Another widely disjunct, rare and local North American moonwort (Ophioglossaceae: *Botrychium* subg. *Botrychium*). American Fern Journal 84(1): 5-10.

Wagner, W. H., F. S. Wagner, and J. M. Beitel. 1985. Evidence for interspecific hybridization in pteridophytes with subterranean mycoparasitic gametophytes. Proc. Royal Soc. of Edin. 86B: 273-281.

Walton, G. B. 1999. Draft literature review: *Botrychium rugulosum*. USDA Forest Service Region 9.

Whittier, D. P. 1972. Gametophytes of *Botrychium dissectum* as grown in sterile culture. Botanical Gazette 133: 336-339.

Whittier, D. P. 1973. The effects of light and other factors on spore germination in *Botrychium dissectum*. Canadian Journal of Botany 51: 1791-1794.

Whittier, D. P. 1996. [Abstract] Delayed gametophyte growth in *Botrychium*. Am. Journal Botany 83(Supple.): 133.

Whittier, D. P. 2000. [Abstract] Gametophyte and young sporophyte development in the Ophioglossaceae. Am. Journal Botany (Supple.):

Wolff, R. J., C. M. Leibl, S. Mortensen, and A. S. Elwell. 1997. The sowbugs (terrestrial *Isopoda*) in earthworm impacted forest communities. Unpublished preliminary report.

Zika, P. F. 1992. Draft management guide for rare *Botrychium* species (moonworts and grapeferns) for the Mount Hood National Forest. Unpublished report. Oregon Natural Heritage Program, Portland, OR. 43 pp. plus appendices.

Zika, P. F. 1994. A draft management plan for the moonworts *Botrychium ascendens, B. crenulatum, B. paradoxum,* and *B. pedunculosum* in the Wallowa-Whitman, Umatilla, and Ochoco National Forests. Unpublished report. Oregon Natural Heritage Program, Portland, OR. 41 pages plus figures, tables, and appendices.

Natural Heritage Program Databases consulted and queried

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* 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.

	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 var. angustisegmentum	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/N2 N3
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

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).

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

Taxon	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	wide	broad	increasing	good	low
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

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	high	medium	medium	low	medium	medium
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 B. 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 C. 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.

Contact Information

Steve W. Chadde
PocketFlora Press
700 Calumet Street, Suite 304
Lake Linden, MI 49945
Tel: (906) 296-0506
Fax: (810) 314-4295
Internet: www.pocketflora.com
E-mail: steve@pocketflora.com

Dr. Greg Kudray
EIA – Ecological Inventory and Analysis
RR1, Box 492
Chassell, MI 49916
Tel: (906) 523-4817
Internet: www.ecologyusa.com
E-mail: greg@ecologyusa.com
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.
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

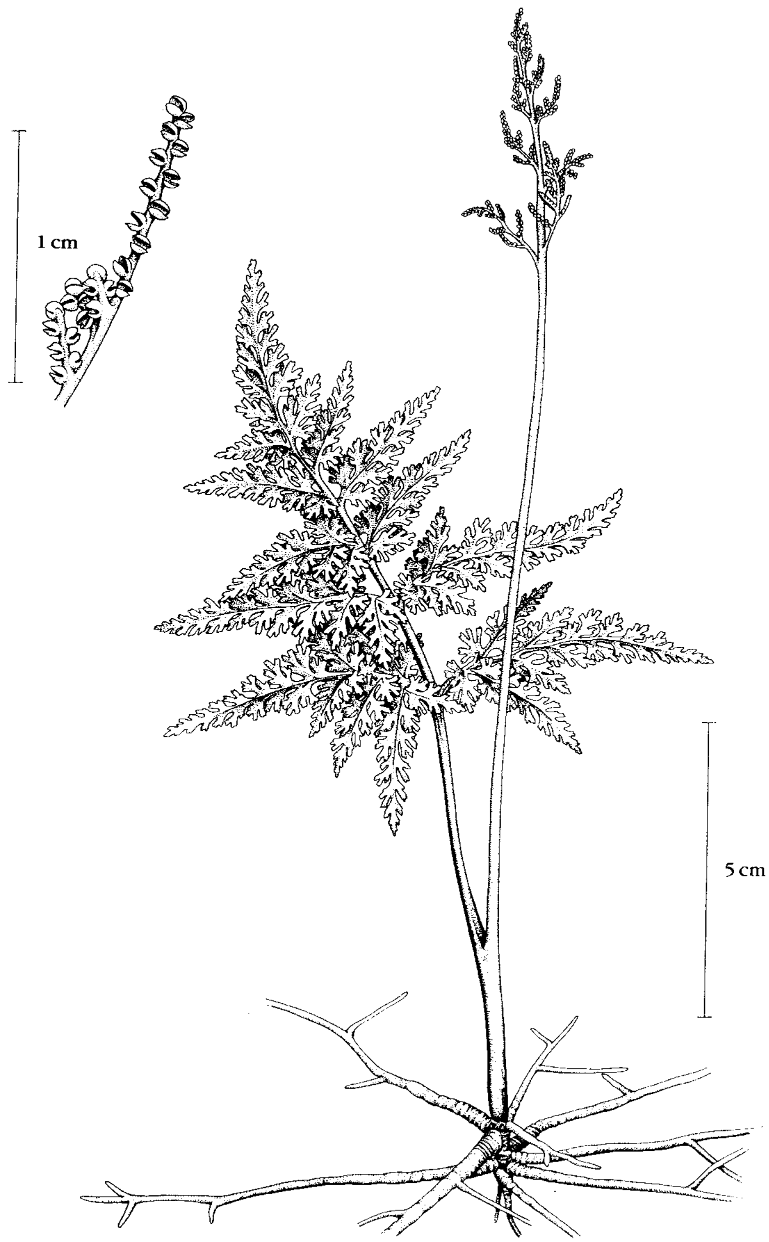
Michigan Technological University, Houghton, Michigan. Ph.D. in Wetland Ecology. 1999. Research project involved the development of a ecosystem classification system for the wetlands of the Hiawatha National Forest. Attended University of Michigan Biological

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)

Botrychium dissectum var. *dissectum.*
Drawing from Arkansas Ferns and Fern Allies (Taylor 1984).



Botrychium dissectum var. *obliquum*.
Drawing from Arkansas Ferns and Fern Allies (Taylor 1984).