CONSERVATION ASSESSMENT OF SENSITIVE MOONWORTS (OPHIOGLOSSACEAE; *BOTRYCHIUM* SUBGENUS *BOTRYCHIUM*) ON THE KOOTENAI NATIONAL FOREST

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SUMMARY

Over one hundred occurrences of six sensitive or proposed sensitive *Botrychium* species are documented on the Kootenai National Forest. These include most of the largest known populations of *B. minganense* and *B. montanum* in the state and a few large populations of *B. crenulatum*. There are also a few small occurrences of three extremely rare species, *B. ascendens, B. paradoxum*, and *B. pedunculosum*. The sensitive *Botrychium* species occupy a variety of moist habitats distributed across the glaciated landscapes of Forest; mostly western red cedar and western hemlock habitat types in the western part and mostly deciduous wetland habitat types in the eastern part. Primary potential threats to populations include direct impacts of logging and road building to upland occurrences and indirect and cumulative effects of these activities to lowland occurrences. USFS Region 1 sensitive status is proposed for *B. pedunculosum* which was found for the first time in the Region on the Forest in 1996, and current sensitive status is recommended retained for the other five species.

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INTRODUCTION

This report summarizes current knowledge on the distribution, ecology, and conservation status of sensitive species of moonworts (*Botrychium* spp.) on the Kootenai National Forest (KNF). It is based on information gathered in the field by KNF botanists and myself with information from the literature, from related studies in other states, and from Montana Natural Heritage Program sources. The priorities which were identified for this project were to:

- Resolve questions concerning identification, location, and population size and condition of known occurrences of sensitive *Botrychium* species.

- Locate and survey new populations, and evaluate biological factors conditioning the results of fieldwork

- Characterize the habitats and microhabitats of each species

- Assess conservation status and threats to populations of each species and recommend interim management guidelines.

Moonworts are primitive ferns with some of the highest chromosome numbers in the plant kingdom, which are characterized by a simple morphology but an often confounding taxonomy. The sporophyte, the conspicuous spore producing generation of the plant, is a small perennial which arises from a simple underground stem with roots which lack roothairs. The plants generally produce one aboveground leaf, or frond, per year with successive primordia enclosed in a sheath at its base. The frond is divided into two parts which share a common stalk, a usually sterile segment, the trophophore, and a fertile segment, the sporophore. The trophophore is laminar and usually pinnatifid (ternate in *B. lanceolatum*) and features of its lobing are the primary characters which distinguish the species. The sporophore bears grape-like sporangia where spores are produced. Spores germinate and develop into tiny underground gametophytes which are rarely seen or studied. Both generations of the ferns are associated with mycorrhizal fungi.

In recent years, knowledge of the diversity and distribution of moonworts has expanded at an extremely rapid pace. Nine of the fourteen moonwort species now recognized in Montana were described after 1980, and the traditional taxonomy of the group, as represented for the Pacific Northwest in Hitchcock and Cronquist (1976), has been almost completely rewritten. Even since the very recent release of the second volume of the Flora of North America, which covers the ferns and their allies, a new species, *Botrychium lineare*, has been described (Wagner and Wagner 1994), and at least two more new species are now in the process of being described (W. H. Wagner, pers. commun.). In 1996 two species of moonworts were documented for the first time in Montana; *B. pedunculosum* was found and verified (W. H. Wagner, pers. commun.) on the KNF, and a specimen collected near Columbia Falls in 1993 was identified as *B. campestre* (collected by T. Spribille, determined by W. H. Wagner).

These rapid advances have been mirrored by recent discoveries of moonworts on the Kootenai National Forest. Although a few occurrences of sensitive moonworts on the KNF were known by individual botanists (M. Arvidson, G. Heslink, pers. commun.) and a single 1971 collection labeled *B. lunaria* var. *onondagense* (annotated *B. minganense*) from the Forest was deposited at the herbarium at the University of Montana (MONTU), it was not until 1993 that any occurrences of rare moonworts documented from the Forest were recorded in the Biological Conservation Database maintained by the Montana Natural Heritage Program (MTNHP). In a recent assessment of grapeferns and moonworts of the Columbia Basin (Zika et al. 1995) a Lincoln County, MT distribution is given only for the common moonwort species *B. lanceolatum* and *B. lunaria*. There are now over 100 known occurrences, most discovered by KNF employees, of six sensitive or proposed sensitive moonwort species (U.S. Forest Service 1994, revisions pending), and additional occurrences of four non-sensitive moonworts known from the KNF.

The six moonwort species which are covered in detail in this report are *Botrychium ascendens* (upward-lobed moonwort), *B. crenulatum* (wavy moonwort), *B. minganense* (Mingan Island moonwort), *B. montanum* (mountain moonwort), *B. paradoxum* (peculiar moonwort), and *B. pedunculosum* (stalked moonwort). Also found on the KNF are four moonwort species which are considered more secure due to statewide and rangewide abundance and broad distribution; these include *B. lanceolatum* var. *lanceolatum* (triangle moonwort), *B. lunaria* (common moonwort), *B. pinnatum* (pinnate moonwort), and *B. simplex* (least moonwort). In addition to the moonworts, two additional species of *Botrychium* which are quite common on the KNF are *B. multifidum* (leathery grapefern) and *B. virginianum* (rattlesnake fern).

Most of the six sensitive or proposed sensitive species have a multi-state distribution yet are known from so few places rangewide that they are ranked globally imperilled (G2) or vulnerable (G3). This paucity of information about their distribution, as well as their species biology and ecology, underscores the need for a conservation assessment to compile all available information and to build on it.

Survey and field determination of moonworts is complicated by their species biology. They often occur in "genus communities" (Wagner and Wagner 1983), a sympatric pattern of distribution which is unexplained. They cannot be identified with certainty in their immature stages, and fronds may emerge from the ground over a three month span during favorable growing seasons, or not appear at all during unfavorable seasons. To complicate matters further, the plants are small and difficult to find even where they are common, and they are usually scarce.

The ecology of moonworts and the associated vulnerability of their populations to management activities is not well understood. Some species occupy a diversity of habitats across their range, raising questions about habitat specificity. For example, in the Storm Lake vicinity in the Anaconda Mountains, *Botrychium paradoxum* at the type locality in abundance on montane to subalpine grasslands (Vanderhorst 1993). But on the KNF where it is extremely rare, the same species grows in western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*)

habitats. Some species have been documented at sites of natural or man-made disturnace, raising questions whether moonworts are adapted to disturbance and early successional habitats (Wagner and Wagner 1993, Lellinger 1985, Lesica and Ahlenslager 1996). However, their occurrence in the stable habitats of ancient cedar groves seems to contradict this. The puzzling phenomenon of "genus communities,"where species grow together in the same apparent habitat, is unique to *Botrychium* spp. and seems to run counter to the competitive exclusion principle. Keeping in mind these unique attributes of moonwort species biology and ecology, fieldwork was specially designed to address to assess their status and assemble a reference for future conservation and biological evaluation.

The following three sections provide background on taxonomy, life history, and mycorrhizal associations which is common to all moonworts. These are followed by sections describing the methods and results and discussion of field studies on the KNF in 1995 and 1996. Information particular to each species is given in the status reviews for each of the six sensitive or proposed sensitive moonwort species on the KNF. The final section makes recommendations on status, and provides preliminary management guidelines for the conservation of these rare plants.

CLASSIFICATION AND IDENTIFICATION

Moonworts comprise the subgenus *Botrychium* of the genus *Botrychium* in the Ophioglossaceae, a family of primitive ferns sometimes considered fern allies (Gifford and Foster 1989). The family consists of just three genera: *Ophioglossum*, *Botrychium*, and *Helminthostachys*, the first two of which occur in North America. The subfamily Botrychiodeae is sometimes recognized as a distinct family (Wagner and Wagner 1993). The genus *Botrychium* also includes the grapeferns (subgenus *Sceptridium*) and rattlesanke fern, *B. virginianum* (subgenus *Osmundopteris*), both of which are also represented in Montana. Recent molecular evidence (Hauk and Chase 1993, Hauk 1995) supports the traditional taxonomy of the group and the monophyly (descent from a single origin) of the genus *Botrychium* and each of its three subgenera. There are about 25 species of moonworts described worldwide, with 22 now described in North America (Wagner and Wagner 1993, 1994).

The taxonomy of moonworts is controversial because it is based on subtle distinctions in morphology. Disagreements on plant identification and species validity are common. Throughout this report the modern taxonomy of *Botrychium*, as presented by Wagner and Wagner (1993) in Flora of North America, Volume 2, is followed. The Wagners have utilized the "genus community method" (Wagner and Wagner 1983) in recognizing species. The tendency for species of *Botrychium* to grow together in mixed communities is a "natural common garden experiment" - if taxa growing together maintain consistent morphological distinctions and do not form fertile hybrids, then they are considered legitimate species. Hybrids between species of moonworts are rare, but when found, have been determined to have abortive spores (Wagner and Wagner 1983, 1986, Wagner et al. 1984).

Molecular evidence supports the recognition of four sections within the subgenus *Botrychium*, however, placement of certain polyploid species is uncertain (Hauk 1995). There are species known from Montana from all four groups: 1) section Lanceolatum includes the diploid *Botrychium lanceolatum*, and the tetraploids *B. hesperium*, *B. pinnatum*, and *B. pedunculosum*, 2) section Simplex includes the diploids *B. montanum* and *B. simplex*, 3) section Lunaria includes the diploids *B. crenulatum* and *B. lunaria*, and 4) section "Campestre" includes the diploid *B. campestre*, the tetraploid *B. ascendens*, and *B. lineare* with unknown ploidy level. The tetraploids *B. minganense* and *B. paradoxum* could not be placed in sections based on molecular data. These sections are, for the most part, in agreement with those hypothesized by the Wagners based on morphological characters (Hauk 1995). Intraspecific variation in plastid DNA sequences was detected for *B. lunaria* and *B. simplex*, two widespread species, indicating the need for additional genetic research at the species and population levels to validate current concepts of species and phylogeny.

Identification of moonworts is often complicated because the species have few diagnostic characters, these characters may not be apparent in small plants, there is often a high degree of morphological variability between individuals in a population and between populations of the same species, and several species may grow together at the same site. Reliable field determination depends on the careful use of technical keys, comparison with silhouette outlines and verified specimens, and development of field experience. Taxonomic distinctions in the subgenus are based mostly on the lobing of the trophophore, but also on color, lustre, and texture of the plants and, to some degree, features of the sporophore. Accuracy of identification and documentation of moonwort populations is greatly improved by collecting voucher specimens. Since color and lustre are apparent only in live and freshly pressed plants, field notes on these characters are often necessary to identify pressed specimens. Collection guidelines and techniques for moonworts are outlined in Appendix E.

There are a number of references available to assist in identifying moonworts. The treatment of the genus in Flora of North America (Wagner and Wagner 1993) is the most complete guide to all but he most recently described species on this continent. In his flora of Montana, Dorn (1984) follows the Wagners but does not include recently described or discovered species, however, the key is simple and has useful features. For a current guide to the moonworts of western Montana, including keys to most species and pictures, consult Mantas and Wirt (1995). Lellinger (1985) includes excellent color photographs of many moonwort species. The classification in Hitchcock and Cronquist (1976) predates the treatment of the Wagners and does not recognize any of the sensitive species from Montana.

LIFE HISTORY

Like all ferns, moonworts are characterized by alternation of generations with physiologically independent 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 extreme difficulty of obtaining material (Gifford and Foster 1989, Mason and Farrar 1989). Early morphological studies (Campbell 1922, and citations therein) show there is diversity in patterns of embryo development among moonworts. *Botrychium simplex* has a relatively large cotyledon and rapid development, perhaps capable of maturing a small above-ground fertile frond in a year or so, while *B. lunaria* has a relatively small cotyledon and may take as many as seven years to produce an emergent frond. Sporophytes of some species, including *B. minganense* (Farrar and Johnson-Groh 1990) and *B. montanum* (Comacho 1996), can also develop vegetatively from underground propagules called gemmae, explaining the high plant densities often seen in populations of these species on the KNF. Mature moonwort sporophytes generally produce a single above ground, photosynthetic, fertile frond per growing season, but prolonged dormancy has been documented for several species (Johnson-Groh and Farrar 1993, Lesica and Ahlenslager 1996). Mature sporophytes of moonworts whose demography has been studied have been shown to be short-lived perennials, but longevity varies between species (Lesica and Ahlenslager 1996) and has not been determined for most species. In contrast, grapeferns (*Botrychium* subg. *Sceptridium*) may be quite long-lived (Kelly 1994, Montgomery 1990).

Above ground fronds of moonwort species are all fertile and bear sporangia; this is contrasted by rattlesnake-fern (*Botrychium virginianum*) which may produce vegetative fronds, a useful character for distinguishing between small plants of *B. virginianum* and the moonwort *B. lanceolatum*. The sporangia is the site of meiosis; each large eusporangia of *Botrychium* species produces thousands of haploid (1N) spores (Gifford and Foster 1989). Spores are small and lightweight enough to be carried by air currents. Even under a closed forest canopy on a calm day, when a mature moonwort sporophyte is flicked, a small cloud of yellow dust can be seen rising in the air. The effectiveness of long distance dispersal by spores helps explain the broad and often disjunct distributional patterns which are often exhibited by ferns, including moonworts (Barrington 1993, Peck et al. 1990). Dispersal of moonwort spores by droppings of small mammals has also been suggested (Zika 1992) and is consistent with observations of nibbled sporophores of some species at many KNF sites. This method of dispersal may help explain the tendency of moonworts to grow in patches and may be especially important for dispersal in forest environments with little wind. Although *Botrychium* spores were not studied, fern spores remained viable in nature for at least as long as one year, and spores on herbarium sheets germinated after over 50 years, demonstrating potential for a soil spore bank (Dyer and Lindsay 1992).

In nature, *Botrychium* spores germinate underground, and development of the haploid, non-photosynthetic gametophyte is dependent on early infection by an endophytic fungus (Bower 1926, Gifford and Foster 1989). Spore germination requires variable periods of darkness depending on the species (Whittier 1981). Gametophytes of *Botrychium* species can be grown in sterile culture without a fungal symbiont if a suitable source of soluble sugars are supplied (Whittier 1984). *Botrychium* gametophytes are bisexual with the antheridia positioned above the archegonia (Bower 1926, Campbell 1922, Gifford and Foster 1989), facilitating self-fertilization, an advantage for colonizing following long distance spore dispersal (Peck et al. 1990). Self-

fertilization may be the norm due to limited range of the flagellated sperm in the soil (Barrington 1993) and high levels of inbreeding have been demonstrated for some *Botrychium* species based on electrophoretic evidence (Soltis and Soltis 1986). However, the occurrence of interspecific hybrids which exhibit hybrid vigor may be evidence of intergametophytic crossing (Ahlenslager and Lesica 1995). Campbell (1922) reported that in *Botrychium simplex* several archegonia of a gametophyte may be fertilized at about the same time, but only one embryo was found to develop. Gametophytes with two embryos were reported for *B. lunaria*. The gametophyte, with its fungal associate, is thought to nourish the young embryonic sporophyte (Comacho 1996). The longevity of gametophytes and their fate following maturation of an associated sporophyte has not been reported. Some moonwort species are distinguished by having the gametophyte remaining attached to the mature sporophyte (Wagner and Wagner 1981).

MYCORRHIZAL RELATIONS

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 achorophyllous, depending on an endophytic fungus for carbohydrate nutrition, while the roots of the sporophyte lack root hairs and probably depend on the fungal symbiont for absorption of water and minerals (Gifford and Foster 1989). *Botrychium* gametophytes were considered saprophytic (Bower 1922), 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). The gametophytes cannot utilize complex carbohydrates (starch, cellulose etc..) but can be grown in sterile culture without a fungus if they are supplied with a source of soluble sugars (Whittier 1984). In nature, a fungal associate is present within the plant at the earliest stages of development of the gametophyte and sporophyte (Bower 1926). In the gametophyte, fungal infection is confined to the interior of the prothallus; areas of apical growth and the sexual organs are left uninfected (Bower 1926, Campbell 1922). 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). The species are unknown and may be undescribed. *Botrychium* mycorrhizae have been described as the vesicular-arbuscular (VAM) type (Berch and Kendrick 1982, Schmid and Oberwinkler 1994), however, preliminary results of recent investigations suggest there are unique features of the system (Camacho 1996). VAM fungi are thought to be obligate symbionts and have never been axenically cultured, and are thus extremely difficult to study and identify (Comacho 1996). There is as yet nothing known about their symbiotic specificity or habitat requirements.

The mycotrophic condition is important to the ecology of *Botrychium* species in several ways. Heterotrophic life stages may include gametophytes, young sporophytes, dormant sporophytes, and gemmae (Camacho 1996). Nutrition supplied through a fungal symbiont may allow the ferns to withstand repeated herbivory or prolonged dormancy (Kelly 1994, Montgomery 1990) and growth in dense shade, and may have allowed the evolution of a species, *B. paradoxum*, whose sporophyte lacks a sterile lamina and is presumed to have reduced photosynthetic capacity (Wagner and Wagner 1981). Specificity of 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 (Vanderhorst 1993, Zika 1992, 1994) and between grapeferns (*Botrychium* subgenus *Sceptridium*) 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 and monotropids (reviewed by Leake 1994) and in many respects behave much like mushrooms (Zika 1994).

METHODS

Prior to fieldwork in 1995, the Biological Conservation Database (BCD) maintained by MTNHP was queried for known occurrences of sensitive *Botrychium* species on the KNF. There were nineteen records in the database, 1 of *Botrychium ascendens*, 3 of *B. crenulatum*, 10 *B. minganense*, 3 of *B. montanum*, and 2 of *B. paradoxum*. Kootenai National Forest botanists and other knowledgeable local individuals were interviewed to obtain leads on other possible moonwort sightings which were not entered in the database. The herbaria at the University of Montana (MONTU) and Montana State University (MONT) were searched for collections of moonworts from the KNF; only one specimen from the KNF area was found at MONTU, a collection labeled *B. lunaria* var. *onadogense* (the poorly pressed specimen has been tentatively determined to be *B. minganense*).

Unresolved questions were compiled and populations were relocated to resolve them. Special attention was given to the globally rare species originally treated in Category 2 by the U.S. Fish and Wildlife Service: *Botrychium ascendens*, *B. crenulatum*, and *B. paradoxum*, whose occurrences on the KNF represented significant range extensions in Montana and whose identities remained unverified. High priority was also given to relocating reports of moonworts not identified to species.When occurrences were relocated the populations were surveyed and mapping was checked for accuracy. To obtain reliable species determinations, the plants were keyed out in the field, close-up photographs (35 mm slides) of the plants were taken, and whenever population numbers allowed, specimens were collected in accordance with guidelines established by the Montana Native Plant Society (1993) with special amendments for *Botrychium* species (Appendix E). Kootenai National Forest botanists from all districts were contacted and encouraged to collect specimens as appropriate when they revisited known populations or located new occurrences. At the end of the 1995 season, all specimens were photocopied (black and white), and these "silhouettes" were sent for determination by Peter Zika (Oregon Natural Heritage Program), a botanist who has worked extensively with moonworts. Color photocopies of selected problematic 1996 collections were also sent to Warren H. Wagner (University of Michigan) for determination. All collections will be deposited at the herbarium of the University of Montana (MONTU). Many Forest Service collections will remain at the KNF herbarium at the Supervisors Office in Libby.

Methodology to address the second established priority, *de novo* searches and determination of habitat breadth, included several strategies. Aerial photographs of known population sites were used to locate nearby similar habitats and altered habitats (e.g. clearcuts and second growth stands) to be searched. Searches were also conducted in alternate habitats as they were located on the ground; for example, deciduous thickets adjacent to known moonwort populations in forested habitats and vice-versa were searched. Since most known moonwort occurrences on the KNF were in mature cedar stands, a list of old-growth cedar stands (L. Kuennen, pers. commun.) was used to select areas to be searched to test the predictability of moonworts occurring in these habitats. Additional moist habitat types where moonworts have been found elsewhere (e.g. meadows and aspen stands) were searched when they were encountered. An attempt was made to cover the diversity of moist habitats throughout the KNF. Moonwort surveys involved

deliberate and lengthy searches, the time devoted depending on the habitat. Thus, cedar types with little ground cover required less time than types with heavy shrub, forb, or moss cover. A listing of areas and habitats which I searched is given in Appendix A.

The composition of genus communities was studied to assess relative abundance, conservation status, and relationships between sensitive and non-sensitive moonwort species. Sites known to harbor single species were thoroughly searched for occurrences of other more cryptic species. Individuals of each species were censused and microsite differences were noted whenever genus communities were encountered.

Ecodata methodology was utilized to characterize the habitats of each of the sensitive *Botrychium* species on the KNF. Standard forms, including general field, location linkage, and plant composition (U.S. Forest Service 1992) were completed for 27 1/10 acre plots. Sampling included all *B. ascendens* and *B. paradoxum* occurrences and representative occurrences of *B. crenulatum*, *B. minganense*, *B. montanum* and *B. pedunculosum*. In a few cases plot locations are best approximations of where moonwort taxa were seen in past years (*B. crenulatum* at Swamp creek., *B. paradoxum* at two Can Creek sites). Most large populations and significant genus communities were sampled. The plots include occurrences of *B. lanceolatum* and *B. pinnatum* in association with the sensitive species. An attempt was made to sample across the geographic and ecological range of the species on the Forest, but a few habitats were neglected, most notably, the roadside and reported subalpine habitats of *B. crenulatum* on the Fortine District, and *Abies lasiocarpa* and *A. grandis* habitats of *B. mingnense* on the Libby District. An Ecodata plot was also taken at a clearcut adjacent to a moonwort genus community at Red Top Creek.

The Ecodata was analyzed using the Strata program on the Data General System. A strata was created for each of *Botrychium ascendens*, *B. crenulatum*, *B. minganense*, *B. montanum*, *B. paradoxum*, and *B. pedunculosum*. Plots were assigned to more than one strata if they were genus communities with more than one sensitive species; thus the sets are not mutually exclusive. The plot in a clearcut at Red Top Creek was not included in the analysis. Strata produces synthesis tables of site physical data and plant composition, tables of averages and standard deviations of continuous site variables, tables of constancy and abundance of discrete site variables and plant species composition, tables of diversity and dominance for each plot and strata, and tables of similarity between plots, between strata and individual plots, and between strata. The indices of dominance calculated by Ecodata were inconsistent between runs using the same data and should be ignored.

To study *Botrychium* microhabitats at two sites, including a population of *Botrychium crenulatum* at Alexander Mountain and a *Botrychium* genus community at Zulu Creek, randomized replicated microplots (U. S. Forest Service 1992) within standard Ecodata plots were sampled in 1995 to compare with microplots selected for the presence of moonworts. This data is included in Appendix C. The data was statistically analyzed using correlation matrices and analysis of variance (ANOVA) and although a few significant associations were found at Zulu

Creek, the methodology was deemed inappropriate because assumptions of randomness were not met (L. Crone, pers. commun.) and the time consuming procedure was not continued in 1996.

In 1996, we enlisted the assistance of other specialists to identify associated mosses and mushrooms. This information further characterizes habitat, and the patterns of association with fungi may provide clues in symbiosis. Collections of mosses and fungi were taken from the immediate microhabitats of moonworts from chosen significant communities representing a range of species and habitat types. Joe Elliott (Helena, Mtcollected and identified mosses from 5 sites (Kelsey Creek, Zulu Creek, Alexander Mountain, Houghton Creek, and West Fisher Creek) on July 29 and 30. Larry Evans (Missoula MT) collected and identified mushrooms from four sites (Sutton Creek, Alexander Mountain, Kelsey Creek and French Creek) on September 23 and 24. Both of these researchers also identified moss and fungi collections taken from several other *Botrychium* sites by myself and KNF employees in 1995 and 1996.

Also in 1996, two graduate students incorporated *Botrychium* material from the KNF into their research. Living samples of *B. montanum* with root substrate were collected from two sites and mailed overnight to Francisco Comacho (Dept. of Botany and Plant Pathology, Oregon State University, Corvallis) for isolation, description, and identification of mycorrhizal fungi and moonwort vegetative propagules. Linda Swartz (Dept. of Forestry, University of Idaho) visited the KNF and collected leaf samples of *B. minganense* and *B. crenulatum* for morphological and DNA analysis.

Permanent belt transects as described by Lesica (1987) were established at French Creek both within a proposed logging unit and nearby outside the unit to monitor phenology and demography of *Botrychium minganense* and *B. montanum*. Individual plants were identified, measured, and mapped on a grid within plots in mid-July and again in early September 1995 and 1996. Three Rivers District botanist Leslie Ferguson, and biological technicians Mike Arvidson and Laura Sedler helped establish the plots and/or collect data and are aware of the locations. Further details on establishment and raw data from both years are attached as Appendix D.

RESULTS AND DISCUSSION

Summary Statistics: There are now a total of 104 known occurrences of six sensitive or proposed sensitive *Botrychium* species in or, in a few cases, adjacent to the Kootenai National Forest (Table 1). Thirty-four of these were 1996 discoveries and at least 30 were observed for the first time in 1995. Many more are verifications or species determinations of reports that had not been included in the Biological Conservation Database prior to 1995. There are now more than five times the number of occurrences documented as there was in 1995 before this project began. *Botrychium pedunculosum*, a former C2 species, was documented in 1996 for the first time in Montana at five sites on the KNF and is proposed for listing as sensitive in Region 1. Three sites have been documented with *Botrychium ascendens*, a former C2 species which was reported but not verified from the KNF before 1995, but one of these populations was probably extirpated by floods in 1996. Two occurrences of *B. paradoxum*, another former C2, consisting of a single plant each, were observed in 1993, and a 1995 collection of a third occurrence verified the species on the KNF, but none of these have been relocated in years subsequent to their discovery despite exhaustive surveys in both of the last two years.

Table 1. Occurrences of Sensitive and proposed Sensitive *Botrychium* species on the Kootenai National Forest. New occurrences are those not in the BCD prior to 1995.

Species/District*	D1	D3	D4	D5	D7	Total/New
B. ascendens		1		2		3/3
B. crenulatum	2	8	1	4	1	16/13
B. minganense	5	4	27	16	1	53/43
B. montanum	3	1	14	5	1	24/21
B. paradoxum			3			3/1
B. pedunculosum	4		1			5/5
Total	14	14	46	27	3	104/86

*D1 = Rexford, D3 = Fortine, D4 = Three Rivers, D5 = Libby, D7 = Cabinet.

Genus Communities: A total of at least 25 sites were found on the KNF which harbor more than one species of moonwort (Table 2). These sites represent over half of the total number of sensitive moonwort occurrences on the Forest, including all occurrences of the rarest species *Botrychium ascendens*, *B. paradoxum*, and *B. pedunculosum*. The relative rarity of the sensitive species on the KNF is reflected both by number of occurrences and by number of individuals in populations. *Botrychium minganense* and *B. montanum* are the most common co-occurring species pair. The species most commonly occurring by themselves are *B. crenulatum* (13 of 17 occurrences) and *B. minganense* (31 of 53 occurrences). Rattlesnake fern (*B. virginianum*) is present in most, but not all, genus communities.

Table 2. Moonwort genus communities on the KNF.

Site\Species*	as	cr	la	mi	mo	pa	pe	pi	vi
Arbo Ck.				20	1				
Beaver Ck.	6	100							x
Beetle Ck.			x	45	26				x
Big Ck.			13	10			5		x
Big Ck. SF			10	45	45		8		x
Can Ck.				120	150	2			x
Cedar Ck.				17	15				x
Clay Mt.			x		13				
French Ck.				53	241				x
Houghton Ck.	5			?	1				x
Keeler Ck.			10		1		3		
Kelsey Ck.				57	95				
Meadow Ck. NF			x	37	18				
Mt. Baldy				x	x				
Parsnip Ck.			35	40	20		1		x
Pete Ck.			10	5					x
Poorman Ck.			4	8					
Redtop Ck.			3	150	50			200	
Rock Ck.		?	x						x
Sterling Ck.				20	100				
Sutton Ck.		?	1	100	35		1	2	x
Swamp Ck.		8		1					x
Turner Ck.				19	4				
W. Pipe Ck.				6	43				x
W. Fisher Ck.	6			5					x
Zulu Ck.				65	6	1		1	x

* as=*Botrychium ascendens*, cr=*B.crenulatum*, la=*B. lanceolatum*, mi=*B. minganense*, mo=*B. montanum*, pa=*B. paradoxum*, pe=*B. pedunculosum*, pi=*B. pinnatum*, vi=*B. virginianum*.

Numbers are population estimates for each site in the same year. x = presence ? = uncertain identification.

Habitat characterization: The results of two years of extensive surveys suggest that individual moonwort species occupy a relatively narrow range of habitats on the KNF. All known habitat types for each species are listed in Table 3. *Botrychium ascendens* was found and verified only from alder (*Alnus*) thickets and a spruce (*Picea*) habitat with alder. *Botrychium crenulatum* was found mostly in open habitats with calcareous substrates (wetlands, openings, and roadsides). *Botrychium minganense*, *B. montanum*, and *B. paradoxum* were found mostly in maturing to old growth western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) habitats. *Botrychium pedunculosum* was found only in old floodplain channels in old growth western red cedar stands. No moonworts were found in recent clearcuts or stands of young regeneration but *B. minganense* and *B. montanum* were found in maturing second growth cedar. *Botrychium minganense* has the broadest ecological and geographical amplitude. Unlike the moonworts, the larger *Botrychium* species, *B. multifidum* (leathery grapefern) and *B. virginianum* (rattlesnake fern), were found in relatively recently logged areas.

Table 3. Documented habitat types of sensitive *Botrychium* species on the Kootenai National Forest. Types are listed in descending order of number of occurrences. Major types are in bold. Habitat types are described in Cooper et al. (1991), Pfister et al. (1977), and/or Hansen et al. (1995).

SPECIES	HABITAT TYPES
B. ascendens	***Alnus sinuata***, *Picea/Cornus stolonifera*
B. crenulatum	**roadsides and old roadways**, *Picea/Cornus stolonifera, Alnus sinuata*, subalpine rock outcrops, *Picea/Cornus stolonifera* (seral aspen), *Thuja plicata/Clintonia uniflora?*
B. minganense	***Thuja plicata/Oplopanax horridum, Thuja plicata/Clintonia uniflora, Tsuga heterophylla/Clintonia uniflora***, *Thuja plicata/Athyrium filix-femina, Alnus sinuata, Abies lasiocarpa/Clintonia uniflora, Abies grandis/Clintonia uniflora, Picea/Cornus stolonifera* (including seral aspen), *Agrostis stolonifera* grazing disclimax
B. montanum	***Thuja plicata/Clintonia uniflora, Thuja plicata/Oplopanax horridum, Tsuga heterophylla/Clintonia uniflora***, *Thuja plicata/Athyrium filix-femina, Alnus sinuata*
B. paradoxum	*Tsuga heterophylla/Clintonia uniflora, Thuja plicata/Clintonia uniflora*
B. pedunculosum	***Thuja plicata/Oplopanax horridum***, *Thuja plicata/Athyrium filix-femina*

Negative results (Appendix A) can be used to roughly indicate the probability of sensitive *Botrychium* species occurring in broad categories of seral stages and habitat types. I found sensitive moonworts in 63% (27/43) of the old growth cedar and hemlock stands, 19% (3/16) of the second growth cedar and hemlock stands with closed canopies, 0% (0/7) of the recent cutting units with cedar or hemlock potential, 25% (2/8) of the alder thickets, and 14% (1/7) of the moist meadows which were searched. These figures should be viewed cautiously because searches were biased towards cedar and hemlock habitat types and were not random.

Results of the Ecodata analysis using Strata are presented in Appendix C. Included are synthesis tables of site physical data and plant composition, tables of averages and standard deviations of continuous site variables, tables of constancy and abundance of discrete site variables and plant species composition, tables of diversity for each plot and strata, and tables of similarity between plots, between strata and individual plots, and between strata. Note: indices of dominance calculated by Strata were inconsistent between runs using the same data and should be ignored. Habitat variables for each sensitive *Botrychium* species are discussed in the six status reviews which follow this section.

Analysis of Ecodata and analysis of moonwort genus community composition (Table 2) reveal two main *Botrychium* species groups with similar habitats on the KNF. The larger group, which includes *B. lanceolatum, B. minganense, B. montanum, B. paradoxum, B. pinnatum*, and *B. pedunculosum*, occurs mostly in forest habitats with high canopy cover by trees, relatively low understory cover and usually heavy litter layers. A smaller group made up of *B. ascendens* and *B. crenulatum* occurs mostly in deciduous wetlands. Habitat and geographic distribution of species appear to be correlated, with the forest dwelling species more common in the western part of the KNF, while the species of deciduous wetlands are more common in the eastern part. The most common forest species, *B. minganense* and *B. montanum*, in a few cases grow with *B. ascendens* or *B. crenulatum* in the eastern part of the Forest. In these instances, their numbers are very low, and the habitats are deciduous wetlands.

Associated mushrooms and mosses: Larry Evans identified fruiting bodies of 63 taxa of fungi associated with one or more sensitive *Botrychium* species on the KNF (Appendix F). The summer of 1996 was dry and few mushrooms were up throughout western Montana, but rains in September allowed development of some by the survey date. In western red cedar and western hemlock habitat types there was a noticeably higher diversity of mushrooms in moonwort habitats than in surrounding habitat without moonworts. This is most likely a shared requirement for moist microhabitats, but could also be related to low levels of root zone competition, substrate characteristics, or mycorrhizal relationships. At Kelsey Creek, 29 mushroom taxa were identified, approaching in number the 35 vascular plants identified in an Ecodata plot at the same site. Since many species of fungi do not produce mushrooms or produce them rarely, or only in spring or summer, the diversity of fungi associated with moonworts is expected to be much higher than two days of survey indicate.

Of the fungi identified, the genera *Cortinarius, Hebloma, Hygrophorus, Russula*, and *Suillus* are known to be mycorrhizal with conifers, while the rest are saprophytic or parasitic (L. Evans, pers,

commun., Aurora 1986). Two mycorrhizal species, *Hygrophorus eburneus* and *Suillus sibericus* (or *S. umbonatus*) were observed in direct contact with moonworts (see slide #17 in Appendix I). The identity of the fungal symbionts of moonworts are unknown (see below, and the preceding section on mycorrhizal relations), and the existence of mycorrhizal links between moonworts and conifers is merely speculative.

Joe Elliott identified 28 taxa of mosses from 24 sites on the KNF with sensitive *Botrychium* species (Appendix G). Typically, the mosses are species adapted to decomposing duff and organic soils with high moisture levels. The closest and most consistent group of moss associates are the leafy mosses in the Mniaceae (*Mnium, Plagiomnium*, and *Rhizomnium* spp.). *Plagiomnium insigne*, which appears to be an especially common moss associate, was collected from six sites distributed across the KNF with several sensitive *Botrychium* species of both forests and alder thicket openings. Two species, *Brachythecium asperimum* and *Bryum pseudotriquetrum* were found in the alder habitats of both *Botrychium ascendens* and *B. crenulatum*, but were not collected from forested habitats of other sensitive moonwort species. Several associated mosses are West Coast endemics with eastern-most distributions including only habitats of western Montana most strongly influenced by Pacific-maritime climatic patterns. *Plagionmnium venustum, Plagiomnium insigne, Eurhynchium oreganum, Rhizomnium nudum, Rhytidiopsis robusta* and *Brachythecium asperimum* are restricted to the warmest, most humid habitats in northwestern Montana (Vitt et. al. 1988, Schofield 1992, and Lawton 1971).

Mycorrhizae and vegetative propagules: Francisco Camacho (pers. commun.) isolated 9 taxa of fungi and 2 taxa of bacteria from sterilized roots of *Botrychium montanum* and found evidence of vegetative reproduction in plants of this species sent to him from the KNF. The identities of the fungi have not yet been determined and it is probable that some of the fungi may be undescribed species. Some of the more abundant fungi within the roots from the KNF are similar to fungi extracted from *B. montanum* and *B. pumicola* from other locations.

Evidence of vegetative reproduction was deduced by the presence of 10 immature underground sporophytes without attached gametophytes found in close proximity to a mature sporophyte. No gemmae or gametophytes were found associated with the plants from the KNF, but were found in samples of *B. montanum* from other locations. It is possible that KNF plants are reproducing by gemmae and these had disappeared by the sampling date, or that they are reproducing by some other form of root fragmentation.

French Creek monitoring transects: Two years' results of intraseasonal monitoring of *Botrychium minganense* and *B. montanum* at French Creek (Table 4) show that the phenology of frond emergence in these populations is staggered across the growing season and that there are considerable levels of herbivory. Between July and September in both years fronds of both species disappeared and new fronds of both species emerged. Actual population size was larger than was apparent at either one date. The appearance and disappearance of fronds within a season does not necessarily represent recruitment and mortality, but indicates a variable phenology of leaf development and senescence or predation. Fronds appearing late in favorable growing seasons are consistent with season long dormancy documented for sporophytes of

Botrychium species (Johnson-Groh and Farrar 1993, Lesica and Ahlenslager 1996, Montgomery 1990). Nibbled plants of both species, including plants nibbled to ground level, were observed at the later dates indicating that herbivory was the likely mechanism for fronds disappearing. Individual plants which were mapped on both dates in the same season were generally taller or nibbled on the second date (Appendix D).

Table 4. Summary of intraseasonal population monitoring results at French Creek, transects 1 and 2.

	B. minganense		*B. montanum*	
	1995	1996	1995	1996
# fronds July	16	16	177	107
# disappeared	8	2	96	56
# new	7	2	64	48
# fronds September	15	16	145	99
# nibbled	5	8	13	34
total fronds	23	18	241	155

Data from two years is not adequate to document mortality and recruitment in the populations, but some interesting trends are apparent. The fate of individual plants was tracked over the monitoring period by assigning each plant a letter code (Appendix D). High densities of *B. montanum* in transect 1 in 1995 made reliable analysis difficult, so only the moderate density plots 2 and 3 from this transect were used for this analysis. Individual plants were observed at almost every possible permutation of the four dates.

Table 5 summarizes data from the three transects in both years. There were fewer fronds of *B. montanum* in transect 1 and fewer fronds of *B. minganense* in transect 2 in 1996 than in 1995. However, there were higher numbers of *B. montanum* in transect 2, and higher numbers of *B. minganense* in transect 3 in 1996. Transect 2 is located in relatively wet ground below a seep while transect 1 is in dryer ground above the seep. *Botrychium* montanum was the only moonwort in transect 1 in both years. In 1995, transect 2 contained mostly *B. minganense*, but the proportion of *B. montanum* increased dramatically in 1996. These results suggest that *B. montanum* is adapted to somewhat dryer microhabitats; this conclusion is also supported by observations of the two species elsewhere on the KNF. These results also show that populations (and genus communities) are not homogenous; some areas (or species) may have increased numbers of emergent fronds while other areas (or species) have decreased numbers over the same

period. These differences are an indication of interactions between the individual species with climate and microhabitat.

Table 5. Summary results of two years of monitoring of *Botrychium minganense* and *B. montanum* at French Creek, Transects 1, 2 (plots 2 and 3 only), and 3.

	B. montanum		*B. minganense*	
transect #	1	2 2		3
# fronds 1995	41	6	23	32
# disappeared	23	5	14	7
# new	7	12	9	9
# fronds 1996	25	13	18	37

Status Reviews: The Status Reviews for each of the six sensitive or proposed sensitive *Botrychium* species which follow this section further summarize the results of the surveys and provide pertinent information from other sources particular to each species. Included are sections on classification, formal status, description, geographical distribution, habitat, population demography and biology, land ownership, and management considerations. Throughout the remainder of this report occurrences of sensitive moonworts are referred to by their site names and three digit element occurrence numbers assigned in the Biological Conservation Database. These reference the Element Occurrence Records (EORs) and topographic maps in Appendix B which give precise location and other details for each occurrence. Indices to the EORs by KNF districts and by species are included at the beginning of Appendix B.

Upward-lobed Moonwort
Botrychium ascendens

A. CLASSIFICATION

1. FAMILY: Ophioglossaceae, a family of primitive ferns

2. GENUS: *Botrychium* subgenus *Botrychium*

3. SPECIES: *Botrychium ascendens* Wagner, described in Wagner and Wagner (1986).

B. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL STATUS

a. U.S. FISH AND WILDLIFE SERVICE: Previously recognized as C2 (U.S. Fish and Wildlife Service 1993), indicating that it is a species "for which information now in the possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which sufficient data on biological vulnerability and threat are not currently available to support proposed rules." Recognition of C2 species was officially discontinued by the Service in 1996 (U.S. Fish and Wildlife Service 1996).

b. U.S. FOREST SERVICE: Sensitive in Region 1 (U.S. Forest Service 1994a).

c. BUREAU OF LAND MANAGEMENT: none.

2. STATE: The Montana Natural Heritage Program ranks the species G3? and S1 (Heidel 1996). Global rank of G3 signifies vulnerability to extinction throughout its range; the state rank S1 signifies that it is critically imperiled because of extreme rarity in Montana.

C. DESCRIPTION

1. GENERAL NONTECHNICAL DESCRIPTION: The sporophyte produces a single above ground frond per year which is divided into two segments, a mostly sterile trophophore and a fertile sporophore, which share the same stalk. The frond stands up to 8" above ground but is usually smaller and is a bright yellow-green color. The trophophore is pinnatifid with as many as 10 pairs of pinnae, which are strongly upswept away from the base, so that the upper angle between the axis and the pinnae is much smaller than the lower angle. The upper margins of the pinnae are usually divided into narrow teeth-like or saw-like segments, or the pinnae are deeply incised. Often there are sporangia (spore bearing bodies) born on the margins of the lower pinnae of the sterile leaf segment. The fertile segment, when mature, is longer than the sterile segment and is branched, the branches bearing grape-like sporangia which contain the spores; when

mature they release the spores, which appear as a yellow dust. The inconspicuous and rarely seen gametophyte grows underground.

2. TECHNICAL DESCRIPTION: "Trophophore stalk 3-10 mm, 1/6 length of trophophore rachis; blade yellow-green, oblong to oblong-lanceolate, 1-pinnate, to 6 X 1.5 cm, thin but firm. Pinnae to 5 pairs, strongly ascending, well separated, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, basal pinnae pair approximately equal in size and cutting to adjacent pair, obliquely narrowly cuneate, undivided to tip, margins sharply denticulate and often shallowly incised, apex rounded, venation like ribs of a fan, midrib absent. Sporophore 2-pinnate at base of sporangial cluster, 1.3-2 times length of trophophre. $2n = 180$." from Wagner and Wagner (1993).

3. LOCAL FIELD CHARACTERS: On the KNF, *Botrychium ascendens* is known to grow with *B. crenulatum* and *B. minganense* and is similar in appearance to both. It can be distinguished from both by its strongly ascending pinnae with sharply serrate or incised margins, vs. the others' usually spreading pinnae with entire to crenulate margins. It differs from *B. minganense* by its bright yellow-green vs. deep, dull green color and by its thinner blade texture. Although *B. ascendens* is reported as the only moonwort species to commonly have sporangia on the proximal pinnae of the trophophore (Wagner and Wagner 1986, 1993, Mantas and Wirt 1995), this condition has also been observed in *B. crenulatum*, *B. minganense*, *B. montanum*, and *B. pedunculosum* on the KNF, and Zika (1992) also reports it for *B. lanceolatum* and *B. pinnatum* in Oregon.

D. GEOGRAPHICAL DISTRIBUTION

1. RANGE: North America: Alberta, British Columbia, Ontario, Yukon Territory, Alaska, California, Montana, Nevada, Oregon, Wyoming (Wagner and Wagner 1993); in addition it is recently reported in Idaho (Idaho Conservation Data Center, pers. commun.) and Washington (Washington Natural Heritage Program, pers. commun.).

2. MONTANA DISTRIBUTION: Prior to 1995, *B. ascendens* was reported from two locations in the state. A specimen from one site in Lewis and Clark County in the Bob Marshall Wilderness is cited in the description of the species (Wagner and Wagner 1986). The other report, in Lincoln County on the KNF (Can Creek), is not represented by a specimen and after revisiting the site, it is believed to have been based on misidentified plants of *B. minganense* or *B. montanum* and has been deleted from the Biological Conservation Database. Three populations were found on the KNF in 1995, bringing the state total to four occurrences. The known distribution of the species in Montana is shown on the inset of Figure 1.

figure 1

3. KOOTENAI NATIONAL FOREST OCCURRENCES

a. CURRENT SITES: *B. ascendens* was found and verified on the KNF for the first time in 1995. Two sites were located by Jon Reny and Terese Bielak on the Libby District at West Fisher Creek (002) and Houghton Creek (004) and one by myself at Beaver Creek (003) in a state school section surrounded by the KNF on the Fortine District. Collections were made from all populations and photocopy silhouettes of those from Beaver Creek and Houghton Creek were verified by Peter Zika (pers. commun.). The West Fisher Creek population is believed to have been extirpated by spring floods in 1996. The Houghton Creek population was relocated in 1996. Figure 1 shows the approximate locations of these four populations. Element Occurrence Records and maps showing the precise locations are given in Appendix B.

b. UNVERIFIED/UNDOCUMENTED REPORTS: The reported occurrence of *Botrychium ascendens* at Can Creek is now believed to have been based on a misidentification and has been removed from the Biological Conservation Database. The specimen from West Fisher Creek (002) could not be identified by P. Zika (pers. commun.), however, the collector observed additional plants at the site, is familiar with the species, and differentiated them from *B. minganense* at the same site (T. Bielak, pers. commun.); in addition the habitat is similar to the nearby Houghton Creek site.

c. AREAS SURVEYED BUT SPECIES NOT LOCATED: see Appendix A for a listing of areas which were searched.

E. HABITAT

1. ASSOCIATED VEGETATION: At its type locality in the Wallowa Mountains in Oregon where it is most abundant *Botrychium ascendens* grows in mesic to moist meadows in the *Picea engelmannii* zone (Wagner and Wagner 1986, Zika 1992, 1994). In Idaho and Washington it is reported from western red cedar (*Thuja plicata*), subalpine fir (*Abies lasiocarpa*), and alpine meadow habitats (Idaho Conservation Data Center, Washington Natural Heritage Program, pers. commun.).

On the KNF *Botrychium ascendens* is associated with shrub or conifer dominated wetlands. At Beaver Creek the plants grow in a small opening in second growth *Picea/Cornus stolonifera* habitat (Hansen et al. 1995) with relatively low tree, shrub, and forb cover and heavy ground cover by mosses. The Libby District sites have insignificant tree cover, but high cover of shrubs and wet-site forbs and ferns. They are probably best classified as *Alnus sinuata* habitat types (Cooper et al. 1991, Hansen et al. 1995).

Vegetation was sampled by Ecodata (Appendix C) at all known KNF sites although data from West Fisher Creek represents post flood conditions. *Picea*, the only well represented tree, was present only at Beaver Creek. Shrubs have moderate to heavy cover (20-80%). Well represented shrubs in one or more plots include *Acer glabrum*, *Alnus*

incana, Alnus sinuata, Cornus stolonifera, Rhamnus alnifolia, Rubus parviflorus, and *Symphoricarpos albus*. Grasses are scarce, but *Elymus glaucus* is constant. Forbs contribute significant cover (20-80%) but no single species is well represented. Forbs constant in the plots include *Aralia nudicaulis, Fragaria virginiana, Geum macrophyllum* and *Smilacina stellata*. The grapefern *Botrychium virginianum* and horsetails *Equisetem arvense* and *E. hymale* are constant. Moss cover is heavy (70-80% cover) at Beaver Creek and Houghton Creek. Mosses immediately associated with *Botrychium ascendens* include species of *Bryum, Brachythecium*, and *Plagiomnium* (Appendix G).

Vegetation at all KNF sites is effected by high water tables and flooding events. Scouring and deposition of gravel, caused by flooding at West Fisher Creek in 1996 eliminated nearly all moss cover and is believed to have extirpated the population of *B. ascendens*, but cover by flood resistant shrubs and forbs remained very high. The Houghton Creek site, which was not subject to catastrophic floods in 1996, retains heavy cover by mosses. Suitable habitat for *B. ascendens* is likely to be temporary. The small meadows where *B. ascendens* grows in Oregon are also believed to be temporary phenomena subject to reforestation (Zika 1994).

At Beaver Creek *Botrychium ascendens* grows with *B. crenulatum*, at West Fisher Creek it grew with *B. minganense*, and at Houghton Creek it grows with *B. montanum*. Throughout its range it has also been found with *B. lunaria*, *B. pinnatum* and *B. simplex* (Wagner and Wagner 1986, Zika 1992).

Analysis of Ecodata using Strata shows that the vegetation of *Botrychium ascendens* sites on the KNF shares many attributes with that of *B. crenulatum* sites (Appendix C). These two strata have relatively high indices of diversity, reflecting high shrub, forb, fern, and moss cover by a large number of species. In contrast, other sensitive moonworts on the KNF usually grow in habitats with high canopy cover by conifers (mostly *Thuja plicata*) and depauperate middle and lower vegetation layers.

Vegetation is described in further detail in the general site description fields of the Element Occurrence Records in Appendix B and in the Ecodata tables in Appendix C. Photographic slides of the vegetation at Beaver Creek and Houghton Creek are included in Appendix I.

2. TOPOGRAPHY: The sites on the KNF are in glaciated valley stream floodplain bottoms in the eastern part of the Forest. Elevations range from 3,180 to 3,850 feet. At West Fisher Creek the plants grew on hummocks above the saturated floodplain bottom, while at Beaver Creek they grow in a concave swale. The sites are level to gently sloping.
3. SOIL RELATIONSHIPS: The soils have alluvial parent materials and are subject to seasonal inundation and periodic perturbation by catastrophic floods. At West Fisher Creek (002) the floodplain was saturated at the survey date in 1995 but the plants grew on raised hummocks. Floods in the spring of 1996 washed away these hummocks and deposited several inches of gravel. At Beaver Creek (003), the plants grew on the slightly

moist raised side of a swale, and the soil had a high percentage of reprecipitated calcium; the site lies within landtype 325 (Kuennen and Nielsen-Gerhardt 1985) with "soils formed in very limy alluvial deposits." Although the soil at Beaver Creek is highly calcareous, *Botrychium ascendens* is apparently not restricted to calcareous soils.

4. CLIMATE FACTORS: Moonworts in general are adapted to cool, moist climates. In Montana they are thus most common at low elevations in the northwest part of the state with its cool temperate, maritime influenced climate, while in semi-arid regions of the state (e.g. Granite, Deer Lodge, and Lewis and Clark counties) they are mostly found at higher elevations which receive heavy accumulations of snow. The occurrences of *Botrychium ascendens* on the KNF are found in the more dry eastern parts of the Forest, but these are located adjacent to wetlands. Mean annual normal precipitation (1951-1980) at the nearby stations at Fortine and Libby were 17.25 and 18.66 inches (National Oceanic and Atmospheric Administration 1982). Climatic fluctuations may dramatically effect the phenology, numbers, and distribution of moonwort sporophytes which produce above ground leaves in a growing season. Because it grows in subirrigated habitats, *B. ascendens* is likely to be less affected by precipitation during the growing season, and more affected by total annual precipitation.

F. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: In 1995, plants were found at Beaver Creek (003) in late June with immature sporangia and at West Fisher Creek (002) in early August with mature sporangia. An earlier survey of the West Fisher Creek site found only *Botrychium minganense* but it is not known whether *B. ascendens* has consistently later phenology. At Beaver Creek both *B. ascendens* and *B. crenulatum* were at approximately the same stage of development on the survey date. Mature plants were reported from northern Idaho in late July and August (Idaho Conservation Data Center, pers. commun.).

2. POPULATION SIZE AND CONDITION: In total numbers, among moonworts, *Botrychium ascendens* is exceeded in rarity in Montana only by *B. lineare* and *B. spathulatum* (neither known from the KNF), and on the KNF only by *B. paradoxum*. There were only six plants counted at each of the Beaver Creek and Houghton Creek sites in 1995 and only five were relocated at Houghton Creek in 1996. The population at West Fisher Creek was probably extirpated by floods in 1996, although the persistence of underground gametophytes or dormant sporophytes cannot be ruled out. The populations in Idaho consist of just one or two plants. *B. ascendens* is reported as rare and scattered throughout its range (Wagner and Wagner 1986, P. Zika, pers. commun.), but it occurs in hundreds at its type locality in the Wallowa Mountains of Oregon (Wagner and Wagner 1986, Zika 1994) and in one Washington population (Washington Natural Heritage Program, pers. commun.). The individual plants of *B. ascendens* observed on the KNF have been robust and healthy.

3. REPRODUCTIVE BIOLOGY: See the discussion of life history following the introduction to this report.

G. POPULATION ECOLOGY

1. COMPETITION: On the KNF, *Botrychium ascendens* sites have relatively high ground cover by shrubs, forbs, and mosses. Competition in these habitats is expected to be much higher than in the forested habitats of other moonwort species. It is possible that root zone competition is reduced by periodic flooding.

   The occurrence of moonworts, including *Botrychium ascendens*, in genus communities seems to run counter to the competitive exclusion principle, however, plant densities are usually so low that competition between moonwort species is not expected. Our observations also suggest that the individual species do have subtly different microhabitat preferences. For example, at Beaver Creek, where *B. ascendens* and *B. crenulatum* grew together, the six plants of *B. ascendens* were confined to a small area on the uphill edge of a swale on the north side of the opening in spruce woods, while *B. crenulatum* occurred in greater numbers and was distributed in the bottom of the swale throughout the opening. *B. ascendens* may be adapted to slightly dryer, warmer microsites; similar observations on microsite differences between these two species are reported from Oregon (Zika 1992).

2. POSITIVE INTERACTIONS: See the discussion of mycorrhizal relationships following the introduction to this report.

3. HERBIVORY: Herbivory of *Botrychium ascendens* was not observed, but nibbled sporophores of other species of moonworts was noted on the KNF in 1995 and 1996. The clusters of sporangia are often selectively browsed leaving the trophophore intact. Small animals, possibly rabbits, rodents, or snails, may play a role in spore dispersal of moonworts (Zika 1992).

H. LAND OWNERSHIP: The Beaver Creek (003) population is on state land surrounded by the KNF on the Fortine District. The Houghton Creek (004) and West Fisher Creek (002) populations are on the Libby District of the KNF. The Houghton Creek site was proposed for a land exchange with Plum Creek Timber Co. (U. S. Forest Service 1995), however 160 acres were removed from the exchange to provide protection for the *B. ascendens* occurrence (U.S. Forest Service 1996).

I. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

1. THREATS TO CURRENTLY KNOWN POPULATIONS: Because of its low numbers and occurrence in dynamic riparian habitats, *Botrychium ascendens* is extremely vulnerable to extirpation from the KNF and Montana. Flooding in 1996 probably extirpated the West Fisher Creek population. The degree to which land use patterns in the drainage affected this flood event are not known. A new road was built by Plum

Creek Timber Co. in 1995 nearby in the drainage and there is a long history of logging in the vicinity. The Beaver Creek population (003) is on state land but activities on KNF land upstream could potentially affect the hydrology of this site. The Houghton Creek site (004) was removed from a proposed land exchange with Plum Creek Timber Company (U. S. Forest Service 1996), however, land upstream from the site was exchanged, and the occurrence remains vulnerable to indirect effects of logging and road building on Plum Creek land.

2. MANAGEMENT PRACTICES AND RESPONSE: unknown

3. MANAGEMENT SUMMARY: Although the range of *Botrychium ascendens* is fairly broad, its distribution is highly disjunct and its population numbers are usually very low, thus Forest Service Region 1 sensitive status and Montana Natural Heritage Program S1 status remain appropriate.

Conservation management for this species should be a high priority for the sensitive plant program on the KNF. All known populations on the KNF and on adjacent state land deserve protection and proposals of management activities in their drainages must consider potential impacts to populations downstream. The KNF occurrences of *B. ascendens* are associated with streambottom riparian zones whose vulnerability to catastrophic flooding was demonstrated in 1995 at West Fisher Creek. The causes of this local flood event should be determined, and preventative measures should be explored to protect known *B. ascendens* sites from similar events. Permanent Ecodata plots established at Houghton Creek and at the flooded West Fisher Creek site in 1996 provide an opportunity to study vegetational succession and *B. ascendens* population persistence and potential reestablishment in these riparian habitats. Surveys to locate additional occurrences of *B. ascendens* on the KNF are needed. Project clearance surveys are often inadequate because they do not cover downstream riparian habitat which may be subject to indirect effects of management. *B. ascendens* is likely to be especially difficult to find due to its occurrence in habitats with heavy shrub and forb cover.

Wavy Moonwort
Botrychium crenulatum

A. CLASSIFICATION

1. FAMILY: Ophioglossaceae, a family of primitive ferns

2. GENUS: *Botrychium* subgenus *Botrychium*

3. SPECIES: *Botrychium crenulatum* Wagner, described in Wagner and Wagner (1981).

B. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL STATUS

a. U.S. FISH AND WILDLIFE SERVICE: Previously recognized as C2 (U.S. Fish and Wildlife Service 1993), indicating that it is a species "for which information now in the possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which sufficient data on biological vulnerability and threat are not currently available to support proposed rules." Recognition of C2 species was officially discontinued by the Service in 1996 (U.S. Fish and Wildlife Service 1996).

b. U.S. FOREST SERVICE: Sensitive in Region 1 (U.S. Forest Service 1994a).

c. BUREAU OF LAND MANAGEMENT: none.

2. STATE: The Montana Natural Heritage Program ranks the species G3? and S1 (Heidel 1996). The global rank G3 signifies vulnerability to extinction throughout its range; the state rank S2 signifies that it is imperiled because of rarity in Montana.

C. DESCRIPTION

1. GENERAL NONTECHNICAL DESCRIPTION: The sporophyte produces a single yellow-green leaf per year which is divided into two segments, a sterile trophophore and a fertile sporophore, which share a common stalk. The leaf stands up to 6 inches tall but is usually shorter. The trophophore is pinnatifid with usually three or four thin textured, non-overlapping pairs of pinnae and a terminal pinnae. The pinnae are broadly fan shaped with wavy margins. The sporophore is longer than the sterile segment when mature and bears "grape-like" sporangia which, when mature, release thousands of spores, which appear as yellow dust. Photographic slides of the sporophytes are provided in Appendix I. The small and rarely seen or studied gametophyte grows underground.
2. TECHNICAL DESCRIPTION: "Trophophore stalk 0.5-7 mm; blade yellow-green, oblong, 1-pinnate, to 6 X 2 cm, thin, herbaceous. Pinnae to 5 pairs, spreading, well

separated, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, basal pinna pair approximately equal in size and cutting to adjacent pair, broadly fan-shaped, undivided to tip, margins mainly crenulate to dentate, proximal pinnae with 1 or more shallow incisions, apex rounded, apical lobe linear to linear-cuneate, well separated from adjacent lobes, venation like ribs of a fan, midrib absent. Sporophores 1-2 pinnate, 1.3-3 times length of trophophore. 2*n* = 90." from Wagner and Wagner (1993)

3. LOCAL FIELD CHARACTERS: *Botrychium crenulatum* is one of the most difficult moonwort species to recognize and plants are often misidentified, especially juvenile and "old growth" plants (Zika 1994). On the KNF It is similar to and confused with *B. ascendens, B. lunaria,* and *B. minganense*. It is distinguished from *B. ascendens* by having broadly spreading pinnae with crenulate margins rather than strongly upswept pinnae with narrowly dentate to lacerate margins. It can be distinguished from B. lunaria by having non-overlapping pinnae which are thinner textured, more yellow-green, and more prominently veined. *B. minganense* is usually a deep dull green, somewhat succulent, and may have more pinnae pair than the usual 3-4 pair of *B. crenulatum.*

D. GEOGRAPHICAL DISTRIBUTION

1. RANGE: North America; Arizona, California, Idaho, Montana, Oregon, Nevada, Utah, and Wyoming (Wagner and Wagner 1993).

2. MONTANA DISTRIBUTION: *Botrychium crenulatum* is now reported from 19 sites in the northwestern part of the state in Flathead, Lake, and Lincoln Counties (Figure 2 inset).

3. OCCURRENCES ON THE KOOTENAI NATIONAL FOREST

a. CURRENT SITES: There are now 16 occurrences reported from the KNF, however, some sites are not represented by specimens, and there remain disagreements or uncertainty concerning the identities of some collections (see c. below). Most of the sites are in the eastern half of the Forest on the Fortine, Libby, and Rexford Districts, with single locations found on the Cabinet (reported on adjacent land owned by ASARCO) and Three Rivers Districts. Figure 2 shows the approximate locations of the 15 reported occurrences on the KNF. Element Occurrence Records and maps showing the precise locations are given in Appendix B.

Collections for which silhouettes were verified as *B. crenulatum* in 1995 (P. Zika, pers. commun.) come from Alexander Mountain (005), Basin Creek (004), Beaver Creek (007) and Chief Creek (009). Color photocopies of the specimens from Chief

figure 2

Creek were also verified by W. H. Wagner (pers. commun.). In 1996, collections were taken from Lime Creek (017), Stewart Creek (019), Watertrough Draw (012), and Wolverine Creek (013), and these were determined to be *B. crenulatum* based on comparison with the previous years verified collections. Information on collections, including collectors, collection numbers, herbaria where they are deposited, and annotation comments are included on the individual Element Occurrence Records in Appendix B.

b. HISTORICAL SITES: none

c. UNVERIFIED/UNDOCUMENTED REPORTS: A previously reported occurrence at Can Creek is now believed to be based on misidentification and has been deleted from the Biological Conservation Database. Several KNF sites remaining in the database are represented by specimens with contested or uncertain identity and others are not represented by specimens. Peter Zika identified silhouettes of specimens from Alexander Creek (010) and Bristow Creek (011) as *B. minganense*, and a specimen from Sunday Creek (018) as "*B. lunaria* ?". In my opinion, the plants at Alexander Creek, which grew in heavy shade, are etiolated forms of *B. crenulatum*. Widely spreading pinnae with crenulate margins, indicative of *B. crenulatum*, were more apparent in life than on photocopies of pressed specimens (see photographic slide 2 in Appendix I). The two specimens from Bristow Creek, collected by J. Reny, are difficult for me to identify. The specimen from Sunday Creek is a large "monstrosity" and may not be typical of the population; its calcareous roadside habitat is typical for *B. crenulatum*. The small plants collected from Swamp Creek (008) could not be positively identified as *B. crenulatum* by Zika. No collections are available from Sutton Creek (003) or Rock Creek (002), and the habitat of these occurrences is atypical for the species. In 1996, surveys of Sutton Creek located large numbers of five species of moonworts, but *B. crenulatum* was not found. Surveys of the Rock Creek site located no moonworts in 1996 (J. Elliott, pers. commun.). Plants from high elevations in the Whitefish Range (Bluebird Lake .015, Green Mountain .016), have been tentatively identified as *B. crenulatum*, but may belong to an undescribed taxon; similar plants have been found at high elevations elsewhere in Montana (T. Spribille, pers. commun.). Resolution of these dubious reports will require additional collections and consultation with experts.

d. AREAS SURVEYED BUT SPECIES NOT LOCATED: See Appendix A for a listing of areas which I searched for moonworts on the KNF in 1995 and 1996. Extensive additional surveys have been conducted by KNF personel.

E. HABITAT

1. ASSOCIATED VEGETATION: Wagner and Wagner (1993) describe the habitat of *B. crenulatum* throughout its range as "marshy and springy areas." In Oregon, it grows in marshy meadows and in the wettest microsites of mesic meadows (Zika 1994). In contrast, the species is reported from *Thuja plicata* habitats in Idaho and Washington

(Idaho Conservation Data Center and Washington Natural Heritage Program, pers. commun.)

On the KNF, the habitats of *Botrychium crenulatum* include wetlands dominated by native trees and shrubs and wet roadsides dominated by herbaceous exotic species. Ecodata plots of six occurrences with native vegetation are included in the *B. crenulatum* strata (Appendix C). Most of these sites are openings with wetland attributes, canopy dominance by deciduous trees or shrubs, and heavy ground cover by a high diversity of forbs and mosses. Climax vegetation (Hansen et al. 1995) includes *Picea/Cornus stolonifera* habitat types at Beaver Creek and Chief Creek, *Picea/Equisetum arvense* habitat type in the seral aspen stand at Swamp Creek, and *Thuja plicata* habitat types at Alexander Creek and Sutton Creek. The vegetation at Alexander Mountain was classified as an *Alnus sinuata* habitat type (Cooper et al. 1991, Hansen et al. 1995). The successional status of these openings is questionable. High water tables and occasional flooding may maintain these deciduous openings for relatively long periods. The Sutton Creek site is anomalous, with heavy canopy cover by *Thuja plicata*.

Tree cover in the plots is generally low to moderate (ca. 3-30%) except at Sutton Creek which has about 80% cover by *Thuja plicata*. *Picea* is constant and usually well represented (ca. 3-20% cover). Shrubs contribute moderate to high (ca. 20-90%) cover. Well represented shrubs and subshrubs in one or more plot include *Acer glabrum, Alnus incana, Alnus sinuata, Linnaea borealis, Rhamnus alnifolia, Rubus pubescens* and *Symphoicarpos albus*. Cover by grasses and sedges is low to moderate (1-20%) and mostly confined to areas outside the immediate moonwort habitat. The grass with highest constancy, *Elymus glaucus* was found in 50% of the plots. All plots have significant cover (ca. 20-80%) and diversity of forbs but few individual species are well represented. Forbs with relatively high constancy (>50%) include *Actaea rubra, Aralia nudicaulis, Clintonia uniflora, Galium triflorum, Mitella nuda, Pyrola asarifolia, Smilacina stellata,* and *Veronica americana*. Rattlesnake fern, *Botrychium virginianum,* was found in all plots. Moss cover is usually significant (ca. 3-80%). Mosses immediately associated with *Botrychium crenulatum* include species of *Brachythecium, Bryum, Drepanocladus, Hypnum*, and *Plagiomnium* (Appendix G).
Analysis of Ecodata using Strata (Appendix C) shows that the vegetation of *Botrychium crenulatum* sites on the KNF shares many attributes with that of *B. ascendens* sites (Appendix C). These two strata have relatively high indices of diversity, reflecting high shrub, forb, fern, and moss cover by a large number of species. In contrast, other sensitive moonworts on the KNF usually grow in habitats with high canopy cover by conifers (mostly *Thuja plicata*) and depauperate middle and lower vegetation layers. The vegetation at Sutton Creek is more similar to that of the forest dwelling moonwort species, and its inclusion in the *B. crenulatum* strata lessens these similarities and differences in the analysis.

Many of the known populations of *B. crenulatum* on the KNF (Basin Creek .004, Lime Creek .017, Stewart Creek .019, Sunday Creek .018, Water Trough Draw .012, Wolverine

Creek .013) are in old roadways or along active roads. These sites are dominated by exotic forbs and graminoids, but native wet site species are also present. Spruce seedlings are present at some of the roadside sites.

Plants tentatively identified as *B. crenulatum* from high elevations in the Whitefish Range grow in habitat quite different from the lowland occurrences on the KNF. These sites are rocky, open habitats dominated by native alpine forbs. These plants may belong to a different, undescribed taxon (T. Spribille, pers. commun.).

Throughout its range *B. crenulatum* is known to grow with the other moonworts *B. ascendens, B. lunaria, B. minganense,* and *B. simplex* (Wagner and Wagner 1993). At most sites on the KNF it grows alone, but it occurs with *B. ascendens* at Beaver Creek (007), with *B. minganense* at Swamp Creek (008), and nearby *B. lunaria* at Basin Creek (004).

Additional information on associated vegetation is provided in the general site description fields of the Element Occurrence Records in Appendix B and in the Ecodata tables in Appendix C.

2. TOPOGRAPHY: All but two populations were found at relatively low elevations ranging from 2,400 to 4,500 feet. These are in glaciated valley stream bottoms or along roads in glaciated valleys, where the altered hydrology may approximate natural wetland features. There is usually little or no slope to the sites, and their drainages have various aspects. At more mesic sites (e.g. Alexander Mountain .005), plants are scattered across flats, while at the wettest sites (e.g. Chief Creek .009) plants grow on mossy hummocks which rise above the water table. Two occurrences (Bluebird Lake .015, Green Mountain .016) are located at high elevations in the Whitefish Range at 6,840 and 7,700 feet, below rock ledges.

3. SOIL RELATIONSHIPS: More than those of other species of *Botrychium* on the KNF, the distribution of *B. crenulatum* seems to be related to soil conditions. While most of the other species usually grow in deep layers of litter and humus which are relatively well drained, the substrates of *B. crenulatum* usually have a significant mineral fraction, are usually calcareous, and are often poorly drained. At some roadside sites the substrate was described as compacted gravel. Most of the sites are within landtypes 322, 323, or 325 (Kuennen and Nielsen-Gerhardt 1995) with soils derived from calcareous alluvial deposits and glacial till. The lime is derived from the Precambrian Siyeh formation, which is mapped on the Kalispell $1° \times 2°$ quadrangle (Harrison et al. 1992) as the Helena formation, composed of dolomites and dolomitic siltites.

4. CLIMATE FACTORS: Moonworts in general are adapted to cool, moist climates. In Montana they are thus most common at low elevations in the northwest part of the state with its cool temperate, maritime influenced climate, while in semi-arid regions of the

state (e.g. Granite, Deer Lodge, and Lewis and Clark counties) they are mostly confined to higher elevations which receive heavy accumulations of snow. The concentration of *Botrychium crenulatum* occurrences are in the eastern part of the KNF, which has lower precipitation than the western part. The dryer climate may be a factor in the formation of calcareous soil types (see above) which are more prevalent in the eastern part of the Forest (L. Kuennen, pers. commun.). Climatic fluctuations may dramatically effect the phenology, numbers, and distribution of moonwort sporophytes which produce above ground leaves in a growing season. Because it grows in subirrigated habitats, *B. crenulatum* is likely to be less affected by precipitation during the growing season, and more affected by total annual precipitation.

F. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: Wagner and Wagner (1993) state that the leaves appear in middle to late spring and die in late summer and in dry years may be of shorter duration or not appear at all. Plants with immature sporophores were seen on the KNF as early as late June and senescent plants were found in late August. At high elevations in the Whitefish Range plants were found in late September. Compared to other species of moonworts on the KNF, *B. crenulatum* generally has earlier phenology, but this may be effected by seasonal climate and watertable status. Populations on sunny roadsides are the first to mature.

2. POPULATION SIZE AND CONDITION: Most population numbers reported from Montana are small (< 50 fronds), but a relatively large population with 100-200 fronds was found in Flathead County by T. Spribille. Numbers in Idaho are also small (Idaho Conservation Data Center, pers. commun.). In 1994 thousands of fronds were observed in a meadow in the Uinta Mountains of Utah (Utah Natural Heritage Program, pers. commun.) and some large populations are also reported from Washington (Washington Natural Heritage Program, pers. commun.). Many populations on the KNF are small but populations at Alexander Mountain (005), Alexander Creek (010), and Beaver Creek (007) were estimated to consist of about 100 fronds each in 1995. The Alexander Creek site had fewer fronds on the survey date in 1996, possibly because of dormancy or delayed phenology caused by a high water table at the site. Roadside sites at Basin Creek (004), Lime Creek (017), Stewart Creek (019), and Water Trough Draw (012) support over 40 plants apiece, demonstrating some success of the species in these habitats. All populations on the KNF cover less than 1 acre each. Population parameters for individual sites are reported in the size and element occurrence data fields of the Element Occurrence Records in Appendix B.

3. REPRODUCTIVE BIOLOGY: See the discussion of life history following the introduction to this report.

G. POPULATION ECOLOGY

1. COMPETITION: On the KNF, many *Botrychium crenulatum* sites have relatively high ground cover by shrubs, forbs, and mosses. Competition in these habitats is expected to be much higher than in the forested habitats of other moonwort species. It is possible that root zone competition is reduced by periodic flooding. At Alexander Creek (010) *B. crenulatum* grows under a dense shrub canopy (90%) and the moonworts are etiolated and probably have reduced reproductive capacity. Plants growing in sunny roadside habitats are often robust and have early, copious spore production.

   The occurrence of moonworts, including *Botrychium crenulatum*, in genus communities seems to run counter to the competitive exclusion principle, however, plant densities are usually so low that competition between moonwort species is not expected. Our observations also suggest that the individual species do have subtly different microhabitat preferences. For example, at Beaver Creek (007), where *B. crenulatum* and *B. ascendens* grew together, the six plants of *B. ascendens* were confined to a small area on the uphill edge of a swale, on the north side of the opening in spruce woods, while *B. crenulatum* occurred in greater numbers and was distributed in the bottom of the swale throughout the opening. Thus *B. crenulatum* may be adapted to slightly wetter, colder microsites; similar observations on microsite differences between these two species are reported from Oregon (Zika 1992). At many of its occurrences on the KNF *B. crenulatum* is the only moonwort, perhaps because of unique soil adaptations (see above).

2. POSITIVE INTERACTIONS: See the discussion of mycorrhizal relationships following the introduction to this report.

3. HERBIVORY: Herbivory of *Botrychium crenulatum* was not observed, but nibbled sporophores of other species of moonworts was noted on the KNF in 1995 and 1996. The clusters of sporangia are often selectively browsed leaving the trophophore intact. Small animals, possibly rabbits, rodents, or snails, may play a role in spore dispersal of moonworts (Zika 1992).

H. LAND OWNERSHIP: All but two populations in the vicinity are on KNF land, on the Eureka, Fortine, Libby and Three Rivers Districts. The Beaver Creek (007) population is on state land surrounded by the Fortine District and the Rock Creek (002) population is on ASARCO land adjacent to the Cabinet District.

I. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

1. THREATS TO CURRENTLY KNOWN POPULATIONS: The roadside populations at Basin Creek (004), Stewart Creek (019), and Sunday Creek (018) are potentially threatened by traffic, road maintenance, herbicide spraying, and trampling by cattle. At Basin Creek, the population was directly impacted in 1996 by skidding and decking of logs (L. Ferguson, M Arvidson, pers. commun.); the location of the population was known prior to administration of the sale. The populations in the old roadways at Lime

Creek (017), Water Trough Draw (012), and Wolverine Creek (013) would be threatened if the roads were reopened.

The intact native wetland habitats of *B. crenulatum* at other sites on the KNF are potentially impacted by road construction, logging, or other activities in their drainages, especially upstream, which may effect the sites' hydrology and/or access to the site by cattle, game, and humans. Road stream and draw crossings and log decks are often located along low gradient reaches where *B. crenulatum* and other sensitive plants (e.g. ladies slipper orchids) are most likely to be found. In 1996, road widening, log decking, and extensive soil disturbance occurred just above the Alexander Mountain (005) population, leaving the occurrence vulnerable to washouts and siltation. At Chief Creek (009) many plants were trampled in 1995, apparently by game, but possibly by people; this site had a conspicuously flagged trail leading to it. Weed invasions are another potential threat to the native habitats. Canada thistle (*Cirsium arvense*) was present in the sampled Ecodata plots at Alexander Mountain (005) and Beaver Creek (008), and the rhizomatous Kentucky bluegrass (*Poa pratensis*) was well represented in one plot at Swamp Creek (008).

2. MANAGEMENT PRACTICES AND RESPONSE: The occurrence of *Botrychium crenulatum* at roadside sites is an indication that the species is adapted to colonizing bare soil of disturbed sites. It is common on the KNF to observe many native wetland plants in roadside ditches, and among moonworts on the KNF, *Botrychium crenulatum* grows in the wettest habitats. *B. crenulatum* may also be resistant to cattle grazing, as evidenced by cattle grazing of roadsides where it grows on the Fortine District.

   At Alexander Mountain (005), the population is just below where a gravel road crosses the drainage and this population survives as perhaps the largest and healthiest on the KNF; it may be significant that a seep with standing water is located below the road and above the population, thus road construction may not have significantly altered the hydrology at this site. In 1996, this road was widened, a log deck was placed just above the population, and soil was disturbed on the roadway and in the cutting unit above; future effects on the population await to be determined. Recovery of the Basin Creek population following log skidding and decking on the site in 1996 also awaits determination.

3. MANAGEMENT SUMMARY: Management activities (i.e. log decking, skidding, and road widening without culvert maintenance) which may impact populations of *Botrychium crenulatum* occurred at two sites in 1996. Although effects have yet to be determined, these activities demonstrate a lack of communication or procedural inadequacies of timber sale administration. Proposals of management activities must not only assess potential impacts, but must outline steps to minimize these impacts. These steps should be outlined in writing on timber sale documents, and all persons concerned should be knowledgeable of population locations and steps to avoid impact.

Questions concerning the identities of reported *Botrychium crenulatum* occurrences remain and make assessment of vulnerability of the species difficult. Identification of plants in the field has been done by several workers, often specimens have not been collected or photographs taken, and even when collections were taken, they are sometimes in poor condition or in insufficient numbers for positive determination (P. Zika, pers. commun.). There are trends in geographical and ecological distribution of the species, but exceptions (e.g. highly disjunct occurrences and those in cedar and high elevation habitats) are incompletely studied, and the species, more than others, remains taxonomically difficult.

The priority for conservation management of this species on the KNF should be protection of native wetlands with significant known, verified populations (e.g. Alexander Mt. .005, Chief Creek .009) and further study of the species at questionable sites. Since *Botrychium crenulatum* is often not associated with genus communities a separate conservation strategy may be required for this species.

Mingan Island Moonwort
Botrychium minganense

A. CLASSIFICATION

1. FAMILY: Ophioglossaceae, a family of primitive ferns

2. GENUS: *Botrychium* subgenus *Botrychium*

3. SPECIES: *Botrychium minganense* Victorin. This a controversial species which has often been considered a variety of *B. lunaria*. The morphological and cytological distinctions between these two taxa are discussed in Wagner and Lord (1956). Throughout this report, the modern taxonomy of *Botrychium,* as represented in Wagner and Wagner (1993), is followed and *B. minganense* is recognized as a distinct species, however, it should be realized that disagreement continues. Many floras (e.g. Dorn 1992, Hitchcock and Cronquist 1976) designate plants referable to *B. minganense* as *B. lunaria* var. *onondagense* and many herbarium sheets of *B. minganense* are variously identified as *B. onondagense*, *B. lunaria* var. *onondagense*, *B. lunaria* var. *minganense*, or just *B. lunaria*. Taxonomic questions remain concerning this species, and what is now considered *B. minganense* in the west may include more than one cryptic taxa (Hauk 1995, W. Wagner, pers. commun.).

B. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL STATUS

a. U.S. FISH AND WILDLIFE SERVICE: none

b. U.S. FOREST SERVICE: Sensitive in Region 1 (U.S. Forest Service 1994a).

c. BUREAU OF LAND MANAGEMENT: none

2. STATE: The Montana Natural Heritage Program ranks the species G4 and S2S3 (Heidel 1996), signifying that it is apparently secure globally but imperiled or vulnerable because of rarity in Montana. It is recommended that state rank be changed to S3 to reflect the many populations discovered on the KNF in 1996. This is the point where most taxa are dropped from tracking by MTNHP, however, there are compelling reasons not to do this at this point. See the discussion under management summary in this status review and the status reccomendations at the end of this report.

C. DESCRIPTION

1. GENERAL NONTECHNICAL DESCRIPTION: Each year the sporophyte produces a single dull green, somewhat fleshy frond which is divided into two parts, a sterile

trophophore and a fertile sporophore, which share the same stalk. The frond is usually less than 6 inches tall and is often much smaller. The trophophore is pinnatifid with as many as ten pair of non-overlapping pinnae. The pinnae are variable but they are usually narrowly fan shaped and have nearly entire margins. The fertile leaf segment is longer than the sterile segment when mature and bears grape-like sporangia which, when mature, release thousands of spores which appear as yellow dust. Photographic slides showing sporophytes from several sites are included in Appendix I. The small gametophyte grows underground and is rarely seen or studied.

2. TECHNICAL DESCRIPTION: "Trophophore stalk 0-2 cm, 0 to 1/5 length of trophophore rachis; blade dull green, oblong to linear, 1-pinnate, to 10 X 2.5 cm, firm to herbaceous. Pinnae to 10 pairs, horizontal to slightly spreading, approximate to remote, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, basal pinna pair approximately equal in size and cutting to adjacent pair, occasionally basal pinnae and/or some distal pinnae elongate, lobed to tip, nearly circular, fan-shaped or ovate, sides somewhat concave, margins nearly entire, shallowly crenate, occasionally pinnately lobed or divided, apex rounded, venation like ribs of a fan with short midrib. Sporophores 1-pinnate, 2-pinnate in very large, robust plants, 1.5-2.5 times length of trophophore. $2n = 180$." from Wagner and Wagner (1993).

3. LOCAL FIELD CHARACTERS: *Botrychium minganense* is a variable species and is similar in appearance to *B. ascendens*, *B. crenulatum*, and *B. lunaria*. It can be distinguished from *B. ascendens* by its dull green color and usually spreading or slightly ascending rather than strongly ascending pinnae which usually have entire or broadly lobed rather than lacerate margins. However, KNF plants identified as *B. minganense* by W. H. Wagner (pers. commun.) have ascending pinnae and lacerate pinnae margins similar to *B. ascendens*, but color, texture, and habitat are typical of *B. minganense*. Similar plants have also been found on the Colville National Forest in Washington. *Botrychium minganense* differs from *B. crenulatum* by having dull green rather than yellow-green color, a more fleshy texture, and by often having more than 3 or 4 pairs of pinnae which are usually narrower and have entire rather than crenulate margins. It differs from *B. lunaria* by having narrower pinnae which do not overlap.

D. GEOGRAPHICAL DISTRIBUTION

1. RANGE: Transcontinental across northern North America, extending south in the western mountains; St. Pierre, Miquelon; Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Ontario, Prince Edward Island, Quebec, Saskatchewan, Yukon; Alaska, Arizona, California, Colorado, Idaho, Maine, Michigan, Montana, Nevada, New Hampshire, New York, North Dakota, Oregon, Utah, Vermont, Wisconsin, Wyoming (Wagner and Wagner 1993).

2. MONTANA DISTRIBUTION: In 1992 there were just seven known occurrences of *Botrychium minganense* in Montana (Achuff 1992) and by 1995, prior to commencement

of this project there were 23 occurrences in the Biological Conservation Database. Adding 1995 and 1996 documentations and discoveries on the KNF and elsewhere there are now at least 62 occurrences known in Montana. These are from the northwestern part of the state in Cascade, Flathead, Glacier, Granite, Lake, Lincoln, Missoula, and Teton counties (Figure 3 inset).

3. OCCURRENCES ON THE KOOTENAI NATIONAL FOREST

a. CURRENT SITES: There are now 53 populations of *Botrychium minganense* reported on the KNF with occurrences on all districts (Table 1). Sixteen of these are represented by specimens, silhouettes of which were verified by P. Zika (pers. commun.). Color photocopies of specimens from South Fork Big Creek and Sutton Creek were also verified by W. H. Wagner (pers. commun.). Most occurrences are in the northwestern part of the Forest. The approximate locations are shown in Figure 3. Element Occurrence Records and topographic maps showing the precise locations are given in Appendix B.

b. HISTORICAL SITES: One occurrence (North Fork Dodge Creek .041) on the Eureka District is represented only by a 1971 collection (labeled *B. lunaria* var. *onadogense*) deposited at the herbarium of the University of Montana (MONTU); I searched for but did not relocate this population in 1995.

c. UNVERIFIED/UNDOCUMENTED REPORTS: Peter Zika identified silhouettes of specimens, which we identified as *B. crenulatum*, from Alexander Creek and Bristow Creek as *B. minganense*. In my opinion, the plants at Alexander Creek, which grow in heavy shade, are etiolated forms of *B. crenulatum*. Widely spreading pinnae with crenulate margins, indicative of *B. crenulatum*, were more apparent in life than on photocopies of pressed specimens (see slide 2 in Appendix I). The two specimens from Bristow Creek, collected by J. Reny, are difficult for me to identify and I could not relocate the population in 1996. Element Occurrence Records in Appendix B treat these two occurrences as *B. crenulatum.* In 1996 W. H. Wagner (pers. commun.) identified plants from Othorp-Morgan Lake (066) with atypical morphology and habitat as *B. minganense* or possibly an undescribed species "*B. sublunaria*." Tom Desy (Three Rivers District) reported *B. minganense* from Door Skeels recreation area but I was unable to locate any plants in 1995 or 1996. Reports of unidentified moonworts from North Fork Parsnip Creek (B. Koncerak, pers. commun.) and Seventeenmile Creek (L. Ferguson, pers. commun.) may also be this species; these have not been entered in the BCD.

figure 3

d. AREAS SURVEYED BUT SPECIES NOT LOCATED: See Appendix A for a listing of areas which I searched for moonworts on the KNF.

E. HABITAT

1. ASSOCIATED VEGETATION: Throughout its range *Botrychium minganense* grows in a broad variety of moist habitats. In Michigan it usually grows in second growth deciduous forests (Wagner and Lord 1956). In Idaho it is reported from western red cedar, hemlock, grand fir, and lodgepole pine forest habitat types as well as from alder thickets (Lorain 1990, Idaho Conservation Data Center, pers. commun.). In Washington it is found mostly in riparian areas with western red cedar or mixed conifers but is also reported from rocky subalpine and alpine habitats (Washington Natural Heritage Program, pers. commun.). In Montana it is known from rocky alpine areas, montane grasslands, mossy lakeshores, alder thickets, and conifer and deciduous forests. Vegetation where *B. minganense* grows in the Ninemile Valley on the Lolo National Forest is *Thuja plicata/Oplopanax horridum* and *Thuja plicata/Clintonia uniflora* habitat types (Achuff 1992), also the predominant habitats on the KNF.

Botrychium minganense has the broadest ecological amplitude of the sensitive moonworts on the KNF, but most occurrences, including all large populations, are in mature stands of western red cedar and/or western hemlock. The most common habitats are *Thuja plicata/Oplopanax horridum*, *Thuja plicata/Clintonia uniflora*, and *Tsuga heterophylla/Clintonia uniflora* types. A few small populations of *Botrychium minganense* are also found on the KNF in *Abies lasiocarpa/Clintonia uniflora* habitat types (Weigel Creek .054, Upper Weigel Creek .061, Wiegel Mountain .055), an *Abies grandis/Clintonia uniflora* habitat type (Brush Creek .042), a seral aspen stand with *Picea/Equisetum arvense* potential (Swamp Creek .045), a *Picea/Cornus stolonifera* habitat type (Grave Creek Campground .047), and a heavily grazed *Agoseris stolonifera* disclimax next to an alkaline pothole (Othorp-Morgan Lake .066).

Ecodata from 18 plots are included in the *B. minganense* strata (Appendix C). Included are 15 plots with cedar or hemlock habitat types, and single examples of spruce, alder, and grazed meadow habitats. The strata has low indices of similarity, even though it does not represent the full range of habitats on the KNF.

In the *Thuja plicata* and *Tsuga heterophylla* habitat types canopy cover is usually high and is mostly contributed by medium to very large trees of these species. *Picea* has high constancy but is never abundant. The largest cedar at some sites (e.g. Red Top Creek .038, South Meadow Creek .014) are probably over 1,000 years old. At four sites (Beetle Creek .033, Hemlock Creek .037, Spread Creek .015, and Zulu Creek Pack Trail .031) in drainages which were mostly burned by fires early in this century, *Botrychium minganense* appears to be confined to old growth remnants missed by the fires, but at another site (Cedar Creek .027) the plants grow next to an old fire scarred, sawed stump in maturing second growth cedar. It is possible that fire intensity and its effects on the

duff layer and fungal communities are important factors which determine appropriate habitat for the species. One plot sampled at Bull River (047) is dominated by seral pole sized *Abies grandis*. Although clearcuts and stands of young trees adjacent to *B. minganense* populations were searched, no moonworts were found in these habitats (Appendix A).

In the cedar and hemlock habitats, understory cover by shrubs, graminoids, forbs, ferns, and mosses is usually low to moderate. Exceptions are sites in very old stands of cedar which have more open tree canopies and heavy cover by *Oplopanax horridum* and/or *Athyrium filix-femina*. Understory vascular plant species with high constancy (>50%) in Ecodata plots include the subshrub *Linnaea borealis*, the forbs *Actaea rubra*, *Clintonia uniflora*, *Galium triflorum*, *Orthilla secunda, Smilacina stellata*, *Streptopus amplexifolius*, *Tiarella trifoliata*, and *Trillium ovatum*, and the ferns *Athyrium filix-femina*, *Botrychium virginianum*, and *Gymnocarpium dryopteris*. Mosses collected in close association with *Botrychium minganense* include species of *Aulacomnium, Brachythecium, Dicranum, Eurhynchium, Mnium, Plagiomnium, Ptilium, Rhizomnium, Rhytidiopsis, Roellia*, and *Timmia* (Appendix G).

Throughout its range *Botrychium minganense* was reported growing with *B. echo*, *B. hesperium*, *B. lanceolatum*, *B. lunaria*, *B. matricariifolium*, *B. montanum*, *B. mormo*, *B. paradoxum*, and *B. pinnatum* (Wagner and Wagner 1983). On the KNF it grows with *B. ascendens*, *B. crenulatum*, *B. lanceolatum*, *B. montanum*, *B. paradoxum*, *B. pedunculosum* and *B. pinnatum*. *Botrychium minganense* and *B. montanum* are an especially common pair on the KNF, although they usually occupy slightly different microhabitats (see discussion of soil relationships below, and results from monitoring transects at French Creek in the Results section).

Additional information on associated vegetation is provided in the general site description fields of the Element Occurrence Records in Appendix B and in the Ecodata tables in Appendix C.

2. TOPOGRAPHY: On the KNF, *Botrychium minganense* grows at elevations ranging from 2,850 to 5,000 feet. The sites are usually in glaciated stream bottoms or are topographic microfeatures of glaciated slopes such as level benches, swales, and gentle slopes or draws with seeps or streamlets. The microsites are usually level and are in drainages with all aspects. Microtopography of many sites is undulating or patterned, caused by windthrow hummocks and buried rotten logs.

3. SOIL RELATIONSHIPS: At most sites the plants grow in thick layers of litter or humus rather than in soil, but at a few floodplain sites they grow in silty alluvium with a high organic fraction. The duff layers are expected to be acidic because they are derived from conifer, mostly cedar, leaves (L. Kuennen, pers. commun.), however, ground water at some sites may be calcareous. Two sites, Zulu Creek (028) and Can Creek (044), which support moonwort genus communities with *B. minganense* in significant numbers, lie in

drainages surrounded by the Helena formation composed of dolomites and dolomitic siltites (Harrison et al. 1992), which is associated with calcareous soils in the eastern part of the KNF; limy seeps and rivulets were observed at Can Creek. All but a few sites are within landtypes 352, 355, and 357 (Kuennen and Gerhardt 1984) with "soils formed in volcanic ash-influenced loess overlying dense glacial till."

Botrychium minganense often grows nearby *B. montanum*, but the two species seem to have slightly different microhabitat preferences, probably related to substrate moisture. At French Creek *B. montanum* grows mostly on the uphill side of a small seep while *B. minganense* is concentrated on the downhill side.

4. CLIMATE FACTORS: The majority of *Botrychium minganense* occurrences on the KNF are in the wetter western part of the Forest and most large populations are at relatively high elevations which receive heavy snow accumulation. Moonworts in general are adapted to cool, moist climates. In Montana they are thus most common at low elevations in the northwest part of the state with its cool temperate, maritime influenced climate, while in semi-arid regions of the state (e.g. Granite and Deer Lodge Counties) they are confined to higher elevations which receive heavy accumulations of snow. Climatic fluctuations may dramatically effect the phenology and numbers of moonwort sporophytes which produce above ground leaves in a growing season; in dry years fewer plants are expected to be found and the length of the growing season is expected to be shorter.

F. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: Wagner and Wagner (1993) state that leaves appear in spring through summer. On the KNF, plants were observed with immature sporangia from mid-July to late August, and plants with spores being released were observed as early as late July and as late as October. Data from monitoring transects at French Creek (021) show that *Botrychium minganense* has a staggered phenology of frond emergence (see results section). Individual plants of *Botrychium minganense* and *B. montanum* were mapped and measured in permanent belt transects in mid-July and again in early-September of 1995 and 1996. At the latter date in both years some fronds of both species had disappeared, some were nibbled, others had grown larger, and new fronds had emerged. *Botrychium minganense* has an earlier phenology than its often close associate *B. montanum*.

2. POPULATION SIZE AND CONDITION: Reported population numbers in Montana are usually small, most populations consisting of fewer than 50 plants and many with less than 10. Likewise, most of the 27 reported populations in Idaho consist of only a few plants, but a few have as many as 500 (Idaho Conservation Data Center, pers. commun.). Many large populations are reported from Washington (Washington Natural Heritage Program, pers. commun.).

On the KNF, the bulk of the populations consist of fewer than 50 plants but more significant numbers (50-200) were found in 1995 at Can Creek (044), French Creek (021), Kelsey Creek (025), Red Top Creek (038), and Zulu Creek (028). These large populations all occur in mature stands of western red cedar at relatively high elevations. Censuses in 1996 at most of these sites found fewer emergent fronds, but numbers at Kelsey Creek were about the same, possibly because the site is subirrigated. 1996 had lower summer precipitation but spring flooding resulted in persistent high water tables at wetland sites such as Kelsey Creek. A large, dense population was found in 1996 at the relatively low elevation floodplain of Sutton Creek (049), where other moonworts were previously reported. The largest populations cover 5 to 10 acres, while most others cover less than one acre. Population parameters for individual sites are reported in the size and element occurrence data fields of the Element Occurrence Records in Appendix B.

3. REPRODUCTIVE BIOLOGY: See the discussion of life history following the introduction to this report. *Botrychium minganense* is capable of vegetative reproduction by underground sporophytic propagules, called gemmae (Farrar and Johnson-Groh 1990), possibly explaining high densities and clumps of this species which are sometimes seen on the KNF.

G. POPULATION ECOLOGY

1. COMPETITION: In the western red cedar habitats where *Botrychium minganense* is most common on the KNF, competition for light is high, but rootzone competition is low. Increased competition may be a factor in the apparent exclusion of *Botrychium minganense* from a clearcut at Red Top Creek (038). At this site, *B. minganense* grows in intact *Tsuga heterophylla* habitat surrounding a clearcut in the same habitat type and having similar topographic features. The clearcut was thoroughly searched for moonworts by two people for a total of over 5 hours, concentrating on swales with seeps, but none were found. When the clearcut was left, *B. minganense* was found within minutes. Ecodata plots were sampled in the moonwort habitat and in a swale within the clearcut without moonworts (Appendix C). The most obvious differences between these paired plots are 1) decreased canopy cover by trees in the clearcut 2) increased ground cover by wood and a corresponding decrease in litter cover in the clearcut, and 3) increased cover by shrubs, forbs, graminoids, ferns, and mosses in the clearcut.

The occurrence of moonworts, including *Botrychium minganense*, in genus communities seems to run counter to the competitive exclusion principle, however, plant densities are usually so low that competition between moonwort species is not expected. Our observations also suggest that the individual species have subtly different microhabitat preferences (see discussion of soil relationships above). At Zulu Creek, however, several plants of *B. minganense* grew within inches of a single plant of *B. paradoxum* in apparently equivalent habitat, suggesting that *B. minganense* may have a competitive advantage over *B. paradoxum* in this habitat. The opposite may be true at Cub Ridge in

the Anaconda Range, where *B. paradoxum* is the dominant moonwort and only a few plants of *B. minganense* were found (Vanderhorst 1993).

2. POSITIVE INTERACTIONS: All *Botrychium* species are believed to be obligately dependent on mycorrhizal relationships in both the gametophyte and sporophyte generations. See the discussion of mycorrhizal relations following the Introduction of this report. Although assumptions of randomness were not met, statistically significant positive close associations were found in microplots at Zulu Creek between *B. minganense* and *Osmorhiza chilensis*, *Tiarella trifoliata*, and *Viola glabella* (L. Crone, pers. commun.). These associations may be an indication of shared habitat preferences (e.g. wet microsites) or could be a manifestation of mycorrhizal links between the moonworts and these forbs.

c. HERBIVORY: Herbivory of *Botrychium minganense* was observed and documented at French Creek (021) in 1995 and 1996 (see Results section), and has been reported elsewhere for moonworts in general (Zika 1992). The clusters of sporangia are often selectively browsed leaving the trophophore intact. Small animals, possibly rabbits, rodents, or snails, may play a role in spore dispersal of moonwort species (Zika 1992).

H. LAND OWNERSHIP: All but one population documented in this report are on KNF land. Populations are known from all Districts. The occurrence at East Pipe Creek (036) is on Plum Creek Timber land. The Houghton Creek site (022), which also hosts the extremely rare *Botrychium ascendens*, was proposed for a land exchange with Plum Creek Timber, but 160 acres were removed from the exchange to protect the moonworts (U.S. Forest Service 1995, 1996).

I. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

1. THREATS TO CURRENTLY KNOWN POPULATIONS: A subpopulation at French Creek (021) is included in a proposed timber sale and the status of the unit has not been resolved (L. Ferguson, pers. commun.). Most of the population area at Red Top Creek (038) was within a unit prescribed for a clearcut which had already been sold, but logging of the unit was discontinued five years ago when wildfires broke out nearby; the timber has since been bought back by the KNF and logging will not proceed (L. Ferguson, pers. commun.). Of the five largest known populations on the KNF, Zulu Creek (028) is protected as designated old growth and part of Kelsey Creek (025) is protected as a Botanical Special Interest Area, but the others are designated as suitable timberland (USDA Forest Service 1987). The boundaries of the Kelsey Creek Botanical Area do not encompass a large portion of the population of *Botrychium minganense* and *B. montanum* and was erroneously established to protect *B. crenulatum* which does not occur at the site. Many of the occurrences of *B. minganense* located in 1996 are within proposed timber sale boundaries.

2. MANAGEMENT PRACTICES AND RESPONSE: Our searches for moonworts in a variety of habitats, including paired searches of altered habitat adjacent to known populations (Appendix A), demonstrate that *Botrychium minganense* on the KNF is primarily a species of maturing to old growth stands of western red cedar. Although the species is known to grow in second growth deciduous forests in Michigan (Wagner and Lord 1956) and was found in maturing second growth cedar on the KNF at Cedar Creek (027), it has not been found in recently logged areas or in units with young regeneration. It is likely that logging will at least temporarily eliminate the species from an area. Data on fire relations are somewhat contradictory (see discussion of associated vegetation above) but suggest that fire will also exclude moonworts from a site and this effect may be long lasting.

3. MANAGEMENT SUMMARY: The many populations of *Botrychium minganense* which were documented on the KNF in 1995 required that the state rank designated by the Montana Natural Heritage Program be elevated from S1 to S2S3 (Heidel 1996). With several more populations found in 1996, it is now recommended changed to S3. The species occurs in many but not all mature cedar stands and in a range of other moist habitats and there is a high probability that additional populations will be found on the KNF. Relatively few occurrences are known in Montana outside the KNF, however this may be an artifact of sensitive plant budgets and survey intensity.

In spite of these many recent discoveries retention of Forest Service Sensitive status and continued tracking by MTNHP is recommended at this time for the following reasons: 1) *B. minganense* often occurs in genus communities with other more rare species of moonworts and initial surveys have not always found all species which occupy a site. For example, at Houghton Creek (022) where *B. minganense* was reported, a follow-up survey located the rare *B. ascendens*. Likewise, *B. paradoxum* was found where *B. minganense* was known at Zulu Creek (028) and a state record of *B. pedunculosum* was located at South Fork Big Creek (046). The inadequacy of a single survey stems from survey intensity, the staggered phenology within and between species, and the possibility of plants remaining below ground in some years. 2) Misidentification of moonworts in the fan-leaved group is common. For example, the population of *B. crenulatum* at Chief Creek (009) was originally identified as *B. minganense*. 3) Taxonomic questions concerning the species remain. *Botrychium minganense* is a highly variable species and is viewed by many workers as a "garbage can" taxon. Western "*B. minganense*" may be distinct from the eastern taxon (W. H. Wagner, pers. commun.). Description of new moonwort species in the fan-leaved group is currently in progress (K. Ahlenslager, W. H. Wagner, pers. commun.). The entity now considered *B. minganense* may be better considered as more than one cryptic taxa; genetic tests and additional taxonomic revision are awaited to resolve this confusion.

Populations with large numbers of *B. minganense* tend to harbor additional species of moonworts, thus conservation efforts should be focused on identifying and protecting these occurrences. The Botanical Special Interest Area at Kelsey Creek (025) protects

part of a significant population of *B. minganense* and *B. montanum* but the boundaries do not contain the entire population. Significant genus communities with *B. minganense* at Can Creek (044), French Creek (021), Parsnip Creek (059), Red Top Creek (038), Sutton Creek (049), and Zulu Creek (028) should also be considered for designation as Special Interest Areas.

Mountain Moonwort
Botrychium montanum

A. CLASSIFICATION

1. FAMILY: Ophioglossaceae, a family of primitive ferns

2. GENUS: *Botrychium* subgenus *Botrychium*

3. SPECIES: *Botrychium montanum* Wagner, described in Wagner and Wagner (1981).

B. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL

a. U.S. FISH AND WILDLIFE SERVICE: none

b. U.S. FOREST SERVICE: Sensitive in Region 1 (U.S. Forest Service 1994a).

c. BUREAU OF LAND MANAGEMENT: none

2. STATE: The Montana Natural Heritage Program ranks the species G3S2 (Heidel 1996), signifying that it is vulnerable to extinction throughout its range and imperiled in Montana.

C. DESCRIPTION

1. GENERAL NONTECHNICAL DESCRIPTION: *Botrychium montanum* is a small perennial fern with a single above ground frond. The frond varies in height up to about 12 cm tall, is a dull glaucous gray-green, somewhat succulent, and divided into two segments which share a relatively short common stalk. The sterile segment is once pinnatifid with well separated, irregular, angular, ascending lobes with entire or toothed margins. The fertile segment is longer than the sterile segment, is branched, and bears grape-like sporangia. Spores germinate underground and develop into minute subterranean, non-photosynthetic gametophytes. Photographic slides of the sporophytes from several KNF sites are provided in Appendix I.

2. TECHNICAL DESCRIPTION: "Trophophore stalk 0.3-2 cm, 0.2-0.5 times the length of the rachis; blade dull, glaucus, gray-green, mostly linear, lobed to 1-pinnate, to 6 X 0.7 cm, somewhat succulent. Pinnae or lobes to 6 pairs, ascending, mostly widely separated, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, extremely variable in outline, linear to cuneate, undivided to tip, margins entire to coarsely dentate, distal pinnae or blade tip cut into 3-5 lobes, apex angular, venation like

ribs of a fan, midrib absent. Sporophores 1-pinnate, 1.5-4.5 times length of sporophore. 2*n* = 90." (Wagner and Wagner 1993)

3. LOCAL FIELD CHARACTERS: Glaucous gray green color, succulent texture, a relatively short common stalk, and irregular angular lobes rather than distinct pinnae are diagnostic of *B. montanum*. Among the moonworts of Montana, *B. montanum* is relatively easily recognized, but may be mistaken for *B. ascendens* and small plants may be confused with other species.

D. GEOGRAPHICAL DISTRIBUTION

1. RANGE: Western North America; British Columbia, California, Montana, Oregon, Washington (Wagner and Wagner 1993), Idaho (Idaho Conservation Data Center, pers. commun.).

2. MONTANA DISTRIBUTION: *Botrychium montanum* is now documented in the Biological Conservation Database (BCD) from 31 sites in northwestern Montana in Flathead (4 occurrences), Lake (3 occurrences), Lincoln (23 occurrences) and Sanders (1 occurrence) counties (Figure 4 inset). In addition, while examining moonwort specimens at the herbarium of the University of Montana, I found 9 collections of *B. montanum* which were identified as *B. simplex* prior to the description of *B. montanum*. These are from Lake County and Glacier National Park and some are from locations already in the BCD and cited in the description of the species (Wagner and Wagner 1981). I annotated these specimens and put them in the *B. montanum* folder which was previously empty; those which represent new locations will be entered in the BCD.

3. OCCURRENCES ON THE KOOTENAI NATIONAL FOREST

a. CURRENT SITES: Prior to 1995, three occurrences of *B. montanum* were documented in the BCD, all in the drainage of Can Creek on the Three Rivers District. In 1995, these were relocated and 13 more populations were discovered, and in 1996, 8 more populations were found making a total of 24. There are known occurrences on all Districts but most are in the northwestern part of the Forest on the Three Rivers District (Table 1). Figure 4 shows the approximate locations of the occurrences on the KNF. Element Occurrence Records and topographic maps showing the precise locations are given in Appendix B.

b. HISTORICAL SITES: none

c. UNVERIFIED/UNDOCUMENTED SITES: none

d. AREAS SURVEYED BUT SPECIES NOT LOCATED: See Appendix A for a list of areas on the KNF which I surveyed for moonworts.

figure 4

HABITAT

1. ASSOCIATED VEGETATION: Wagner and Wagner (1981) state that "it is most abundant in moist, springy western red cedar (*Thuja plicata*) forests." They also report the species from a high elevation grassy trailside at Logan Pass. Nearly all Montana, Idaho (Idaho Conservation Data Center, pers. commun.), and Washington (Washington Natural Heritage Program, pers. commun.) occurrences are in *Thuja plicata* or *Tsuga heterophylla* habitat types. In Oregon, the species has been found in 10 year old clearcuts with regeneration on the Umatilla National Forest (D. Pavek, pers. commun.) and in partially shaded mesic meadows in the Wallowa Mountains (Zika and Alverson 1996).

   Most of the sites on the KNF are in maturing to old growth western red cedar stands. Habitat types include *Thuja plicata/Clintonia uniflora*, *Thuja plicata/Oplopanax horridum, Thuja plicata/Athyrium filix-femina,* and *Tsuga heterophylla/Clintonia uniflora* (Cooper et al. 1991, Pfister et al. 1977). Average tree age of the dominant layer in 9 forested Ecodata plots with *B. montanum* (Appendix C) ranges from 49 to 210 years. At Berray Mountain (017), where *B. montanum* was the only moonwort found, some ancient cedars are probably over 1,000 years old. At Cedar Creek (014) *B. montanum* grows in second growth cedar in an area that burned in the early 1900's, at Can Creek (011) part of a population grows under a dense canopy of pole sized seral conifers (*Picea* and *Abies* sp.), and at Pipe Creek (016) a few plants grow on an old skidtrail. Clearcuts of the same habitat type and topography as and adjacent to *B. montanum* populations were searched at Clay Mountain (019) and Red Top Creek (022) but no moonworts were found. In 1996, a single *B. montanum* plant was found in an anomalous habitat for the KNF at Houghton Creek (026) where it grows nearby *B. ascendens* in a shrub dominated wetland.

   Canopy cover in the cedar habitats is usually high, while ground cover by forbs and graminoids is usually low. Understory vascular plant species with high constancy (>50%) in sampled Ecodata plots (Appendix C) include *Actaea rubra, Athyrium filix-femina, Botrychium minganense, B. virginianum, Chimaphilla umbellata, Clintonia uniflora, Galium triflorum, Goodyera oblongifolia, Gymnocarpium dryopteris, Linnaea borealis, Orthilla secunda, Rosa woodsii, Rubus parviflorus, Smilacina stellata, Streptopus amplexifolius, Tiarella trifoliata,* and *Trillium ovatum*. On the KNF, *Botrychium montanum* grows by itself and with the other moonworts B. *ascendens, B. lanceolatum, B. minganense, B. pinnatum,* and *B. pedunculosum.*

   Botrychium *montanum* is often the only plant growing in dense litter of cedar leaves in deep shade, but also grows among mosses. Closely associated mosses include species of *Aulacomnium, Brachythecium, Dicranum, Eurhynchium, Mnium, Plagiomnium, Pleurozium, Ptilium, Rhizomnium, Rhytidiopsis, Roellia, Sanionia,* and *Timmia* (Appendix G).
   Additional information on associated vegetation on the KNF is described in the general site description fields of the Element Occurrence Records in Appendix B and in the

Ecodata tables in Appendix C. Photographic slides of the vegetation at several sites are provided in Appendix I.

2. TOPOGRAPHY: Throughout Montana, *Botrychium montanum* occurs in the western mountains at elevations ranging from 2,960 to 6,000 feet. On the KNF it grows in glaciated stream bottoms and in swales, draws and on benches of glaciated slopes at elevations ranging from 2,600 to 4,950 feet. The species is usually associated with small hydrological features such as seeps, rivulets, draws, and swales and the microtopography is usually level or patterned.

3. SOIL RELATIONSHIPS: *Botrychium montanum* almost always grows in organic substrates, usually composed of cedar (*Thuja plicata*) leaves or decomposed wood. At West Pipe (013) it also grew in partially decomposed layers of alder (*Alnus* sp.) leaves. These organic substrates are expected to be acidic (L. Kuennen, pers. commun.) although ground water and underlying soils at some sites may be calcareous. Most sites are within landtype 352 (Kuennen and Gerhardt 1984) which has underlying soils derived from volcanic ash-influenced loess overlying dense glacial till. Calcareous groundwater may occur in the Can Creek (009, 010, 011) and Zulu Creek (015) drainages whose headwaters are within the Helena formation geological mapping unit (Harrison et al. 1992) composed of dolomites and dolomitic siltites; calcium laden seeps were observed at Can Creek. At West Pipe (013) the soils and groundwater are also likely to be calcareous as the site is within landtype 329 (Kuennen and Gerhardt 1984).

   Although they often grow nearby, *Botrychium montanum* and *B. minganense* have discrete microhabitat preferences which differ in substrate characteristics, *B. montanum* usually growing in somewhat dryer microsites. At French Creek (020) *B. montanum* grows mostly on the uphill side of a seep while *B. minganense* is concentrated on the downhill side. *Botrychium montanum* has been observed growing in lines down moss covered, decomposed, buried logs. These observations suggest that its distribution is controlled by substrate composition and moisture, possibly related to the presence of a fungal symbiont.

4. CLIMATE FACTORS: *Botrychium montanum* is most common in relatively low elevation areas in northwestern Montana with maritime influenced climates which support western red cedar; average annual precipitation in these habitats is 32 inches or more (Pfister et al. 1977). On the KNF, the species is mostly confined to the wetter, western part of the Forest. Climatic fluctuations may dramatically effect the phenology and numbers of moonwort sporophytes which produce above ground leaves in a growing season; in dry years fewer plants can be expected to be found and the length of the growing season is expected to be shorter.

F. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: Wagner and Wagner (1993) state that leaves appear from late spring to late summer. Data from monitoring transects at French Creek (020) show that *Botrychium montanum* has a staggered phenology of frond emergence (see results section). Individual plants of *Botrychium montanum* and *B. minganense* were mapped and measured in permanent belt transects in mid-July and again in early-September of 1995 and 1996. At the latter date in both years some fronds of both species had disappeared, some were nibbled, others had grown larger, and new fronds had emerged. *Botrychium montanum* has an later phenology than its often close associate *B. minganense*. Plants observed in September at French Creek (020) and Sutton Creek (004) still had mostly indehiscent sporangia.

2. POPULATION SIZE AND CONDITION: Wagner and Wagner (1981) state that "a single locality may have hundreds of plants in a small area." High population numbers and densities were observed on the KNF at French Creek (020, see the general results section and Appendix D), Kelsey Creek (012), and Sterling Creek (028) but most populations had less than 100 plants and 12 populations had less than 20 plants.

3. REPRODUCTIVE BIOLOGY: See discussion of life history following the Introduction of this report. *Botrychium montanum* has recently been shown to be capable of vegetative reproduction by underground sporophytic gemmae (Camacho 1996 and pers. commun., see results section). Vegetative reproduction may be responsible for the high densities often observed in populations of this species.

G. POPULATION ECOLOGY

1. COMPETITION: *Botrychium montanum* is often the only plant growing in deep duff layers under heavy cedar canopies. These habitats have high competition for light, but low root zone competition. Increased competition may be a factor in the apparent exclusion of *Botrychium montanum* and *B minganense* from a clearcut at Red Top Creek (022). Ecodata plots were sampled in the moonwort habitat and in a swale within the clearcut without moonworts (Appendix C). The most obvious differences between these paired plots are 1) decreased canopy cover by trees in the clearcut 2) increased ground cover by wood and a corresponding decrease in litter cover in the clearcut, and 3) increased cover (competition) by shrubs, forbs, graminoids, ferns, and mosses in the clearcut.

   The occurrence of moonworts, including *Botrychium montanum,* in genus communities seems to run counter to the competitive exclusion principle, however, plant densities are usually so low that competition between moonwort species is not expected. Our observations also suggest that the individual species do have subtly different microhabitat preferences (see discussion of soil relationships above).
2. POSITIVE INTERACTIONS: All *Botrychium* species are believed to be obligately dependent on mycorrhizal relationships in both the gametophyte and sporophyte generations. See the discussion of mycorrhizal relations following the introduction of

this report. The high habitat fidelity of *B. montanum* to cedar habitat types and its local distribution along buried logs suggests it is associated with a fungus associated with these habitats.

3. HERBIVORY: Nibbled sporophores and sometimes entire plants of *Botrychium montanum* were observed at several sites and were quantified at French Creek (see Results section and Appendix D). Often the sporophore is selectively browsed leaving the trophophore intact. Small animals, possibly rabbits, rodents, or snails, may play a role in spore dissemination (Zika 1992). One plant of *B. montanum* was observed in which "pruning" by nibbling apparently caused abnormal regrowth of the moonwort with sporangia borne on the trophophore.

H. LAND OWNERSHIP: All occurrences in the vicinity are on the Kootenai National Forest.

I. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

1. THREATS TO CURRENTLY KNOWN POPULATIONS: A subpopulation at French Creek (020) was included in a proposed timber sale and the status of this unit is unresolved (L. Ferguson, pers. commun.). The population at Red Top Creek (022) lies within a unit prescribed for a clearcut which was sold, but logging of the unit was discontinued five years ago when wildfires broke out nearby; since then, the standing timber has been bought back by the KNF and logging will not proceed (L. Ferguson, pers. commun.). Several populations were found in proposed cutting units in 1996.

2. MANAGEMENT PRACTICES AND RESPONSE: Clearcuts of the same habitat type and topography as and adjacent to *Botrychium montanum* populations were searched at Clay Mountain (019) and Red Top Creek (022) but no moonworts were found. The species appears to have a high fidelity to cedar habitats with high canopy cover and deep litter layers and it is expected that disturbance by logging and/or fires will at least temporarily exclude it from an area. It has been found in an old logged and burned area at Cedar Creek (014) and in an old skid trail at Pipe Creek (016); both sites have reestablished canopy and litter cover. At Sterling Creek (028) *B. montanum* is frequent in the oldest groves but drops out in adjacent younger late seral stands although shade regime is the same (T. Spribille, pers. commun.). On the KNF *Botrychium montanum* is probably adapted to middle to late seral stages of cedar and hemlock habitat types. In contrast, the species occurs in 10 year old clearcuts on the Umatilla National Forest in Oregon (D. Pavek, pers. commun.).

3. MANAGEMENT SUMMARY: Current State rank (S2) and Forest Service Sensitive status remain appropriate. Although high population numbers and densities were observed at some sites on the KNF and are reported elsewhere (Wagner and Wagner 1981) most populations on the KNF are small. Most of the largest populations are in management areas designated as suitable timberland (U.S. Forest Service 1987). Many

populations of *Botrychium montanum* are on forested slopes or at topographical and hydrological microfeatures not protected by standard riparian guidelines (U.S. Forest Service 1994b). Clearcutting or burning a population area is likely to extirpate the species from the site at least temporarily but it may be able to recolonize maturing second growth.

Conservation management should prioritize large populations and genus communities. The Botanical Special Interest Area (Management Area Maps, Kootenai National Forest, Libby) at Kelsey Creek (012) protects part of a significant population of *B. minganense* and *B. montanum* but the boundaries do not contain the entire population. The Clay Mountain (019) and Berray Mountain (017) populations are also protected as Botanical Special Interest Areas but few plants were found at these sites in 1995. Significant genus communities with *B. montanum* at South Fork Big Creek (029), Can Creek (011), French Creek (021), Parsnip Creek (030), Red Top Creek (038), Sterling Creek (028), Sutton Creek (024), and Zulu Creek (028) should also be considered candidates for designation as Special Interest Areas.

Peculiar Moonwort
Botrychium paradoxum

A. CLASSIFICATION

1. FAMILY: Ophioglossaceae, a family of primitive ferns

2. GENUS: *Botrychium* subgenus *Botrychium*

3. SPECIES: *Botrychium paradoxum* Wagner, described in Wagner and Wagner (1981).

B. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL

a. U.S. FISH AND WILDLIFE SERVICE: Previously recognized as C2 (U.S. Dept. of Interior 1993), indicating that it was a species "for which information now in the possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which sufficient data on biological vulnerability and threat are not currently available to support proposed rules." Recognition of C2 species was officially discontinued by the Service in 1996 (U.S. Fish and Wildlife Service 1996).

b. U.S. FOREST SERVICE: Sensitive in Region 1 (U.S. Forest Service 1994a).

c. BUREAU OF LAND MANAGEMENT: none

2. STATE: The Montana Natural Heritage Program ranks the species G2 and S1 (Heidel 1996), indicating that it is imperiled because of rarity throughout its range and critically imperiled due to extreme rarity in Montana.

C. DESCRIPTION

1. GENERAL NON-TECHNICAL DESCRIPTION: *Botrychium paradoxum* is a small perennial fern with a single above ground frond. The frond varies in height up to about 15 cm tall, is glaucous green, somewhat succulent, and divided into two similar segments which share a common stalk. The segments may be unbranched in small plants or branched in larger plants and are both fertile and bear grape-like sporangia. Spores germinate underground and develop into minute, subterranean, non-photosynthetic gametophytes. A photographic slide (# 40) of a plant from Zulu Creek (010) is provided in Appendix I.

2. TECHNICAL DESCRIPTION: "Trophophores converted entirely to second fertile segment, stalk 1/2 length of fertile segment. Sporophores double, 2 per leaf, 1-pinnate, 0.5-4 cm. 2*n* = 180." (Wagner and Wagner 1993)

3. LOCAL FIELD CHARACTERS: *Botrychium paradoxum* is perhaps the easiest of moonworts to recognize, being the only species to lack a sterile laminar frond segment, but other species could be mistaken for it if the sterile segment has been browsed or bears marginal sporangia.

D. GEOGRAPHICAL DISTRIBUTION

1. RANGE: Alberta, British Columbia, Saskatchewan, Montana, and Utah (Wagner and Wagner 1993), Oregon (Zika 1992), Washington (Washington Natural Heritage Program, pers. commun.).

2. MONTANA DISTRIBUTION: There are currently ten records of *Botrychium paradoxum* in the Biological Conservation Database (Figure 5 inset). These include one population from the Rocky Mountain Front Range (Teton County), three populations in the Anaconda Range (Granite and Deer Lodge Counties), three populations in or near Glacier National Park (Flathead, Glacier, and Pondera Counties), and three populations in the Purcell Range (Lincoln County). The record from Marias Pass near Glacier Park could not be relocated by a survey in 1986.

3. OCCURRENCES ON THE KOOTENAI NATIONAL FOREST

a. CURRENT SITES: *Botrychium paradoxum* has been found at three nearby sites on the Three Rivers District at Can and Zulu Creeks (Figure 5). The species could not be relocated in 1995 at the two Can Creek sites where it was first seen on the Forest in 1993. It was found in 1995 at Zulu Creek where other moonworts were previously known. The Zulu Creek occurrence is represented by a specimen (deposited at MONTU) and a photograph (slide #40 in Appendix I). Exhaustive surveys were conducted at all three sites in 1996 but no *B. paradoxum* plants were relocated.

b. HISTORICAL SITES: none

c. UNVERIFIED/UNDOCUMENTED REPORTS: The two Can Creek occurrences could not be relocated in 1995 or 1996 by thorough searches of the entire drainage and are not documented by specimens or photographs. However, the species is not easily mistaken for other moonworts and the reports are believed to be accurate (L. Ferguson, pers. commun.).

d. AREAS SURVEYED BUT SPECIES NOT LOCATED: See Appendix A for a list of areas which I searched for moonworts.

figure 5

E. HABITAT

1. ASSOCIATED VEGETATION: The habitats of *Botrychium paradoxum* throughout its range are diverse, but most sites outside the Kootenai National Forest are montane to sub-alpine grasslands or forb dominated meadows. In the Anaconda Range where the species is known in most abundant numbers, it grows in grasslands dominated by *Festuca scabrella, Festuca idahoensis,* and *Carex raynoldsii* (Vanderhorst 1993). *Fragaria virginiana* is a conspicuous close associate at the Anaconda Range sites and in the Wallowa Mountains in Oregon (Zika 1992). The open grassland habitats are described as sunny (Wagner 1981, Zika 1992, 1994), but in the Anaconda Range, *B. paradoxum* grows in the shade of dense cover of tall bunchgrasses. The vegetation at the Marias Pass site was a dense stand of *Epilobium angustifolium* (fire weed). In the Rocky Mountain Front Range the habitat is dominated by seral forbs. In 1996, Peter Lesica found a population in Glacier National Park in an area burned in 1988, now dominated by native fescue bunchgrasses. In Utah the species was collected from subalpine "meadows" (Utah Natural Heritage Program, pers. commun.) and in Oregon all occurrences are in mesic meadows (Zika 1994). In Washington it grows in meadows and in forests (Washington Natural Heritage Program, pers. commun.) Wagner and Wagner (1993) state that *B. paradoxum* usually grows "in snowfields and secondary growth pastures."

Vegetation at the three locations of *B. paradoxum* on the Kootenai National Forest is a marked contrast to the open habitats described above. Here the species grows in *Tsuga heterophylla/Clintonia uniflora* (western hemlock/queencup beadlily) and *Thuja plicata/Clintonia uniflora* (western red cedar/queencup beadlily) habitat types (Phister et al. 1977, Cooper et al. 1991). *Botrychium paradoxum* has also been found in cedar and hemlock habitat types in Washington (Washington Natural Heritage Program, pers. commun.).

The three KNF sites were sampled by Ecodata plots (Appendix C), but the locations of the plots at the Can Creek sites only approximate the precise locations of the rare moonwort which was not seen in the year of sampling. Canopy cover at the sites, contributed mostly by *Thuja plicata*, ranges from 70-90% and average age of the dominant tree layer ranges from 120-210 years. *Tsuga heterophylla* is successfully reproducing in the Can Creek plots and *Picea* is present in all three plots. There is little cover by shrubs, but *Ribes lacustre* and the subshrub *Linnaea borealis* occur at all three sites. Vegetative ground cover is low to moderate, dominated by forbs and mosses. Forbs present at all three sites include *Actaea rubra, Chimaphilla umbellata, Clintonia uniflora, Galium triflorum, Streptopus amplexifolius,* and *Trillium ovatum.* The fern *Botrychium virginianum* is present at all sites. In a microplot at Zulu Creek (Appendix C) *B. paradoxum* grew in immediate association with *Botrychium minganense, B. virginianum, Tiarella trifoliata,* and *Viola glabella.*

On the KNF, *Botrychium paradoxum* has been found growing with the other moonworts *B. minganense, B. montanum,* and *B. pinnatum*. Throughout its range, *B. paradoxum* has

been reported growing with *B. hesperium, B. lanceolatum, B. lunaria, B. minganense, B. pinnatum, B. pedunculosum* and *B. simplex* (Vanderhorst 1993, Wagner and Wagner 1983, Zika 1992).

Associated vegetation of the three Kootenai National Forest sites is described in detail in the general site description fields of the Element Occurrence Records in Appendix B and in the Ecodata tables in Appendix C. A photographic slide of the vegetation at Zulu Creek is provided in Appendix I.

2. TOPOGRAPHY: In Montana, *Botrychium paradoxum* grows on glaciated slopes and ridgetops, and in glaciated lake basins, stream bottoms and draws at elevations ranging from 3,700 to 8,400 feet. On the Kootenai National Forest, the known sites are in west facing drainages of tributaries of the South Fork Yaak River at elevations ranging from 3,700 to 4,600 feet. Two sites are in flat stream bottoms and the third is in a gently sloping draw with an ephemeral stream and seeps. Microtopography of the sites is patterned, caused by windthrow hummocks, old rotten logs, and streamlet channeling.

3. SOIL RELATIONSHIPS: On the Kootenai National Forest, the Can Creek sites (008, 009) are within landtype 352 and the Zulu Creek (010) site is in landtype 357. Soils from both these landtypes are described as "formed in volcanic ash-influenced loess overlying dense glacial till" (Kuennen and Nielsen-Gerhardt 1995). However, the plants grow in thick layers of litter or humus rather than in soil, and the underlying soils of the riparian microhabitats are influenced by alluvial deposition. At Zulu Creek, the single plant grew in wet duff next to a rivulet. The duff layers are expected to be acidic because they are derived from conifer, mostly cedar, leaves (L. Kuennen, pers. commun.), however, ground water at the sites may be calcareous. Headwaters of the two drainages are within the Helena formation geological mapping unit composed of dolomites and dolomitic siltites (Harrison et al. 1992), which is associated with calcareous soils in the eastern part of the Forest; limy seeps and rivulets were observed in the upper drainage of Can Creek. Limestone parent materials are also reported from sites in the Anaconda Range (Vanderhorst 1993) and possibly from the Wallowa Mountains in Oregon (Zika 1992, 1994). Soils of the meadow habitats in the Anaconda Range have a thin litter layer and a high organic fraction in the upper horizons (Vanderhorst 1993).

4. CLIMATE FACTORS: The known occurrences of *Botrychium paradoxum* on the KNF are at relatively high elevations in the Upper Yaak Valley, an area of the Forest which has heavy precipitation and snow accumulation. Moonworts in general are adapted to cool, moist climates. In Montana they are thus most common at low elevations in the northwest part of the state with its cool temperate, maritime influenced climate, while in semi-arid regions of the state (e.g. Granite, Deer Lodge, and Lewis and Clark counties) they are confined to higher elevations which receive heavy accumulations of snow. Climatic fluctuations may dramatically effect the phenology and numbers of moonwort sporophytes which produce above ground leaves in a growing season; in dry years fewer

plants can be expected to be found and the length of the growing season is expected to be shorter.

F. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: Montana populations have been located in late June to early August when they have generally had immature sporangia. Spore dispersal probably occurs in July through September. Warm, dry weather is likely to shorten the growing season and speed development of the plants.

2. POPULATION SIZE AND CONDITION: The known "populations" on the Kootenai National Forest are very small, with only a single plant found at each site. *Botrychium paradoxum* was not relocated by surveys of the Can Creek drainage in 1995 or 1996, or by surveys of Zulu Creek in 1996. "Populations" of one plant are likely to be ephemeral. At Marias Pass, 45 plants were observed in 1978, but the population could not be relocated in 1986. The occurrence in the Rocky Mountain Front Range was reported to consist of 30 plants in 1989. In 1996, Peter Lesica found a population in Glacier National Park estimated to consist of 100 or more plants. The species is more abundant in Montana in the Anaconda Range where populations consist of hundreds and perhaps even thousands of plants (Vanderhorst 1993). The populations in the Wallowa Mountains in Oregon are also very small (Zika 1992, 1994) and all but one of the seven reported Washington sites (Washington Natural Heritage Program, pers. commun.) had fewer than ten plants.

   Lesica and Ahlenslager (1996) conducted demographic studies of a population which included *Botrychium paradoxum, B. hesperium,* and their putative hybrid *B.* X *watertonense* in Waterton Lakes Park, Alberta. Of the three taxa, *B. paradoxum* had the highest rates of mortality and recruitment, and they suggest that "it is the most adapted to ephemeral habitats and is the most prone to cycles of extinction and recolonization."

3. REPRODUCTIVE BIOLOGY: See discussion of life history following the Introduction of this report.

G. POPULATION ECOLOGY

1. COMPETITION: The occurrence of moonworts, including *Botrychium paradoxum,* in genus communities seems to run counter to the competitive exclusion principle, however, plant densities are usually so low that competition between moonwort species is not expected. Furthermore, our observations suggest that the individual species have subtly different microhabitat preferences. At Zulu Creek (010), however, several plants of *B. minganense* grew within inches of a single plant of *B. paradoxum* in apparently equivalent habitat, suggesting that *B. minganense* may have a competitive advantage over *B. paradoxum* in this habitat. The opposite may be true at Cub Ridge in the Anaconda

Range, where *B. paradoxum* is the dominant moonwort and only a few plants of *B. minganense* were found (Vanderhorst 1993).

The effects of competition from other types of plants is not known, but data from the single microplot with *Botrychium paradoxum* at Zulu Creek (Appendix C) suggest that competition for light may be a factor in the plants poor reproductive success. In this plot there was high canopy cover and very high ground cover by forbs and ferns taller than *B. paradoxum*. The single plant of the moonwort was etiolated and had few sporangia compared to the robust individuals observed in the Anaconda Range. Demographic data from Lesica and Ahlenslager (1984) suggest that *B. paradoxum* may be favored by some disturbance due to the sporophytes short life and poor competitive ability.

b. POSITIVE INTERACTIONS: All *Botrychium* species are believed to be obligately dependent on mycorrhizal relationships in both the gametophyte and sporophyte generations. See the discussion of mycorrhizal relations following the Introduction of this report. Zika (1992) reported an abundance of *Fragaria virginiana* (strawberry) in *B. paradoxum* habitat in Oregon and I observed the same association in the Anaconda Range (Vanderhorst 1993). These relationships may be a manifestation of mycorrhizal links between these plants.

c. HERBIVORY: Herbivory of *Botrychium paradoxum* was not observed, but nibbled sporophores of other species of moonworts was noted on the KNF in 1995 and 1996. The clusters of sporangia are ofetn selectively browsed. Small animals, possibly rabbits, rodents, or snails may play a role in spore dispersal of moonwort species (Zika 1992).

H. LAND OWNERSHIP: All three known occurrences of *Botrychium paradoxum* in the vicinity are on KNF land on the Three Rivers District.

I. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

1. THREATS TO CURRENTLY KNOWN POPULATIONS: The extremely low numbers of *Botrychium paradoxum* at its sites on the KNF raise questions about population viability even under unaltered conditions. None of the occurrences could be relocated in years following their discovery although thorough surveys were conducted in 1995 and 1996. The draw and creek bottom where the species was found at Can Creek have intact native forests, but the area is designated as suitable timberland (USDA Forest Service 1987) and surrounding slopes have been extensively logged. The long term effects of logging on the hydrology at the sites is not known. The Zulu Creek (010) site is designated old growth (USDA Forest Service 1987). In order to positively document the occurrence of the species from the KNF, a wide disjunction and in unusual habitat, the year's aerial leaf of the single plant at Zulu Creek was collected in 1995. However, collection of a species which occurs in such low numbers may significantly threaten its occurrences; apparently the plant did not produce an above ground frond in 1996.

2. MANAGEMENT PRACTICES AND RESPONSE: unknown

3. MANAGEMENT SUMMARY: *Botrychium paradoxum* is probably one of the most rare species in its genus, globally, within Montana, and especially on the KNF. Populations with large numbers have been reported in Montana only from the Anaconda Mountains, and some other populations could not be relocated in years following their discovery and may be extirpated. Current status designations by the U.S. Forest Service as sensitive, and by the Montana Natural Heritage Program as G2 and S1 remain appropriate. Protection of a single plant, as *B. paradoxum* has been found on the KNF, is nearly impossible, and alternative approaches are required. Since the species is usually found in genus communities, protection of these occurrences, whether or not *B. paradoxum* has been found at that particular site in a particular year, may be the best strategy for maintaining potential habitat for the rare species. This is an important reason for retaining the Forest Service sensitive status for the relatively more common moonworts *B. minganense* and *B. montanum.* Sites where *B. paradoxum* has been documented (Can Creek .008, .009, Zulu Creek .010) should be given high conservation priority and further surveys of these sites, other known genus communities, and additional unsurveyed areas for this species should continue. The site of a large population of *B. paradoxum* on Cub Ridge (locally called "Windy Ridge") in the Anaconda Range on the Deerlodge National Forest has been designated a Research Natural Area (J. Joy, pers. commun.) and this site may be crucial in providing a source of spores for long distance migration of the species.

Stalked Moonwort
Botrychium pedunculosum

A. CLASSIFICATION

1. FAMILY: Ophioglossaceae, a family of primitive ferns

2. GENUS: *Botrychium* subgenus *Botrychium*

3. SPECIES: *Botrychium pedunculosum* Wagner, described in Wagner and Wagner 1986)

B. PRESENT LEGAL OR OTHER FORMAL STATUS

1. FEDERAL

a. U.S. FISH AND WILDLIFE SERVICE: Previously recognized as C2 (U.S. Dept. of Interior 1993), indicating that it was a species "for which information now in the possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which sufficient data on biological vulnerability and threat are not currently available to support proposed rules." Recognition of C2 species was officially discontinued by the Service in 1996 (U.S. Fish and Wildlife Service 1996).

b. U.S. FOREST SERVICE: Proposed sensitive in Region 1. The species was found for the first time in the Region in 1996 and so was not previously listed.

c. BUREAU OF LAND MANAGEMENT: none

2. STATE: *Botrychium pedunculosum* will be added to the list of plant species of special concern maintained by the Montana Natural Heritage Program and accorded a state rank of S1, indicating it is critically imperiled due to extreme rarity in Montana. It has a global rank of G3? (Oregon Natural Heritage Program 1995) indicating it is vulnerable due to rarity throughout its range.

C. DESCRIPTION

1. GENERAL NON-TECHNICAL DESCRIPTION: *Botrychium pedunculosum* is a small perennial fern with a single above ground frond. The frond varies in height up to about 20 cm and is divided into two segments which share a common stalk. The lower common stalk is usually reddish brown and the upper part of the plant is a dull glaucous green. The mostly sterile segment is conspicuously stalked and once to twice pinnatifid with up to five pairs of primary pinnae. The pinnae have irregular angular lobes and vary from pinnatifid to bifid to narrowly fan shaped and the lower ones often bear sporangia. The fertile segment is longer than the sterile segment and bears grape-like sporangia; larger plants usually have two large ascending lateral branches. Spores germinate

underground and develop into minute, subterranean, non-photosynthetic gametophytes. Photographic slides of the sporophytes are provided in Appendix I.

2. TECHNICAL DESCRIPTION: "Trophophore stalk 8-26 mm, to 1.1 times length of trophophore rachis; blade dull green, ovate-oblong to deltate-oblong, 1-pinnate, to 4.5 X 2 cm, leathery. Pinnae to 5 pairs, somewhat ascending, approximate to well separated, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, basal pinnae pair approximately equal in size and cutting to adjacent pair, ovate-rhombic to spatulate, lobed to tip, margin entire to irregularly lobed, apex rounded to acute, venation pinnate. Sporophores 1-3 pinnate, 2-4 times length of trophophore. *2n* = 180." from Wagner and Wagner 1993.

3. LOCAL FIELD CHARACTERS: *Botrychium pedunculosum* is a distinctive species which is most similar to *B. pinnatum* and *B. hesperium*, both species which may also have reddish common stalks and pinnatifid pinnae. It differs from the former by having a stalked trophophore, dull green vs. bright green color, and leathery vs. papery texture. *Botrychium hesperium* is also dull green, but the trophophore does not have a long stalk and the lowest pinnae pair are conspicuously larger than the adjacent pair. The presence of extra sporangia on the basal pinnae of the trophophore and the two large lateral branches of the sporophore are useful characters for identifying *B. pedunculosum*. A narrow brown stripe extending down the common stalk from the trophophore is mentioned in the description of the species (Wagner and Wagner 1986), but this character was not apparent on plants found on the KNF. Plants found on the KNF are shade forms (W. Wagner, pers. commun.) and have narrower pinnae which are more well separated than typical plants from Oregon, which grow in sunny places.

D. GEOGRAPHICAL DISTRIBUTION

1. RANGE: Western North America; Alberta, Saskatchewan, Oregon (Wagner and Wagner 1993), Washington (Washington Natural Heritage Program, pers. commun.), Montana.

2. MONTANA DISTRIBUTION: *Botrychium pedunculosum* was found for the first time in the state in 1996; all known occurrences are in Lincoln County on the KNF.

3. OCCURRENCES ON THE KOOTENAI NATIONAL FOREST

a. CURRENT SITES: Five small populations were found in 1996. Four sites are on the Rexford District in creeks draining into Lake Koocanusa (Big Creek .005, South Fork Big Creek .001, Parsnip Creek .002, Sutton Creek .004) and one site is on the

figure 6

Three Rivers District along Keeler Creek (003) south of Troy (Figure 6). Color photocopies of specimens from two populations on Big Creek were verified by W. H. Wagner (pers. commun.).

b. HISTORICAL SITES: none

c. UNVERIFIED/UNDOCUMENTED REPORTS: Collections were not taken from Keeler Creek, Parsnip Creek, or Sutton Creek; I identified plants from these sites as the same taxon at the verified Big Creek sites based on unique coloration and stalked trophophores.

d. AREAS SURVEYED BUT SPECIES NOT FOUND: See Appendix A for a list of areas which I searched for moonworts.

E. HABITAT

1. ASSOCIATED VEGETATION: Outside Montana *Botrychium pedunculosum* grows in meadows and openings. In the Wallowa Mountains, Oregon where it is most abundant, it grows in abandoned oxbows with heavy cover by grasses and in openings in lodgepole pine (*Pinus contorta*) forests in close association with strawberries (*Fragaria virginiana*)(Zika 1994). In Washington it grows in moist meadows, swales, and roadsides (Washington Natural Heritage Program, pers. commun.).

In contrast to these sunny, early successional habitats, the sites on the KNF are old growth stands of western red cedar (*Thuja plicata*) in floodplain bottoms. Four of the sites are *Thuja plicata/Oplopanax horridum* habitat types, and one (Parsnip Creek) is a *Thuja plicata/Athyrium filix-femina* habitat type (Cooper et al. 1991). Canopy cover by cedar is very high while understory cover by shrubs, forbs, ferns and mosses is relatively low. Average age of the dominant tree class is 130 years or older, and some trees at each of the sites probably exceed 500 years in age. Although old growth cedar stands in floodplains are extremely stable, fire resistant climax types, persisting for 1,000 years or more, their understories are dynamic successional habitats prone to cycles of flooding and are influenced by upstream events.

Additional associated trees at one or more site on the KNF include *Picea* sp., *Populus balsamifera, Pseudotsuga menziesii,* and *Tsuga heterophylla*. Associated shrubs include *Acer glabrum, Oplopanax horridum,* and *Taxus brevifolia*. Forbs with high constancy include *Clintonia uniflora* and *Tiarella trifoliata*. Associated ferns, besides moonworts, include *Athyrium filix-femina, Botrychium virginianum, Gymnocarpium dryopteris,* and at Parsnip Creek, the sensitive species *Thelypteris phegopteris*.

At all known sites on the KNF, *Botrychium pedunculosum* occurs in genus communities with other moonworts. It is associated with *B. lanceolatum* at all five sites, and at one or

more site it grows with *B. minganense*, *B. montanum*, or *B. pinnatum*. Outside Montana, it also occurs with *B. lunaria* and *B. simplex* (Wagner and Wagner 1986).

Additional information on associated vegetation at individual KNF sites is provided by the general site description fields of the Element Occurrence Records in Appendix B, and Ecodata in Appendix C.

2. TOPOGRAPHY: On the KNF the sites are relatively low elevation floodplain bottoms of glaciated valleys. Elevations range from 2,600 to 3,200 feet. The microtopography is patterned or undulating caused by old stream channels, windthrow hummocks, and rotten logs. *Botrychium pedunculosum* grows in the bottoms of the depressions. The sites are adjacent to streams, have high water tables, and are prone to periodic flooding.

3. SOIL RELATIONSHIPS: The soils at all sites are formed in alluvial deposits. Landtype mapping units include 101 on alluvial floodplains and 103 on alluvial terraces (Kuennen and Nielsen-Gerhardt 1995). The Sutton Creek (004) and Parsnip Creek (002) sites are mapped as landtype 352 with soils formed in glacial till of mountain slopes, however, this is probably an artifact of mapping scale. At all sites on the KNF, *Botrychium pedunculosum* grows in soils formed in stratified alluvial deposits covered by shallow litter layers. In contrast to other KNF moonwort species of forested habitats, it has not been found growing in deep litter.

3. CLIMATE FACTORS: Moonworts in general are adapted to cool, moist climates. In Montana they are thus most common at low elevations in the northwest part of the state with its cool temperate, maritime influenced climate, while in semi-arid regions of the state (e.g. Granite, Deer Lodge, and Lewis and Clark counties) they are confined to higher elevations which receive heavy accumulations of snow. All known occurrences of *Botrychium pedunculosum* are at low elevations in the extreme northwest corner of the state. Climatic fluctuations may dramatically effect the phenology and numbers of moonwort sporophytes which produce above ground fronds in a growing season; in dry years fewer plants can be expected to be found and the length of the growing season is expected to be shorter. Because it grows in subirrigated habitats, *B. pedunculosum* is likely to be less affected by precipitation during the growing season, and more affected by total annual precipitation.

F. POPULATION DEMOGRAPHY AND BIOLOGY

1. PHENOLOGY: Fronds appear as early as late spring and die in early fall (Wagner and Wagner 1993). Phenology is greatly affected by moisture of the microsite, wetter habitats delay maturation and senescence (Zika 1994). In genus communities on the KNF *Botrychium pedunculosum* was observed to disperse spores later than *B. minganense* and earlier than *B. montanum*.

2. POPULATION SIZE AND CONDITION: The populations on the KNF are very small. The most plants found at one site was eight, and at two sites only one plant could be found. Numbers of *Botrychium pedunculosum* were fewer than other moonworts in the genus communities where they occur (Table 2, in results section). Areas of the populations are also small. At Big Creek and Keeler Creek, the plants are confined to small areas of remnant old-growth. Populations in Canada are also small (Zika 1994). Larger populations are known from Oregon (Wagner and Wagner 1986) and Washington (Washington Natural Heritage Program, pers. commun.). The plants found in Montana are shade forms (Wagner, pers. commun.) and most are relatively small with reduced spore producing capacity.

3. REPRODUCTIVE BIOLOGY: See the discussion of life history of moonworts following the introduction to this report.

G. POPULATION ECOLOGY

1. COMPETITION: The habitats of *Botrychium pedunculosum* on the KNF have dense tree canopies but sparse undergrowth, thus there is high competition for light but low levels of root zone competition. Low light may be a factor in the plants poor reproductive success on the KNF; larger populations are known from Oregon and Washington in sunny habitats. The occurrence of moonworts, including *Botrychium pedunculosum*, in genus communities seems to run counter to the competitive exclusion principle, however, plant densities are usually so low that competition between moonwort species is not expected. Furthermore, our observations suggest that the individual species have subtly different microhabitat preferences. For example, *B. pedunculosum* was found in moist depressions while *B. montanum* was on dryer hummocks at South Fork Big Creek (001).

2. POSITIVE INTERACTIONS: All *Botrychium* species are believed to be obligately dependent on mycorrhizal relationships in both the gametophyte and sporophyte generations. See the discussion of mycorrhizal relations following the Introduction of this report.

3. HERBIVORY: A nibbled plant was observed at South Fork Big Creek. Small animals may play a role in spore dissemination of moonworts (Zika 1992).

H. LAND OWNERSHIP: All known Montana occurrences are on the KNF, on the Rexford and Three Rivers Districts.

I. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

1. THREATS TO CURRENTLY KNOWN POPULATIONS: All known Montana *Botrychium pedunculosum* populations are in floodplain bottoms and are potentially threatened by natural and human induced flooding events. The species is threatened by floods more than other forest dwelling moonworts because its population numbers are

extremely low and plants are confined to the bottoms of swales and channels in low elevation floodplains. In this respect it shares conservation concerns with the sensitive fern *Thelypteris phegopteris* (reviewed by Kuennen and Leavell 1993), with which it occurs at Parsnip Creek. Logging and road building is proposed in the upper drainage of Parsnip Creek (A. Deuker, pers. commun.) and these activities could result in increased stream flows which could potentially impact the populations of *B. pedunculosum* and *T. phegopteris* downstream. At South Fork Big Creek a culvert from a road above drains into the vicinity of the moonwort genus community and flooding in 1996 resulted in sedimentation in the area; no moonworts were found growing through the sediment but it is not known if the ferns previously grew in these areas. Flooding may also be caused by beaver dams.

1. MANAGEMENT PRACTICES AND RESPONSE: At Keeler Creek and Big Creek, the populations of *Botrychium pedunculosum* are confined to small groves of remnant old growth cedar in drainages which were heavily influenced by logging and catastrophic flooding in the last century. The extent to which flooding was caused by logging in these drainages is difficult to assess. Spruce logging occurred in the upper drainage of Keeler Creek prior to catastrophic flooding in the mid-1970's and is likely to have had some influence on the flood event (L. Kuennen, pers. commun.). Since then, "salvage" logging of large cedar in the bottom of Keeler Creek near the moonwort population has probably further depleted potential habitat. The concentration of known populations in the lower floodplains of creeks flowing into Lake Koocanusa suggests that the species may have been more extensive before Libby Dam was built.

3. MANAGEMENT SUMMARY: *Botrychium pedunculosum* was found in Montana for the first time in 1996. The species does not currently have official Region 1 sensitive status but listing is now proposed and in the interim it should be treated as sensitive. The species is one of the rarest moonworts both in Montana and throughout its range and is "of conservation concern" (Wagner and Wagner 1993). The species has been added to the state list of plant species of special concern maintained by MTNHP and accorded the rank of S1. All known populations of this species should be given high conservation priority and additional survey for the species should be conducted not only within proposed project boundaries but also in floodplains downstream.

   Botrychium pedunculosum is probably adapted to a shifting mosaic of understory habitats created by scouring and deposition by flood events followed by accumulation of organic matter and recolonization by plants. However, the areal extent where these natural cycles can occur and intervals between these events have been reduced by management activities such as logging, and road and dam building. It is highly likely that potential habitat for *B. pedunculosum* has been greatly reduced in recent decades.

RECOMMENDATIONS AND CONCLUSION

Status recommendations: Current and recommended Montana Natural Heritage Program state ranks and USFS status of the six moonwort species treated in detail in this report are summarized in Table 6. The species were scored using the most updated information according to USFS Region 1 sensitive plant scoring criteria (Appendix H) and the total score for each is included in Table 6. In the past, species with a total of 15 or more have been nominated for designation as sensitive by the Regional Forester (S.Shelly, pers. commun.). The process of designating sensitive species is currently being evaluated nationally with efforts being made to standardize criteria, so changes are possible within Region 1.

Table 6. Current and recommended Montana Natural Heritage Program state ranks and USFS status of *Botrychium* species on the Kootenai National Forest.

	State rank		USFS status		
	current	recommended	current	score	recommended
B. ascendens	S1	S1	sensitive	20	sensitive
B. crenulatum	S2	S2	sensitive	17	sensitive
B. minganense	S2S3	S3	sensitive	11	sensitive
B. montanum	S2	S2	sensitive	20	sensitive
B. paradoxum	S1	S1	sensitive	15	sensitive
B. pedunculosum	none	S1	none	22	sensitive

The discovery of the first known Montana occurrences of *Botrychium pedunculosum* in 1996 makes its inclusion as a Montana Plant Species of Special Concern appropriate at this time. This species received the highest sensitive plant criteria score due to its extreme global rarity, local habitat specificity, and apparent historical loss of habitat in Montana and is recommended for designation as sensitive in USFS Region 1. It is appropriate to address species deemed of conservation concern, but not yet officially designated sensitive, in NEPA documents apart from the Biological Evaluation process (S. Shelly, pers. commun.).

Documentation of many new populations of *Botrychium minganense* on the KNF in 1995 required that the Montana Natural Heritage Program state rank be changed from S1 to S2S3. Documentation of several more in 1996 makes S3 now appropriate. At this point most taxa are dropped from tracking by MTNHP. It now appears that this species is probably the most common moonwort on the KNF and in Montana. Based on these updates it received a sensitive species criteria score of 11, below the past threshold for designation as sensitive by USFS Region

1. However, I recommend that sensitive status be retained for the species and it continue to be tracked by MTNHP at this time because 1) sites with *B. minganense* may host other more rare *Botrychium* species which may be overlooked by initial surveys, 2) misidentification is common, and 3) taxonomic revisions involving this species group are in progress (K. Ahlenslager, W. Wagner pers. commun.).

Current state ranks and Forest Service sensitive status remain appropriate for the other four species treated in this report. Although a relatively large number of new occurrences of *B. montanum* were also documented on the KNF, this species already had a state rank of S2, a rank which was probably too high based on the few occurrences previously known in the state. Its habitat specificity and occurrence in proposed cutting units are also reason for retaining S2 status. The state rank of *B. crenulatum* was changed from S1 to S2 in 1996 based on the new populations found on the KNF in 1995.

Threats to populations: Occurrences of sensitive moonworts on the KNF are potentially threatened by natural events and by direct and indirect effects of management activities. Natural processes which may impact populations include flooding due to climate or beaver dams, succession, wildfire, herbivory, and drought. Upland sites are most threatened by the direct effects of logging since they are often included in management areas designated suitable for timber harvest (U.S Forest Service 1987). Many of the occurrences of *Botrychium minganense* and *B. montanum* found by KNF personnel are in proposed cutting units. Canopy removal and disturbance of surface substrates by machinery or prescribed burning is likely to eliminate moonworts from a site for a relatively long period. Lowland floodplain sites are especially threatened by indirect and cumulative effects of logging and road building in the drainages upstream. Two of the rarest species, *B. ascendens*, and *B. pedunculosum*, as well as the few known occurrences of *B. crenulatum* in natural settings, are especially susceptible to road washouts, sedimentation, and stream rechanneling caused by increased runoff within their drainages. Mining is less extensive than logging on the KNF but a proposed mine at Rock Creek may effect a population of moonworts on ASARCO land. Roadside sites of *Botrychium crenulatum* are threatened by log decking, road maintenance, parking, cattle trampling and herbicide use. The effects of grazing on populations of moonworts is not known. It is suspected that light levels of grazing would not adversely affect populations, while heavy levels would. This potential threat is mostly confined to the roadside and meadow habitats of *B. crenulatum* and *B. minganense* on the Fortine and Rexford Districts. Collection of specimens by botanists may significantly impact small populations of the rarest species.

Interim management guidelines: The goal of conservation management for sensitive moonworts on the KNF is to maintain viable populations and numbers of all species across their current geographical and ecological range on the Forest into the foreseeable future. To accomplish this goal an integrated program of project assessment and amendment, population protection and preserve designation is recommended. These reccomendations are meant to be **interim** guidelines, are subject to U.S. Forest Service review, and should be amended as new information becomes available.

1. Clearance surveys should pay special attention to identifying and surveying microfeatures such as draws, seeps, benches, and moist flat areas within project boundaries and in floodplains downstream from proposed projects. The vegetation types listed in the results section of this report for each sensitive *Botrychium* species may be used to identify primary potential habitat, but other moist habitat types should also be considered as potentially hosting moonworts.

2. Results of clearance surveys should be assessed in the context of the year's climate, available personnel hours, and the relative ease or difficulty of survey in particular habitats. Populations of moonworts are likely to go undetected or underestimated in dry years, requiring greater reliance on probability analysis and repeated surveys. Habitats with depauperate understories (most seral stages of cedar and hemlock forest types) require less time and survey intensity than habitats with heavy understory cover (some open old growth stands, riparian thickets, meadows).

3. The presence of one moonwort species at a site increases the probability of other species occurring nearby. Over half the known sensitive *Botrychium* occurrences on the KNF are in moonwort genus communities. This phenomenon is a key to identifying and protecting potential habitat for the rarest species.

4. Before any occurrence of a sensitive *Botrychium* species is impacted by a management activity, a complete survey should be conducted of the entire potential habitat to assess the magnitude of the population and species diversity of the community. Repeat surveys will often be needed to accomplish this due to the unique phenological and dormancy attributes of the different species. Collection of specimens and consultation may be required for reliable species identification. In some cases it will be more opportune to protect the population and potential habitat by modifying project plans, rather than postponing actions until a complete survey can be accomplished.

5. Protect all known KNF populations of the rarest *Botrychium* species, *B. ascendens*, *B. paradoxum*, and *B. pedunculosum* from direct, indirect, and cumulative effects of management activities and foreseeable natural threats. *Botrychium ascendens* and *B. pedunculosum* are known only from lowland floodplain habitats and are especially threatened by indirect and cumulative effects of logging and road building upstream in their drainages. Conservation management at the drainage level is required for these species.

6. Accord similar protection for significant verified populations of *Botrychium crenulatum* in unaltered native habitat (Beaver Creek .007, Chief Creek .009, Alexander Mountain .005). These sites are also floodplains subject to indirect and cumulative effects within their drainages.
7. Amend project plans as necessary to maintain viable populations and current geographic range of all sensitive *Botrychium* species on the KNF. Some individuals, subpopulations,

or small populations of the more common species (*B. crenulatum*?, *B. minganense*, *B. montanum*) may be sacrificed if metapopulation structure and/or geographic distribution of the species on the district is maintained. The significance of each occurrence should be determined on a case by case basis. Maintain the integrity of all "core" populations, those with high numbers and high quality habitat, and all peripheral and outlying populations which are important to the geographic distribution of the species on the KNF. Examples of these types are listed in Table 7, however, these lists may not be inclusive and should be amended as new information becomes available.

Table 7. "Significant" populations of the more common sensitive *Botrychium* species on the Kootenai National Forest. Note: all populations of the rarest species *B. ascendens*, *B. paradoxum*, and *B. pedunculosum* are significant.

peripheral and outlying occurrences		"core" populations	
B. crenulatum		*B. crenulatum*	
Basin Creek (004)	D4	Beaver Creek (003)	D3
Chief Creek (009)	D5	Alexander Mountain (005)	D5
Rock Creek (002)	D7	Chief Creek (009)	D5
B. minganense		*B. minganense*	
Grave Creek Campground (047)	D3	S. F. Big Creek (046)	D1
Othorp-Morgan Lake (066)	D3	Sutton Creek (049)	D1
Sterling Creek	D3	Bunker Hill Creek (017)	D4
Ross Creek Cedars (010)	D4	French Creek (021)	D4
Poorman Creek (050)	D5	Kelsey Creek (025)	D4
Bull River (047)	D7	Red Top Creek (038)	D4
		Zulu Creek (028)	D4
B. montanum		Fawn Creek (020)	D5
Sutton Creek (024)	D1	West Pipe Creek (013)	D5
Sterling Creek (028)	D3		
Keeler Creek (026)	D4	*B. montanum*	
Cedar Creek (014)	D5	Sutton Creek (024)	D1
Houghton Creek (026)	D5	Sterling Creek (028)	D3
Berray Mountain (017)	D7	Beetle Creek (031)	D4
		Can Creek (009,011)	D4
		French Creek (020)	D4
		Kelsey Creek (012)	D4
		Red Top Creek (022)	D4
		Roderick Butte (018)	D4
		West Pipe Creek (013)	D5

8. Project modifications to protect moonwort occurrences should be designed to maintain current light levels and hydrological regimes and leave the surface substrate undisturbed

in the population area. Buffer zones should be adequate to compensate for blowdown. Machinery should be kept out of the population area and potential habitat and the area should be protected from controlled burns.

9. Established riparian timber harvest guidelines for the KNF (U.S. Forest Service 1994b) do not provide adequate protection for populations of sensitive moonworts. These allow reduction of canopy cover along perennial streams, larger ephemeral streams, and around wetlands, complete canopy removal in dry draws and swales, and slash burning in all types of riparian zones. The effects of these activities are likely to impact moonwort populations by increasing root zone competition, reducing litter accumulations, and affecting microclimate and hydrology.

10. Monitor populations likely to be impacted by project activities before and after the commencement of the activity to accumulate evidence for assessing impacts of future projects. Lesica and Steele (1994) discuss special monitoring requirements and analysis for species, such as moonworts, which undergo prolonged dormancy. Continue yearly monitoring of *Botrychium minganense* and *B. montanum* at French Creek (Appendix D) to establish baseline demographic parameters for these two species.

11. Continue to pursue resolution of outstanding taxonomic questions. Collect specimens as needed to accomplish this goal in accordance with the guidelines in Appendix E. Take advantage of wet years for resurveying and collecting from populations with unresolved questions. Occurrences with questions concerning identification are listed in the unverified/undocumented reports section of the status reviews in this report.

12. Begin to pursue designation of preserves (botanical special interest areas and research natural areas) for the most significant and defensible populations and genus communities. Base preserve selection on species composition, population numbers and areal extent, habitat quality and stability, geographic representation of the occurrence, and adequacy of protection offered by current management area designation.

Conclusion: Great progress has been made in knowledge of moonwort habitat and distribution in Montana, especially on the KNF, providing the framework for expanding our understanding of the ecology, genetics, and conservation requirements of these unique plants. Pertinent research is underway or proposed at at least four universities. Research on moonwort/fungal mycorrhizal relations is being conducted at the University of Oregon by a graduate student, Francisco Comacho. Research on genetic markers of one of the most confusing pair of species, *Botrychium crenulatum* and *B. minganense*, including material from the KNF, is being conducted by a graduate student, Linda Swartz, at the University of Idaho. A professor at Iowa State University, Donald Farrar, who has developed protocol for studying isozymes of moonworts, has been contracted to investigate genetics of moonwort species on the Colville National Forest in Washington (K. Ahlenslager, pers. commun.). At the University of Montana, Roger Ferreil has

undertaken graduate research to further characterize the habitats of sensitive moonworts on the KNF, and to develop a management strategy for their conservation on the Forest.

A hypothesis to explain the occurrence of large genus communities can be made based on spatial and temporal considerations. Current species concepts of *Botrychium* subgenus *Botrychium* would indicate that genus communities are the result of multiple introduction events, potentially of a single spore of each species, to a mutually suitable habitat. The probability of more than one species colonizing a site is likely to increase with the size of habitat, heterogeneity of microhabitats, and time. Time is also a necessary element for population expansion. The occurrence of large numbers of several moonwort species at a site may indicate ancient habitat. This theory is supported by the preponderance of large genus communities in relatively old stands of western red cedar. Old growth also has structural complexity, of both canopy and microtopograhy, which may allow several moonwort species with similar but slightly different habitat preferences to coexist. This hypothesis may be tested by analyzing Ecodata to distinguish the habitats of large populations and genus communities from those of small occurrences of single species, which may be incidental and ephemeral, or alternately, may have potential for development into larger populations or genus communities.

Expansion of the guidelines recommended on pp. 72-74 in this report into a conservation strategy for the KNF should integrate the results of all new research and set the stage for long term conservation and monitoring of these species. Perhaps the greatest research contributions which can be made are 1) expansion and refinement of Ecodata habitat characterization to include all types and to define "ideal" habitat for genus communities and for each of the sensitive species and 2) determination of landscape processes necessary for perpetuating these habitats across the Forest. Starting with this information, a conservation strategy should establish guidelines for assessing cumulative effects of management activities in drainages where sensitive moonwort populations occur in lowland floodplains. Drainages where catastrophic flooding has apparently impacted occurrences of moonworts (e.g. Keeler Creek, West Fisher Creek) should be analyzed to determine if there are cause and effect relationships between the flood events and past management activities. Historical aerial photographs and stand records, on-site inspections, and GIS mapping techniques may be useful for this purpose. The results of these analyses should then be applied to drainages where management activities are proposed upstream from floodplain occurrences of sensitive moonworts (e.g. Parsnip Creek).

Although genus communities are an indication of overlapping habitat preferences of moonwort species, there are also notable differences between species which need to be considered in developing conservation strategies. There is a growing accumulation of evidence that supports the modern taxonomic treatment (splitting) of *Botrychium* subgenus *Botrychium* (sensu Wagner and Wagner 1993). Besides the morphological and cytological characters emphasized by the Wagners, there are differences between species in genetics (Hauk 1995), developmental parameters (Campbell 1922), demographic profiles (Ahlenslager and Lesica 1995, Lesica and Ahlenslager 1996), possibly mycorrhizal relationships (Comacho 1996, Campbell 1922), and, as shown by the results of this conservation assessment, in phenology, geographic distribution, and micro- and macro-habitat preferences. The most significant variation in habitat on the KNF is

between the "east side" deciduous thicket habitats of *Botrychium ascendens* and *B. crenulatum* and the "west side" old growth forest habitats most typical of *B. minganense* and *B. montanum*. Preferences of *B. ascendens, B. paradoxum,* and *B. pedunculosum* for habitats which are scarce on the KNF may help explain their rarity on the Forest.

In the last few years the Kootenai National Forest has emerged as the "moonwort capital of Montana." About 70% of the known occurrences of sensitive *Botrychium* species in the state are from the KNF and most of these have been documented in the last two years. This high percentage is partly due to the level of funding for botany work on the Forest, and is an indication of the need for further survey work elsewhere in the state. However, it is clear that the KNF is a stronghold for moonworts, especially for *B. minganense, B. montanum,* and *B. crenulatum*. The relative abundance of these species stems from the prevalent biogeoclimatic parameters of the Forest. The KNF has the largest area in the state of low elevation glaciated topography with maritime influenced climate. Growing seasons are long and cool, with high precipitation and humidity. There are recurring examples of old growth stands of western red cedar and western hemlock which are the favored habitats of *B. minganense, B. montanum,* and moonwort genus communities. There are extensive areas with alluvium derived from calcareous glacial till, the substrate preferred, if not required, by *B. crenulatum*. In addition to hosting many significant core populations of these three species, the KNF has all occurrences of *B. pedunculosum* and three of the four occurrences of *B. ascendens* known in the state; these two species are among the most globally rare of the subgenus. Conservation of sensitive moonworts on the KNF is a keystone for their state and global conservation.

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APPENDIX E: MOONWORT COLLECTION GUIDELINES

By J. Vanderhorst and B. L. Heidel

Herbarium specimen vouchers remain the most accepted method of verifying field identifications and documenting occurrences. Collection of moonworts (Botrychium subg. Botrychium) is especially important because of the difficulty in their identification, and the recurrent phenomenon in which multiple species occur at a single site. These guidelines represent an elaboration of the general collecting guidelines of the Montana Native Plant Society (1993) with particular reference to the biology of moonworts, their vulnerability, and the collecting considerations that are necessary and useful for making determinations (Windham pers. commun, Zika pers. commun.).

- Plants should be collected in mature, fully expanded stages. Plants collected early in the season usually do not have completely expanded fronds. Juvenile plants may appear late in the growing season for some species, and even late season juveniles do not have typical leaf morphology. In both cases, plants are likely to be unidentifiable, and their collection is a waste.

- Only the current year's above ground leaf should be taken, except for studies of chromosomes, mycorrhizal associations, and gametophytes, which are beyond the scope of most sensitive plant program projects. The leaf primordia are enclosed within the sheath at the base of the leaf, and if left intact, the plant is expected to survive. Monitoring over the course of the growing season at French Creek suggests that populations of moonworts endure certain levels of herbivory; additional years data may confirm this hypothesis.

- Where population size is large enough to support a collection (over 20 individuals) but still small (less than app. 50 individuals), collection should take place only after spore dispersal has occurred. At this stage, impacts to the potential reproduction and growth are lowest. Spore dispersal occurs late in the growing season (August- October depending on the species and climate).

- Distinct morphological forms are to be sought at the onset of a visit. The emphasis should be on collecting plants that represent typical morphologies in the population(s). Several plants, ideally 5-6 fronds, of each morphological type (putative species) within a site should be collected to display variation as population sizes permit.

- Notes should be taken on color, texture and other plant characters which are lost in pressing and drying (e.g., glossy, glaucous, brown-based stem, red stripe on mid-vein, etc.). These notes should be included on the herbarium label. An accompanying close-up photograph may be useful.

- Special care must be taken in pressing the plants. Zika and Wagner recommend using telephone books with heavy pressure rather than a typical plant press. The plants must be spread out perfectly flat to show the entire outline of the frond so that pinnae do not fold over or overlap (unless that is a characteristic of living plants), and trophophore and sporophore do not overlap.

- As with all plant collections, sufficient data should be collected and included on a typed label accompanying the plants. Data should include country, state, county, geographical province and locality (creek, mountain etc..), legal description, elevation, topography, substrate composition, moisture, and texture, associated vegetation including other moonworts, shade or sun, plant characteristics lost in pressing and drying, date, collector, and collection number.

- Close-up photographs have to substitute for specimen vouchers in small populations where determination is held in question. They should show full length of the plant, leaflet outline, and leaflet venation.

-Repeated collections of the same species from a documented population and other collecting which does not contribute to botanical understanding are counter to species' conservation.

- Collections and their label data should be deposited in herbaria. Primary collections from this project have been and will be sent to the University of Montana (MONTU), which has the states largest holding of the genus, to facilitate future annotation and taxonomic revision by experts. Specimens have also been deposited in the herbaria of taxonomists making determinations and verifications (Peter Zika, Oregon State University; W. H. Wagner, University of Michigan), and to Forest Service and other regional herbaria including Montana State University (MONT) and Intermountain Research Station (MRC).

- Verification of specimens is recommended for all collections by botanists working with moonworts for the first time. It is also advised for specimens that document range extensions. Photocopies of specimens can be used for making verifications, at the light setting showing clearest vein patterns. Color photocopies are especially useful and should be taken as soon as possible after pressing for fresh color representation. Some out-of-state experts will prefer to have specimens deposited as gifts in their herbaria. Taxonomists should be contacted prior to sending specimens to determine if they are able to take the time to make determinations. Below is a partial listing of taxonomists who are providing consultation at this time; this list of contacts will be updated as appropriate:

<u>Instate</u>
Toby Spribille, Kootenai National Forest, Fortine Ranger District, P.O. Box 116, Fortine, MT 59918

Jim Vanderhorst, P.O. Box 1026, Troy, MT 59935

<u>Out-of-state</u>
Warren H. Wagner, Department of Biology, University of Michigan, Ann Arbor, MI 48109-1048. telephone: (313) 764-1484. email: whwag@umich.edu

Peter Zika, Herbarium, Department of Botany and Plant Pathology. Oregon State University. Corvallis, OR 97331.

APPENDIX F: Fungi associated with sensitive moonworts on the Kootenai National Forest identified by Larry Evans. a=Alexander Mountain, c=Can Creek, f=French Creek, k=Kelsey Creek, rb=Roderick Butte, rt=Red Top, s=Sutton Creek, wp= West Pipe, z=Zulu Creek.

Basidiomycetes

Armillaria mellea (group) s
Camarophyllus subviolaceous k
Clavariadelphus ligula k s
C. truncatus k
Clavulina corniculata f
C. cristata k
Clavulinopsis aurantio-cinnabarina s
C. sp. rt
C. corniculata s
C. dichotoma? k
C. laeticolor k s
Clitocybe clavipes f
Collybia acervata k
Coprinus plicatus a
Cortinarius bulbopodium (group) wp
C. cinnamomeus (group) k
C. laniger k
C. sp. a
C. sp. s
C. sp. (brown) s
C. sp. (fibrillose cap) k
Fuscoboletinus aeruginascens f p
Galerina sp. s
Heboloma crustuliniformis f
Hygrocybe coccineus k s
H. miniata s
Hypholoma capnoides k
H. conicus k
H. miniatus k
Hygrophorus eburneus f k
Inocybe geophylla a
I. laetior a
I. maculata a
I. sp. k
Lactarius alnicola rb
L. sanguifluus f k
L. zonata (group) z
Leucopaxillus albissimus a
Leptonia exalbida k

Basidiomycetes continued

L. nigroviolacea k s
L. parva s
L. undlatella s
Marasmiellus candidus (group) f s
Marasmius androsaceus a k p
Mycena alcalina k
M. pura k s
M. sp. f
Naematoloma capnoides k
Paneolus campanulatus a
Pleurotus elongatipes s
Pluteus cervinus a
Psathyrella gracilis (group) s
P. longistriata s
Russula abetina f k p
Suillus fuscotomentosus k
S. grevillei f p
S. sibericus or S. umbonatus c
Tricholoma saponaceum p
Tricholomopsis rutilans k s

Ascomycetes

Hypomyces sp. on Russula sp. k
Chlorocyboria aeruginascens k
Podostroma alutaceum s
Spathularia flavida f k a

APPENDIX G: Mosses associated with sensitive *Botrychium* species on the Kootenai National Forest. Specimens identified by Joe Elliott and collected by Joe Elliott, Jim Vanderhorst, or Terese Bielak.

Aulacomnium palustre K*
Brachythecium sp. Br, E
Brachythecium albicans A, AM
Brachythecium asperimum AM, Ho
Brachythecium erythrorhizon AM
Brachythecium plumosum WP
Brachythecium rutabulum? K
Bryum sp. Ch
Bryum pseudotriquetrum AM, Ho
Dicranum scoparium K
Drepanocladus fluitans AM
Eurhynchium oreganum Su, Z
Eurhynchium pulchellum Ca, Ro
Hypnum pratense Sw
Mnium thomsonii K, RT
Plagiomnium cuspidatum Ho, RT
Plagiomnium drummondii K
Plagiomnium insigne A, AM, Be, BM, Su, Z
Plagiomnium medium? Ba
Plagiomnium venustum E
Pleurozium schreberi UC
Pohlia sp. WP
Ptilium crista-castrensis K
Rhizomnium magnifolium Ch, He, Z
Rhizomnium nudum P, Z
Rhizomnium pseudopunctatum Fo
Rhytidiopsis robusta F, Su
Roellia roellia Fo, RT
Sanionia uncinata E
Timmia austriaca F, Su

* A = Alexander Ck. (*B. crenulatum* 010), AM = Alexander Mountain (*B. crenulatum* 005), Ba = Beaver Ck. (*B. ascendens* 003, *B. crenulatum* 007), Be = Beetle Creek (*B. minganense* 033), BM = Berray Mountain Cedars (*B. montanum* 017), Br = Bristow Ck. (*B. crenulatum* 011), Ca = Can Creek (*B. minganense* 044, *B. montanum* 011), Ch = Chief Ck. (*B. crenulatum* 009), E = Everett Ck. (*B. montanum* 021), Fr = French Ck. (*B .minganense* 021, *B. montanum* 020), Fo = Forest Creek (*B. minganense* 040, He = Hemlock Ck. (*B. minganense* 037), Ho Houghton Ck. (*B. ascendens* 004, *B. montanum* 026), K = Kelsey Ck. (*B. minganense* 025, *B. montanum* 012), P = Pipe Ck. (*B. montanum* 016), Ro = Roderick Butte (*B. montanum* 018), RT = Red Top Ck. (*B. minganense* 038, *B. montanum* 022), Su = Sutton Ck (*B. minganense* 049, *B. montanum* 024, *B. pedunculosum* 004), Sw = Swamp Creek (*B. crenulatum* 008), UC = Upper Can Ck. (*B. montanum* 009), WP = West Pipe Ck. (*B. montanum* 013), Z = Zulu Ck. (*B. minganense* 028, *B. montanum* 015, *B. paradoxum* 010)

APPENDIX H: U.S. Forest service Region 1 sensitive plant scoring criteria.

Table of sensitive plant criteria scores for sensitive and proposed sensitive *Botrychium* species on the Kootenai National Forest. Scored by J. Vanderhorst January, 1997.

species/criteria*	**1**	**2**	**3**	**4**	**5**	**total**
B. ascendens	9	4	3	3	1	20
B. crenulatum	6	4	3	3	1	17
B. minganense	0	0	9	1	1	11
B. montanum	3	4	9	3	1	20
B. paradoxum	6	4	3	1	1	15
B. pedunculosum	9	4	3	3	3	22

***1. ABUNDANCE**

9 Extremely rare: 5 or fewer known populations or an estimated total number of individuals of less than 1000 within Region 1.

6 Rare: From 6-20 known populations or an estimated total number of individuals between 1000 and 3000 within Region 1.

3 Uncommon: From 21-50 known populations or an estimated total number of individuals between 3000 and 10,000 within Region 1.

0 Common to abundant: Greater than 50 known populations or more than 10,000 individuals within Region 1.

2. DISTRIBUTION

6 Local endemic: Limited to one locale and/or occurs on only 1-2 National Forests or Grasslands.

4 Regional endemic: Occurs on more than 2 National Forests or Grasslands.

3 Disjunct (isolated) outlier: Occurs beyond the general perimeter of the range.

2 Peripheral: At edge of range.

0 Widespread: None of the above.

3. DEGREE OF THREAT OF HABITAT LOSS

9 High: Habitat directly threatened by habitat manipulation.

6 Moderate: Habitat moderately threatened by habitat manipulation.

3 Low: Habitat infrequently threatened by habitat manipulation.

0 None: Habitat not currently threatened by habitat manipulation.

NOTE: The "low" category was added during scoring of Montana plants, as many species seemed to fall between 0 and 6 for this criterion.

4. SPECIALIZED HABITAT/ECOLOGICAL AMPLITUDE

3 Narrow: Species is restricted to a unique or limited habitat or combination of habitats, and/or species has a high degree of habitat specificity.

1 Intermediate: Species is restricted to a relatively unique habitat or combination of habitats, and/or species has a moderate degree of habitat specificity.

0 No: Species is not restricted to unique habitats.

5. DOWNWARD TREND

3 Yes: Known or strongly suspected that species has suffered declines historically.

1 Possible: Information lacking, but downward trend a possibility.

0 No: No indication that species has suffered declines.