A conservation strategy for the six sensitive species of Botrychium on the Kootenai National Forest

Roger D. Ferriel
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A CONSERVATION STRATEGY FOR THE SIX SENSITIVE SPECIES OF

*BOTRYCHIUM* ON THE KOOTENAI NATIONAL FOREST

by

Roger D. Ferriel

B.A. The University of Montana. 1981

presented in partial fulfillment of the requirements

for the degree of

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April 2001

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5-14-01

Date
A Conservation Strategy for the Six Sensitive Species of *Botrychium* on the Kootenai National Forest

**Director:** Donald Bedunah

I provide a detailed quantification of the habitats of the six rare species of *Botrychium* that occur on the Kootenai National Forest (KNF) in northwestern Montana. In addition, management recommendations to maintain viable populations and improve management for these species are made. The Endangered Species Act and Forest Service Manual guidelines require the Forest Service to manage for viable populations of all native plants and animals that occur on Forest Service lands. An additional two rare species and possibly two undescribed species of *Botrychium* were documented on the KNF during the course of this work. Ecodata vegetation sampling plots, which included assessment of vascular plant species’ cover and measurement of some environmental characteristics, were completed at 66 *Botrychium* locations on the KNF. Eight *Botrychium* plant associations were described from the TWINSPLAN classification of the Ecodata plots. The ecological ordination programs Canonical Correspondence Analysis (CCA) and Detrended Correspondence Analysis (DCA) were used to create an ordination of *Botrychium* Ecodata plots to understand the important environmental site characteristics associated with *Botrychium* species distribution. Elevation and age of the plant community were the two most important measured environmental variables correlating plot distributions. *Botrychium* population demographics were analyzed with the measurement of permanent *Botrychium* monitoring plots for four years on the KNF. All KNF *Botrychium* occurrences are evaluated based on conservation concerns. The detailed knowledge of *Botrychium* distribution, abundance, habitats, and population demographics are used to develop site-specific management and monitoring recommendations to maintain viable populations of *Botrychium* on the KNF.
ACKNOWLEDGMENTS

This master’s thesis is dedicated to the memory of Dr. Warren Herb Wagner Jr. This research would have been impossible without the insight and work Dr. Wagner poured into understanding the difficult *Botrychium* genus. Dr. Wagner also provided much consultation, information, and species verification of problematic specimens *Botrychium*. I would also like to extend my heartfelt thanks to Dr. Florence Wagner for many discussions on *Botrychium*. Thanks to Dr. Donald Farrar for discussions and information on the genetics and reproductive biology of *Botrychium* and isozyme analysis on *Botrychium* plants from the Kootenai National Forest. Thanks to Jim Vanderhorst for the Conservation Assessment of *Botrychium* on the Kootenai National Forest that this thesis built upon. I am indebted to the Kootenai National Forest botany team for help with the surveys, monitoring, and completion of the Ecodata plots. The team members were: Mike Arvidson, Leslie Ferguson, Therese Gibson, Dan Leavell, Roy Lofts, Jon Reny, Toby Spribille, and Jack Triepke. I would like to thank Nancy Kmonk of the Kootenai National Forest for help with the Arcview portions of this project. Thanks to John Caratti for help with the formatting of the Ecodata plots to get them into the correct format to run through TWINSPAN and CANOCO. Thanks to Larry Bush for help with solutions to all computer software and hardware problems. Thanks to my parents Kay and Zip Ferriel and my sister Kathleen L. Farrell for support and encouragement during this project. Finally my deepest gratitude to Dr. Donald Bedunah for all his time reviewing the five long drafts of this thesis and all of his input to make this a better more readable document. This research was funded in part by the Kootenai National Forest and a grant from the National Forest Foundation. Both of which are very gratefully acknowledged.
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CHAPTER 1

INTRODUCTION

The Endangered Species Act (ESA) of 1973 provides stringent regulations for the preservation of rare species. When species are listed under the ESA, federal agencies and departments must insure that actions authorized, funded, or carried out by them are not likely to jeopardize the continued existence of any threatened or endangered species, or result in the destruction or adverse modification of their critical habitat (US Congress 1973). The Forest Service (FS) has additional departmental regulations that mandate that the agency will avoid actions, which may cause a species to become listed as threatened or endangered (FSM 2670, 1995a).

These regulations have led the Forest Service to create the sensitive species designation, in a proactive attempt to avoid listing species as threatened or endangered under the ESA. For most plant species, we do not have the detailed demographic data to determine population trends. Plant species are listed as sensitive based on their current known number of occurrences within a Forest Service Region and without knowledge of population trends. State Natural Heritage Program's databases are strongly relied upon to determine which species are rare enough to be considered as sensitive. Plant species with a low number of occurrences are assumed to be a population viability concern. The number of documented occurrences is used as a surrogate for knowledge of population demographic trends.

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1 FSM 2670 also directs the Forest Service to manage habitats for all existing native and desirable nonnative plants, fish, and wildlife species in order to maintain at least viable populations of such species and to conduct activities and programs to assist in the identification and recovery of threatened and endangered species.

2 Sensitive species are defined as those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by: 1) significant current or predicted downward trends in population numbers or density, and 2) significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution (FSM 2670, 1995b).
Six sensitive species of *Botrychium* have been documented on the Kootenai National Forest (KNF) (USFS R1 1999). All six species are endemic to North America. *Botrychium*, or moonworts, are small primitive ferns in the family Ophioglossaceae. There is little known about the habitat preferences or the autecology of *Botrychium* species. Resource managers make land management decisions without adequate knowledge about how their decisions will affect sensitive *Botrychium* species. This can increase the probability of a court challenge of management decisions, increasing the costs of land management, reducing the timely implementation of management decisions, and increasing public divisiveness over natural resource management.

A detailed habitat characterization of all sensitive species of *Botrychium* is necessary to ensure that resource managers can accurately assess potential management effects on sensitive *Botrychium* species as required by law and agency guidelines. This study quantifies the habitat requirements for sensitive *Botrychium* species on the KNF, and provides scientifically based documentation for management guidelines for maintaining viable populations of *Botrychium* on the KNF. The detailed description of *Botrychium* habitats will also help to focus plant survey work in areas of highest potential for *Botrychium* occurrence reducing plant survey costs. The overall goal of this thesis is to provide a conservation strategy for *B. ascendens* W. H. Wagner, *B. crenulatum* W. H. Wagner, *B. minganense* Victorin, *B. montanum* W. H. Wagner, *B. paradoxum* W. H. Wagner, and *B. pedunculosum* W. H. Wagner, on the KNF. In addition, field work and literature review were used to identify other *Botrychium* species that should be designated.
as sensitive or rare. The current Montana and FS status for *Botrychium* species were also reviewed and I recommended any appropriate status changes.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Conservation Strategies typically consist of a literature review of the species’ technical description, biology, autecology, distribution, abundance, and threats (US Department of Interior 1995, and 1996). Management recommendations are then written to maintain the viability and persistence of the species and avoid its listing as threatened or endangered based upon the information gathered through the literature review (US Department of Interior 1995, and 1996). A detailed understanding of the taxonomy, systematics, biology, autecology, distribution and abundance of sensitive *Botrychium* species is required to formulate informed management recommendations for the persistence of these species. Therefore, a detailed literature review of these facets of sensitive *Botrychium* species follows. A technical description of the sensitive species of *Botrychium* is not included in this report because it is available elsewhere (Wagner and Wagner 1993, Vanderhorst 1997).

2.2 Taxonomy and Systematics

The family Ophioglossaceae currently consists of five genera, including *Botrychium*, *Helminthostachys*, *Cheiroglossa*, *Ophioderma*, and *Ophioglossum*. Three genera in the family Ophioglossaceae occur in North America: *Botrychium*, *Ophioglossum*, and *Cheiroglossa* (Wagner and Wagner 1993). The family Ophioglossaceae is comprised of two clearly defined subfamilies: Botrychioideae and Ophioglossoideae (Wagner and Wagner 1993). The genus *Botrychium* is further divided into three subgenera:
Botrychium, Osmundopteris (includes B. virginianum), and Sceptridium (includes B. multifidum) (Wagner and Wagner 1993). All sensitive species of Botrychium that occur on the KNF are in the subgenus Botrychium.

Botrychium species are difficult to differentiate, which creates controversy as to whether they are distinct or “good” species. Species of Botrychium are differentiated by subtle morphological differences. Unlike flowering plants, there is no need to attract a pollinator and thus there is no need to create unique reproductive structures (Barrington 1993). Flowering plants are typically differentiated by floral structure. The taxonomy of the Ophioglossaceae is based on the single aboveground leaf. Members of the family Ophioglossaceae possess only a small number of comparative characteristics that can be used to differentiate the species (Clausen 1938). Species determinations are based on leaf cutting, venation, color, texture, and size (Clausen 1938).

The taxonomy of Botrychium has recently undergone rapid change. Fifteen new species of Botrychium have been described since 1980 (Wagner and Wagner 1993, Wagner and Wagner 1994). Today there are 24 species in the subgenus Botrychium. Most flora treatments before 1993 do not adequately cover the newer species of Botrychium. The increased taxonomic understanding of Botrychium is primarily the work of one couple: Drs. Herb and Florence Wagner of the University of Michigan. Dr. Herb Wagner has been at least partial author on all but one of the 15 new species described since 1980 (Wagner and Wagner 1993, Wagner and Wagner 1994). Botrychium taxonomy continues to evolve. Dr. Wagner was recently working on describing three new species of
Botrychium (B. michiganense, B. adnatum, and B. venulosum) that occur in Glacier National Park (Wagner pers. comm.).

Hauk (1995), Farrar (1998a), Hauk and Haufler (1999) used isozyme analysis to determine Botrychium species delimitations and relationships that supports the current controversial taxonomy of the genus. The Botrychium taxonomic picture is further complicated by the presence of hybrids. A number of species have been documented to hybridize (Wagner 1980, Wagner and Wagner 1988, and Wagner et al. 1985), although Botrychium hybrids are not common (Farrar pers. comm.). Botrychium hybrids are typically sterile (except for allopolyplploids) and produce spores that tend to be abortive (Wagner et al. 1985). The most common Botrychium hybrid is B. X watertonense a cross between B. hesperium and B. paradoxum (Wagner and Wagner 1988). It is possible that this "common" hybrid is perpetuating itself by apomixis, reproducing by rhizome, gemmae or unreduced spores, since the spores are abortive (Wagner and Wagner 1988).

2.3 Life Cycle

The Botrychium life cycle is characterized by an alternation of generations, as are all ferns. The life cycle begins with a haploid spore being dispersed by some vector, and carried below ground probably by water infiltration, where it germinates to form the haploid gametophyte (Gifford and Foster 1974, Wagner 1998). The spores must be carried below ground to germinate. Whittier (1991) documented that Botrychium dissectum spores required being placed in the dark for three to four months before they would germinate. Botrychium gametophytes are free living (exosporic as in all
homosporous plants) and wholly dependant on infection by mycorrhizal fungi for uptake of water and nutrients (Gifford and Foster 1974, Wagner 1998). Whittier (1984) found that sugar was necessary in the culture medium to grow *Botrychium dissectum* gametophytes in the lab. The sugar in the nutrient medium replaced the carbohydrates that the gametophyte gets from the mycorrhizal fungal associate in nature. The gametophyte generation may be the most important aspect of habitat fidelity for many ferns for which there is more information (Given 1993). This is the critical sexual stage of the life cycle, which is most susceptible to drought stress (Given 1993).

*Botrychium* gametophytes are small “potato like” structures with rhizoids (Campbell 1922). It is unknown how long it takes gametophytes to reach sexual maturity in the soil. Estimates vary from 5-20 years (Campbell 1922, Farrar pers. comm., Muller 1993). Whittier (1984, and 1991) found that *B. dissectum* gametophytes raised in laboratory cultures would reach maturity in one year. This is probably not the case in nature (Farrar pers. comm.). Each gametophyte is bisexual producing both sexual structures the antheridium and the archegonium. The presence of both male and female sex organs allows a single spore to initiate a new population of genetically identical individuals if it lands on suitable habitat. The archegonium produces the egg and the antheridium produces the multi-flagellate sperm. Uptake of water causes the antheridium to swell and rupture releasing the sperm (Dyer 1979). Thus, the release of the sperm only occurs when water is abundant enough for the sperm to swim to the archegonium. This limits the release of sperm to times when the environment will favor fertilization. The sperm then fertilizes the egg in the archegonium. The fusion of the egg and sperm forms the
diploid phase of the life cycle that grows to become the sporophyte. At first, the sporophyte is wholly dependant on the gametophyte for nutrition and water (Foster and Gifford 1974). The sporophyte develops and soon becomes independent. The sporophyte spends from 5-10 years below ground before it finally emerges above ground (Johnson-Groh pers. comm., Muller 1993). During this time below ground, the newly formed sporophyte produces five leaf primordia (Wagner pers. comm.). These primordia are stored. Only one above ground leaf emerges each year. The additional leaves are left in reserve for future years. The sporophore emerges above ground and through meiosis produces more haploid spores that are then dispersed to start the cycle again.

The significance of the alternation of generations cannot be over stated. It is as if there are two separate plants with very different habitat requirements. Conditions must be favorable for both the gametophyte and the sporophyte for the species to be present. Conditions must be favorable for the mycorrhizal fungi as well (Section 2.5). In fact, this may be the key to the distribution and abundance of species of *Botrychium* (Farrar and Johnson-Groh pers. comm.). There are some documented instances of Central American fern species having their gametophytes growing in the Southeastern United States (US), where the sporophytes have never been observed or reported (Dyer 1979, Farrar 1967). The conditions are favorable for the gametophyte but not the sporophyte. The subterranean gametophyte habitat is believed to be an adaptation to living in a warm dry droughty climate (Wagner pers. comm.). There is more moisture available below ground. Some hypothesize that the alternation of generations with the subterranean gametophyte was an adaptation to allow the first vascular plants to colonize the land. Still others
(Wagner pers. comm.) state that the subterranean gametophyte is the derived character state and the above ground gametophyte is the primitive state.

Some variations of the above life cycle sometimes occur. One oddity of the Botrychium life cycle that has been observed is the production of perennial gametophytes (Wagner 1998). Johnson-Groh (pers. comm.) has observed *B. mormo* gametophytes producing more than one sporophyte of different ages. These are essentially perennial gametophytes. An asexual method of reproduction that has been documented in *Botrychium* is the production of gemmae (Farrar and Johnson-Groh 1990, Camacho 1996, Camacho 1999). Gemmae are small spherical asexual reproductive buds formed from the meristematic tissue of the outer cortex of the sporophyte’s stem (Farrar and Johnson-Groh 1990). These buds break off the parent plant and then form new sporophytes. Gemmae are thought to be an adaptation to drought providing reproductive ability without the water required by the sperm to swim to the archegonium. Gemmae production has been documented in the prairie species of *Botrychium*: *B. campestre* and *B. galicomontanum*, and in *B. echo*, *B. minganense*, and *B. punicola* (Farrar and Johnson-Groh 1990, and Camacho 1996). Dryer prairie habitats are thought to promote the formation of gemmae.

### 2.4 Reproductive Biology

We are at an early stage in the understanding of the genetic structure of *Botrychium* species, populations, and selfing plants in general. The problems with obtaining a clear understanding of fern genetic structure were listed by Yatskievych and Morin (1989) as:
1) high chromosome number, 2) less morphological variability than flowering plants, 3) polyploidy, 4) asexual reproduction, and 5) rampant hybridization. These five attributes of ferns play havoc with tradition species definitions. All homosporous pteridophytes have high chromosome numbers compared to seed plants (Haufler 1987), and polyploidy is common in the genus Botrychium (Wagner and Wagner 1993). There is constantly new and different research being carried out in fern genetics. The results of this research sometimes appear contradictory and mutually exclusive. It is hard to assimilate the differing research outcomes into one clear picture detailing the genetics of selfing plants in general and Botrychium in particular. The research results often seem in conflict because the research is examining different processes. To understand the seeming discrepancies between research results it is important to have some understanding of the methods involved. The following describes some of these conflicting results.

Dr. Donald Farrar at Iowa State University is in the process of determining species relationships for all species of Botrychium occurring in Washington, Oregon, Montana, and Alaska. Farrar has previously done similar work for the Botrychium species found in the eastern US. Farrar is using gel electrophoresis to measure enzyme variation for his examination of Botrychium biosystematic relationships. Enzymes are products of genes and thus a reflection of the genotype (Farrar 1997). Enzymes are good indicators of genetic diversity because of their relatively conservative nature. They are passed down to succeeding generations in unchanged form. Allelic frequencies and thus rates of heterozygosity can be determined from the variation in the plant enzyme migration rates
produced by gel electrophoresis (Farrar 1998a). Nei's Index of Similarity can be derived from the allelic frequencies (Crawford 1989). The Nei Index is on a scale of 0 to 1. Where zero would be two plant species with no alleles in common and a one would indicate that all alleles for the two species are identical. Plant species with a 90% or greater similarity in enzyme banding pattern are regarded as a single species (Farrar 1998a). Plants with an enzyme banding pattern that displays a similarity of less than 90% are regarded as unique species.

Botrychium's subterranean gametophyte combined with the short distance that fern sperm can swim appears to favor self-fertilization. Farrar (1998a) has found less than 1% of the over 2000 Botrychium plants he has analyzed are heterozygous indicating that out-crossing is a rare occurrence. Soltis and Soltis (1986), Hauk (1995), and McCauley et al. (1985) obtained similar results. Soltis and Soltis found that B. virginianum had an intragametophytic selfing rate of 96%. Hauk analyzed the isozyme profiles of 15 species in the subgenus Botrychium, finding six loci that consistently yielded interpretable banding patterns. Heterozygosity rates were low to nonexistent at the six loci that Hauk examined and statistics of genetic variability could not be calculated (Hauk 1995). McCauley et al. (1985) found an intragametophytic selfing rate of 95% for B. dissectum. Even given these low rates of out-crossing some sexual reproduction and genetic recombination does occur. The occurrence of hybrids between different species of Botrychium also substantiates that sexual reproduction does occur on rare occasions (Wagner et al. 1985).
The life cycle has profound effects on the potential survival and adaptability of any species. *Botrychium* must contend with the problems of founder effect reducing genetic diversity in a population because of limited initial genetic stock founding a new population. A single spore can be an effective dispersal mechanism over a long distance, landing on a safe site and initiating a new population (Page 1979). Each individual *Botrychium* gametophyte is derived from a single haploid spore. If the gametophyte is then self fertilized the resulting diploid sporophyte will be completely homozygous for all alleles in a single generation (Holsinger 1990). The diploid sporophyte will contain two exact copies of the same allele for each locus. This is much more extreme than self-fertilization in seed plants, which results in the halving of heterozygosity in each generation (Holsinger 1990). No meiosis or genetic recombination occurs from the haploid spore to the diploid sporophyte in pteridophytes.

Is this lack of genetic diversity detrimental to the species long-term survival? Genetic theory states that homozygosity limits the amount of genetic material available to produce different gene products. Lack of genetic diversity limits an organism's ability to respond to environmental changes, disease, competition, and predation, which may favor an organism with a particular genetic trait (Boyce 1992, Primack 1993, Frankel et al. 1995, Lawrence and Marshall 1997). A species evolutionary potential is dependant on the level of genetic variation within a species and on the distribution of that variation between and among its populations (Soltis and Soltis 1990, Frankel et al. 1995, Lawrence and Marshall 1997). In out-crossing species accumulation of deleterious genes (genetic load), cause self-fertilization to be unsuccessful because it produces a completely
homozygous condition that exposes these deleterious alleles (Farrar 1998a). Some have theorized that the duplication of chromosomes through polyploidy can alleviate the deleterious effects of homozygosity (Klekowski 1973). The duplicate allele can mask any recessive deleterious alleles from being expressed. It may be advantageous for homosporous ferns to double chromosome numbers to override the effects of deleterious alleles (Paris, et al. 1989). The attributes of fern genetics challenge some widely held evolutionary precepts including the importance of heterozygosity (Werth and Cousens 1990).

There is some controversy whether plant species are adversely affected by inbreeding, given the widespread prevalence of selfing breeding systems in many plant species. The major detrimental effect of inbreeding is inbreeding depression (Lande and Schemske 1985). Inbreeding depression results from mating among close relatives producing fewer offspring that are weak or sterile, and increases the expression of harmful alleles. Inbreeding depression has not been well established for plants (Menges 1992, Falk 1992). While inbreeding depression has been documented in domesticated stock animals and zoo populations, studies of inbreeding in wild animal populations have found little evidence of inbreeding depression in natural conditions (Lacy 1992). If the effects of inbreeding depression were the expression of deleterious alleles, then selection would remove most deleterious alleles from populations with a long history of inbreeding (Lande and Schemske 1985, Lacy 1992). Individuals homozygous for recessive alleles would not survive over time due to strong selection against these individuals (Lacy 1992). Thus, selection that favors selfing due to pollinator failure or population
bottlenecks would eventually lead to reduction of inbreeding depression in selfing populations over time (Lande and Schemske 1985, Lacy 1992).

Gel electrophoresis examines only genetic products: enzymes. It does not look at individual genes themselves. The enzymes are surrogates for the actual genotype of the plant. Gel electrophoresis has been shown to be very useful for resolving taxonomic questions between genera, for differentiation of individual species, and elucidating phylogenetic relationships (Soltis and Soltis 1989, Shelly et al. 1998). Studies of isozymes detect variance in genes encoding for enzymes, this may not be representative of the entire genome (Crawford 1989). There is some question of isozyme electrophoresis ability to determine genetic variation within the same species and between populations of the same species, without also utilizing some kind of DNA analysis (Szmidt et al. 1996). This is typically done by examining either chloroplast or mitochondrial DNA. The process involves examining genetic markers or autopomorphies. Rieseberg and Brunsfield (1991) suggest that DNA analysis will replace isozyme analysis for determining genetic relationships. The use of isozyme markers is limited by the relatively low number of alleles distinguishing closely related forms compared to DNA analysis that is not limited (Rieseberg and Brunsfield 1991, Szmidt pers. comm.). The primary draw back to Random Amplified Polymorphic DNA (RAPDs) or other available genetic marker techniques is that dominant characters will preclude precise assessment of population genetic parameter (Szmidt pers. comm.). In diploid organisms, a homozygous gene with the frequency AA cannot be differentiated from Aa (heterozygous) (Wang and Szmidt 2000). Both allelic frequencies will give RAPD bands corresponding to A (Wang
and Szmidt 2000). There is no one perfect system for determining genetic diversity. Szmidt (pers. comm.) recommends the combination of allozymes and RAPDs to determine existing genetic diversity.

The results of the isozyme analyses of *Botrychium* species by Farrar (1998a), Soltis and Soltis (1986), McCauley et al. (1985), and Hauk (1995) are contrasted with the preliminary results of Linda Swartz (Swartz pers. comm.). Linda Swartz, a graduate student at the University of Idaho studying Random Amplified Polymorphic DNA (RAPD) patterns in *Botrychium crenulatum* and *B. minganense*, has found that there is genetic diversity present both within and between populations of the same species of *Botrychium*. In contrast, Dr. Farrar's isozyme research shows no genetic diversity within populations, and only very small genetic diversity between populations of the same species of *Botrychium*. These seemingly incongruous research results are probably due to the different techniques and their sensitivity to detecting genetic variation.

The isozyme results of Farrar (1998a), Soltis and Soltis (1986), Hauk (1995), and McCauley et al. (1985) showing little genetic diversity in *Botrychium* species also vary from the results obtained by Camacho (1999). Camacho (1999) used Inter-Simple Sequence Repeats (ISSR) to determine population structure and genetic diversity of *B. pumicola*, a rare endemic fern of central Oregon and perhaps northern California, which grows on pumice substrates. ISSR produced 15 polymorphic loci, and identified 71 ISSR genotypes, from a sample of 99 *B. pumicola* individuals from three populations. Sixteen of the ISSR identified genotypes were shared by more than one individual, indicating that
these plants were essentially clones. Camacho (1999) found that the greatest genetic diversity was within populations of *B. pumicola*, and not between populations as would be expected for a selfing plant species (Haufler 1987). Typically, the greatest genetic diversity is partitioned within populations for out-crossing plants, and the greatest genetic diversity is partitioned between populations of selfing plant species (Haufler 1987).

ISSR does not measure heterozygosity. Thus, rates of inbreeding cannot be determined. It is expected that ISSR will have higher levels of polymorphism than isozymes (Camacho 1999). ISSR markers do not separate according to Mendelian expectations. ISSR bands may be in portions of the chromosome that do not segregate equally in meiosis even in a completely homozygous individual (Camacho 1999). Variable selection over space may also maintain high levels of polymorphisms identical to random mating in a self-fertilizing population (Hedrick 1998).

DNA markers and isozymes experience different evolutionary dynamics and reveal different patterns of genetic variation (Ayres and Ryan 1997). RAPD bands can arise from coding and noncoding regions of DNA unlike the genes that are responsible for coding for isozymes (Ayres and Ryan 1997). RAPD markers are less responsive to selection, and have a higher tolerance of mutation, than DNA that codes for enzymes (Ayres and Ryan 1997). Thus, differing results of genetic diversity for the same individuals using RAPD and isozyme techniques are highly probable. Ayres and Ryan (1997) found different rates of genetic diversity in the same individuals of *Wyethia reticulata* when they compared results of RAPD with isozyme analysis. The combination of RAPD and isozyme genetic profiles provided the most accurate display of population
genetic structure for *Wyethia reticulata* (Ayres and Ryan 1997). Newbury and Ford (1997) rate the ability of isozyme techniques to detect genetic variation as low. Whereas, the ability of RAPD and Polymerase Chain Reaction (PCR) techniques are rated as high for their ability to detect genetic variation (Newbury and Ford 1997).

These conflicting results of the genetic variation in species and populations of *Botrychium* greatly muddle the understanding of mating system and population genetic structure for these species. Camacho’s (1999) results seem to indicate that some sexual reproduction is occurring although ISSR does not allow calculation of rates of homozygosity and inbreeding. Isozyme analysis has proven to be a very valuable technique for elucidating phylogenetic relationships and differentiating species of *Botrychium*. However, isozyme analysis may not be sensitive enough to determine genetic structure within species and populations of *Botrychium*. A combined study utilizing RAPD and isozyme analysis may be required to obtain an accurate picture of genetic structure of *Botrychium* populations.

2.5 Mycorrhizal Fungi

The energy budget for *Botrychium* has not been well studied. It is unknown how much actual free carbon dioxide (CO₂) that the sporophyte is photosynthetically fixing, and how much carbon is supplied through the mycorrhizal associate. It is hypothesized that the function of *Botrychium*’s trophophore is the protection of the sporophore as it pushes up through the ground (Farrar 1997). The trophophore typically wraps around the sporophore as it emerges. Some *Botrychium mormo* sporophytes do not emerge above
ground, remaining buried below the leaf litter (Berlin et al. 1998). Spore dispersal may then occur through the ingestion of spores by a small mammal and the subsequent passage of the spores through the digestive system (Berlin et al. 1998). *Botrychium* sporophytes may emerge above ground only to release spores. There is probably no great quantity of carbon fixation occurring in these small plants, which often occur in low light environments. Albino *B. lanceolatum* plants without chlorophyll have been found in northern Michigan (Farrar 1997). This further documents the reduced importance for *Botrychium* to photosynthetically fix carbon. The mycorrhizal associates of *Botrychium* may be supplying the majority of the carbon to *Botrychium* plants.

The roots of *Botrychium* sporophytes are large, fleshy, and lacking any root hairs or "magnolioid" (Foster and Gifford 1974). "Magnolioid" roots with few root hairs are frequently associated with high responsiveness to mycorrhizal infection (Smith and Read 1997). *Botrychium* require the additional absorptive surface that they get through their connection with their mycorrhizal associates. The smaller diameter mycorrhizal hyphae can penetrate smaller soil pores and cover more area than the large fleshy *Botrychium* roots.

The mycorrhizal fungal associates of *Botrychium* have not been fully identified (Camacho 1999). It is unknown if the gametophyte and sporophyte have the same mycorrhizal associate. Schmid and Oberwinkler (1994) used transmission electron microscopy to observe that the gametophytes of *B. lunaria* were heavily infected by intracellular aseptate fungal hyphae with vesicles but without arbuscules. These
characteristics are comparable to previous observations for vesicular arbuscular (VA) mycorrhizae (Schmid and Oberwinkler 1994, Smith and Read 1997). *B. lunaria* gametophytes’ intracellular fungal hyphae died and did not infect the sporophyte produced from the sexual reproduction occurring on the gametophyte (Schmid and Oberwinkler 1994).

The fungi that infect *Botrychium* sporophytes were thought to be endo-mycorrhizal fungi of the vesicular arbuscular (VA) fungal type, but without the vesicles, arbuscules, or coils commonly found in VA fungi (Farrar 1997). It was believed that the fungal associates of *Botrychium* were generalist VA fungi (Farrar 1998b). Typically, vascular plants are associated with three or four species of endo-mycorrhizal fungi (Smith and Read 1997). The fungi form a large web below ground connecting a number of plant species. *Botrychium* may be intermediate between autotrophic plants and mycoheterotrophic plants that parasitize fungi for sustenance (Camacho 1999). It is probable that *Botrychium* are supplying some micronutrient to the VA fungi to get the fungi to infect them (Farrar 1998b). Thus, it would be advantageous for *Botrychium* species to be genetically conservative-maintaining very low levels of genetic diversity-to preserve the genes responsible for the production of the micronutrients required by the VA fungi for infection.

The above observation that the major type of mycorrhizal associate of *Botrychium* is endo-mycorrhizal fungi is based on a limited sample of roots, from only a few species of *Botrychium*. Camacho (1999) made a detailed study of the physical structure and
genetics of the fungal species found within the roots of *B. pumicola*. Camacho sampled the roots from 14 *B. pumicola* plants from five populations, staining the roots and looking at the fungal structures in the roots with an electron microscope. Mycorrhizal fungi are differentiated into general types based on the occurrence of fungal septations, intracellular colonization of the roots, fungal sheath, Hartig net, and vesicles (Smith and Read 1997). VA mycorrhizal fungi are characterized by having aseptate fungi, intracellular colonization of the roots, and variable occurrence of vesicles (Smith and Read 1997). Camacho (1999) found that the roots of *B. pumicola* are highly colonized by fungi with septate hyphae most characteristic of an ascomycete. Vesicles were common in the *B. pumicola* roots but these were associated with septate hyphae. Roots of most ferns have been found to have VA mycorrhizal fungi (Smith and Read 1997), although some ferns have been found to contain ericoid-like and orchidoid-like mycorrhizae with regularly septate hyphae (Camacho 1999). The observations of the roots of *B. pumicola* by Camacho indicate that VA mycorrhizal fungi were not always present within the roots sampled, and when VA mycorrhizal fungi were observed it was not the dominant fungal type present in the roots.

Camacho (1999) also examined the DNA of the fungi from the roots of seven *Botrychium pumicola* plants from three locations to try to determine the fungal species present. Camacho used Polymerase Chain Reaction (PCR) amplification, cloning, and sequencing of the fungal Internal Transcribed Spacer (ITS) region of the nrDNA (non-ribosomal DNA) to phylogenetically identify the fungi. The seven plants that Camacho examined produced 26 different RFLP-types (restriction fragment length polymorphisms). Some of
these RFLP-types were very similar and were determined to be from the same fungal species. Thus, Camacho found 16 different phylogenetic groups of fungi within the seven plants sampled. These different phylogenetic groups represent different fungal species. A single 2-cm. section of B. pumicola root was found to contain eight different fungal phylotypes. Camacho compared ITS sequence from the fungi isolated from the roots of B. pumicola with known fungal species’ ITS sequences. The dominant phylotypes found in the B. pumicola roots were ascomycetes. VA mycorrhizal phylotypes occurred in only five of the seven roots sampled, and accounted for 20% or less of the total fungal phylotypes found in these roots. The dominance of ascomycete phylotypes in the sampled B. pumicola roots corroborates Camacho’s electron microscope observations of the abundance of septate hyphae within B. pumicola roots. The findings of the dominance of ascomycete septate fungi and the sometimes absence of VA mycorrhizal fungi within the roots of B. pumicola provide a much more complex picture of the fungal community within the roots of Botrychium than was previously thought. It is possible that only a little VA mycorrhizal fungi are needed to obtain benefit from the association for the host plant (Camacho 1999). Conversely, species of Botrychium may be dependent on ascomycetes mycorrhizal fungi more typical of ericoid mycorrhizae.

2.6 Results of Allozyme Analysis of Botrychium Specimens from the KNF

In 1997 and 1998, the KNF collaborated in the collection of Botrychium specimens for allozyme (different forms of the same enzyme specified by different alleles at the same loci) analysis by Dr. Donald Farrar at Iowa State University. Dr. Farrar is conducting a
larger study of the taxonomic relationships (phylogeny) of all western species of 
*Botrychium* in the subgenus *Botrychium*. The intention of the KNF *Botrychium*
collections for this study was to assess the genetic diversity both within and between
populations of *Botrychium minganense*. This was meant to answer the conservation
question: are some populations more important than others because they have greater
genetic diversity or a rare genome that may be important to be able to adapt to a new or
changing environment? *B. minganense* was chosen because of its relative abundance, its
morphological diversity, and the diversity of habitats where it occurs. The morphological
and habitat diversity would seem to indicate high rates of genetic diversity. There has
also been the ongoing question of whether additional cryptic species are being lumped
together into *B. minganense* (Hauk 1995). Collections were made from the range of
habitats and morphological types of *B. minganense* on the KNF. A minimum of six
plants from each population was collected. Additional collections were made at locations
where species determinations were in question. The species determinations from Farrar’s
isozyme analysis of KNF *Botrychium* are summarized in Table 2.1. *Botrychium*
*montanum* plants from Roderick Butte were collected to add to the geographic range of
*B. montanum* for Dr. Farrar’s study. *B. pedunculosum* was collected at West Fork Quartz
Creek because Dr. Wagner (pers. comm.) had indicated that plants from this population
might be a new species. They differ from typical *B. pedunculosum* by having a much
reduced elaminate trophophore. This appears to be the typical morphology of *B.*
*pedunculosum* in forested habitats on the KNF.
Table 2.1. *Botrychium* species determinations from isozyme analysis of plants collected on the Kootenai National Forest in 1997-1998.

<table>
<thead>
<tr>
<th>Ranger District</th>
<th>Location</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Libby</td>
<td>Doak Creek</td>
<td><em>B. crenulatum</em></td>
</tr>
<tr>
<td>Cabinet</td>
<td>Saint Paul Peak</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Eureka</td>
<td>Sutton Creek</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Eureka</td>
<td>Young Creek</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Fortine</td>
<td>Bluebird Lake</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Fortine</td>
<td>Green Mountain</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Fortine</td>
<td>Wolverine Creek</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Libby</td>
<td>Horse Mountain</td>
<td><em>B. minganense</em></td>
</tr>
<tr>
<td>Eureka</td>
<td>Parsnip Creek</td>
<td><em>B. minganense, B. lunaria</em></td>
</tr>
<tr>
<td>Troy</td>
<td>Basin Creek</td>
<td><em>B. minganense, B. lunaria</em></td>
</tr>
<tr>
<td>Troy</td>
<td>Roderick Butte</td>
<td><em>B. montanum</em></td>
</tr>
<tr>
<td>Libby</td>
<td>West Fork of Quartz Creek</td>
<td><em>B. pedunculosum</em></td>
</tr>
</tbody>
</table>

Dr. Farrar has detected little genetic diversity within any of the *Botrychium minganense* that were sampled in his research; this includes *B. minganense* from the eastern United States. Only two new alleles were found in western *B. minganense* that were not previously reported in eastern *B. minganense* (Farrar 1998a). Western *B. minganense* was found to be variable at 7 of the 17 loci that were examined. This is the highest variability found in any *Botrychium* species that was studied (Farrar 1998a). Still even this relatively high rate of genetic diversity does not produce a Nei’s Index of Similarity less than 90%. All *Botrychium minganense* plants Dr. Farrar has analyzed thus far indicate that *B. minganense* is one species (Farrar 1998a). These results are corroborated by those of Hauk who also found that *B. minganense* was the most genetically diverse of the 15 species of *Botrychium* that he studied (Hauk 1995, Hauk and Haufler 1999). *B. minganense*’s relatively high genetic variability is corroborated by the diversity of habitats
it occurs in on the KNF. *B. minganense* occurs from low elevations in moist, shady, mature, cedar/hemlock forests to open exposed vegetation mats on alpine summits. The physiological variability of *B. minganense* to tolerate this broad habitat range is somewhat manifested in the allozyme results. Different enzymatic products would be necessary to withstand the greater cold, shorter growing season, higher light intensity, and higher winds characteristic of the alpine summits.

The allozyme analysis corrected some *Botrychium* species determinations. Individual *Botrychium* plants can be differentiated correctly with a greater understanding of the morphological variation that characterizes these species. The plants that had been misidentified as *B. crenulatum*, while dwarfish (size 1-6 cm.) and with few pinnae pairs, all had cuneate pinnae. They did not have the lunate or crescent shape pinnae that are diagnostic of *B. crenulatum* (Wagner and Wagner 1993). Conversely, the plants at Doak Creek do have the lunate pinnae characteristic of *B. crenulatum*. The allozyme analysis also shattered some commonly held *Botrychium* beliefs on the KNF: all *Botrychium* with lunate pinnae occurring in cedar/hemlock forests are not *B. minganense*, and all dwarf *Botrychium* with few pinnae are not *B. crenulatum*.

2.7 Global Distribution and State and Global Rarity Rankings for the Six Sensitive Species of *Botrychium* on the Kootenai National Forest

2.7.1 *Botrychium ascendens* W. H. Wagner

*Botrychium ascendens* is known to occur in Alberta, British Columbia, Ontario, and Yukon Territories in Canada (Wagner and Wagner 1993), and in Alaska, California.
Idaho (Idaho Conservation Data Center 1999), Montana, Nevada, Oregon, Washington (Washington Natural Heritage Program 1997), and Wyoming (Wagner and Wagner 1993). Globally *B. ascendens* is ranked as G3 (Table 2.2), and S1 in Montana (MTNHP 1999).

### 2.7.2 *Botrychium crenulatum* W. H. Wagner

*Botrychium crenulatum* is known to occur in British Columbia, Canada (Williston 1999), and in Arizona, California, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming (Wagner and Wagner 1993). Globally *B. crenulatum* is ranked as G3 (Table 2.2), and S2 in Montana (MTNHP 1999).

### 2.7.3 *Botrychium minganense* Victorin

*Botrychium minganense* is known to occur in all Provinces of Canada (Wagner and Wagner 1993) and in Alaska, Arizona, California, Colorado, Idaho, Maine, Michigan, Montana, Nevada, New Hampshire, New York, North Dakota, Oregon, Utah, Vermont, Washington, Wisconsin, and Wyoming (Wagner and Wagner 1993). Globally *B. minganense* is ranked as G4 (Table 2.2), and S3 in Montana (MTNHP 1999).

### 2.7.4 *Botrychium montanum* W. H. Wagner

*Botrychium montanum* is known to occur in British Columbia, Canada (Wagner and Wagner 1993) in California, Idaho (Idaho Conservation Data Center 1999), Montana, Oregon, and Washington (Wagner and Wagner 1993). Globally *B. montanum* is ranked as G3 (Table 2.2), and S3 in Montana (MTNHP 1999).
Table 2.2. *Botrychium* rarity statuses\(^1\) in Washington, Oregon, Idaho, and Montana.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>GLOBAL RANK</th>
<th>WA</th>
<th>OR</th>
<th>ID</th>
<th>MT</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. ascendens</em></td>
<td>G3(^2)</td>
<td>S2</td>
<td>S2</td>
<td>S1</td>
<td>S1</td>
</tr>
<tr>
<td><em>B. campestre</em></td>
<td>G3/G2</td>
<td>S1</td>
<td>S1</td>
<td>ABSENT</td>
<td>S1</td>
</tr>
<tr>
<td><em>B. crenulatum</em></td>
<td>G3</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>S2</td>
</tr>
<tr>
<td><em>B. hesperium</em></td>
<td>G3</td>
<td>S1</td>
<td>S1</td>
<td>ABSENT</td>
<td>S2</td>
</tr>
<tr>
<td><em>B. lanceolatum</em></td>
<td>G5</td>
<td>S3</td>
<td>S3</td>
<td>ABSENT</td>
<td>X</td>
</tr>
<tr>
<td><em>B. lineare</em></td>
<td>G1</td>
<td>S1</td>
<td>S1</td>
<td>S?</td>
<td>S1</td>
</tr>
<tr>
<td><em>B. lunaria</em></td>
<td>G5</td>
<td>S3</td>
<td>S2</td>
<td>S1</td>
<td>X</td>
</tr>
<tr>
<td><em>B. minganense</em></td>
<td>G4</td>
<td>S3</td>
<td>S2</td>
<td>S3</td>
<td>S3</td>
</tr>
<tr>
<td><em>B. montanum</em></td>
<td>G3</td>
<td>X</td>
<td>S2</td>
<td>S1</td>
<td>S3</td>
</tr>
<tr>
<td><em>B. pallidum</em></td>
<td>G2</td>
<td>ABSENT</td>
<td>ABSENT</td>
<td>ABSENT</td>
<td>S1</td>
</tr>
<tr>
<td><em>B. paradoxum</em></td>
<td>G2</td>
<td>S1</td>
<td>S1</td>
<td>S?</td>
<td>S2</td>
</tr>
<tr>
<td><em>B. pedunculosum</em></td>
<td>G2/G3</td>
<td>S1</td>
<td>S1</td>
<td>S?</td>
<td>S1</td>
</tr>
<tr>
<td><em>B. pinnatum</em></td>
<td>G4?</td>
<td>S3</td>
<td>S2/S3</td>
<td>S2</td>
<td>X</td>
</tr>
<tr>
<td><em>B. pumicola</em></td>
<td>G3</td>
<td>ABSENT</td>
<td>S3</td>
<td>ABSENT</td>
<td>ABSENT</td>
</tr>
<tr>
<td><em>B. simplex</em></td>
<td>G5</td>
<td>S3</td>
<td>X</td>
<td>S1</td>
<td>X</td>
</tr>
</tbody>
</table>


X = NOT TRACKED

ABSENT OR NOT DOCUMENTED IN THE STATE

---

1 The Global rank is based on the range wide status of the species. The state wide rank denotes the species' status in the individual state. A scale of 1 (critically imperiled) to 5 (demonstrably secure) is used for both of these rankings (MTNHP 1999).

2 Definitions for global and state rankings are:

1 = Critically imperiled because of extreme rarity (5 or fewer occurrences, or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.

2 = Imperiled because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

3 = Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 to 100 occurrences.

4 = Apparently secure, though it may be quite rare in parts of its range, especially at the periphery.

5 = Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.
2.7.5 *Botrychium paradoxum* W. H. Wagner

*Botrychium paradoxum* is known to occur in Alberta, British Columbia, and Saskatchewan in Canada (Wagner and Wagner 1993) in Idaho (Idaho Conservation Data Center 1999), Montana (Wagner and Wagner 1993), Oregon (Oregon Natural Heritage Program 1998), Utah, (Wagner and Wagner 1993) and Washington (Washington Natural Heritage Program 1997). Globally *B. paradoxum* is ranked as G2 (Table 2.2), and S2 in Montana (MTNHP 1999).

2.7.6 *Botrychium pedunculosum* W. H. Wagner

*Botrychium pedunculosum* is known to occur in Alberta, British Columbia, and Saskatchewan in Canada (Wagner and Wagner 1993) and in Idaho (Idaho Conservation Data Center 1999). Montana, Oregon (Wagner and Wagner 1993), and Washington (Washington Natural Heritage Program 1997). Globally *B. pedunculosum* is ranked as G2/G3 (Table 2.2). and S1 in Montana (MTNHP 1999).

2.8 Study Area

The Kootenai National Forest consists of 2.2 million acres located in the northwestern corner of Montana and a small portion of northeastern Idaho. Vegetation on the KNF consists of mesic mixed conifer dominated forests. The climate is strongly influenced by Pacific maritime weather systems. The abundant precipitation, fertile soils, and moderate temperatures occurring on the KNF create some of the highest productivity forests in Montana.
CHAPTER 3

METHODS

3.1 *Botrychium* Field Survey and Sampling Methods

Field surveys for sensitive species of *Botrychium* were completed by the botany team on the KNF from 1997-1999. Potential habitats were examined by the team during clearance surveys for project work. I completed a broader survey of potential habitats encountered during my other fieldwork. I documented the location of *Botrychium* populations with a Global Positioning System (GPS) recording Universal Transverse Mercator (UTM) coordinates. The UTM coordinates along with previously documented *Botrychium* locations were input into Arcview to display the spatial distribution of *Botrychium* populations on the KNF. The locations of sensitive *Botrychium* populations are displayed by size classes based on the number of plants at each location on Arcview maps (Appendices 1-6). Survey results are summarized in tables with the number of plants of each population, and the Montana Natural Heritage Program Element Occurrence Number used to track all rare plant occurrences. Element Occurrences that were documented during the course of this study from 1997-1999 are shown as being new.

Ecodata plots were collected at 66 *Botrychium* locations on the KNF from 1994-1998 to quantify *Botrychium* habitats. Ecodata plot methodology followed the directions in the Ecodata Manual for Region One of the Forest Service (Jensen and Hann 1992). Ecodata plots were subjectively located at *Botrychium* sites with the largest populations and the least common *Botrychium* species. Thus, plots were located and their dimensions varied
to include the greatest number of *Botrychium* plants. Average heights and percent coverages for all vascular plant species were recorded on all Ecodata plots. All mosses and lichens were deleted from the dataset for analysis because of the inconsistency in recording these life forms by the various observers. Average coverage and constancy values were obtained for each species for each plant association using the Strata Program in the Wineco (Jensen et al. 1998) software program (Appendix Tables 9E-16E).

Environmental site characteristics including elevation, slope, aspect, land form, soil parent material, slope position, erosion status, ground cover, fuel model, duff depth, and down wood coverage were measured at the Ecodata plot locations. The average, maximum, minimum, and standard deviation values of all measured environmental site characteristics were computed using the Strata Program in the Wineco (Jensen et al. 1998) software program (Appendix Tables 9-16). Biological site characteristics recorded for the Ecodata plots included tree basal area, coverage by life form type (i.e. tree, grass, forb, fern, shrub), habitat type (potential vegetation), and dominant species.

Plant taxonomy used follows Hitchcock and Cronquist (1973), except for species of *Botrychium*, which is according to Wagner and Wagner (1993). Pfister et al. (1977), Cooper et al. (1991), and Hansen et al. (1995) were used to determine each site's habitat type. Most *Botrychium* sites on the KNF are forested or have the potential to support coniferous trees. Some shrub wetland sites do not support coniferous trees requiring the use of Hansen et al. (1995) to determine habitat type. The landtype (a description of landform, vegetation, soil, and geology) and the soil parent material were determined for
each plot using Kuennen and Nielsen-Gerhardt (1995). The fuel model was determined using Anderson's (1982) guide to fire behavior fuel models. Fuel model classes are based primarily on fuel load and fuel bed depth, which are good predictors of whether a fire will be ignited, its rate of spread, and its intensity (Anderson 1982).

3.2 *Botrychium* Population Definition

I defined individual *Botrychium* populations based on a distance of 100 meters or more of unsuitable habitat separating *Botrychium* plants. My definition of *Botrychium* populations is based upon our knowledge of *Botrychium*’s reproductive biology and Farrar’s (pers. comm.) suggestion that *Botrychium* populations should be drawn to include all plants of a particular occurrence in a particular habitat. Farrar (1998) has found that 99% of the *Botrychium* plants he has analyzed are homozygous for the isozymes analyzed indicating that they are a product of self-fertilization or clones. The biological definition of a population as a group of individuals that have the potential to mate with one another and produce offspring (Primack 1993) does not fit inbreeding plants such as *Botrychium* (Farrar pers. comm.). The 100-meter distance measure to separate populations is used to include all plants in a particular habitat.

Stream courses are also utilized to define *Botrychium* populations on the KNF as *Botrychium* often occur along stream courses on the KNF. *Botrychium* plants occurring along the same stream are considered a single population given the potential for spores to be carried downstream to initiate new plants at safe germination sites. Thus, plants located along the same stream have the potential to exchange genetic material. The one
exception to this one population per stream rule is at Boulder Creek on the Eureka Ranger District. The *B. mingenense* at Boulder Creek are separated into two populations, based on the different habitats where they occur. The Upper Boulder Creek *B. mingenense* sites are at higher elevation, in *Abies lasiocarpa* forest. The Lower Boulder Creek *B. mingenense* sites are in *Thuja plicata* forest. The difference in associated plant community, elevation, and the one air mile distance between these two sites led to separating the Boulder Creek *B. mingenense* into two populations.

My definition of *Botrychium* populations differs from those used by some conservation agencies. Many conservation agencies often base their definition of a population on convenience of data management and not on the reproductive biology of the species. The Montana Natural Heritage Program (MTNHP) uses a distance measure of one air mile between groups of individuals to determine a population (Heidel pers. comm.). The Chippewa National Forest in Minnesota uses a 40-acre size limit to delineate *B. mormo* populations (Berlin et al. 1998), although some populations exceed 40-acres (Casson pers. comm.). This is based on the Chippewa NF policy of recording sensitive plant species in 40-acre blocks (Casson pers. comm.).

This study’s use of a *Botrychium* population definition based on contiguous suitable habitat and stream courses creates some discrepancies with the Montana Natural Heritage Program’s database. This study probably recognizes a few more *Botrychium* populations than the MTNHP recognizes. MTNHP considers these *Botrychium* populations to be subpopulations based on their being within one air mile of other *Botrychium* occurrences.
3.3 Methods of Ordination and Classification of Botrychium Sites

I determined plant associations for Botrychium locations on the KNF by using TWINSPAN (Hill 1979) to classify the 66 Ecodata plots. The formation of TWINSPAN generated groups of plots was then used to recognize discreet plant communities or plant associations. The naming and description of plant associations follows the protocols of The National Vegetation Classification System (NVCS) (Grossman et al. 1998). Plant association names are based on Indicator Species Scores derived from the Indicator Species Analysis program available in the PC-ORD (McCune and Mefford 1999) software package, and species constancy values derived from the Wineco (Jensen et al. 1998) Strata Program. Indicator Species Analysis combines information on species abundance in a particular group and the faithfulness of a species to a particular group to obtain indicator values for each species (Dufrene and Legendre 1997). Indicator Species Analysis has these advantages over TWINSPAN for determining indicator species for plant associations: a species is independent of the relative abundance of the other species present and pseudospecies are not used (Dufrene and Legendre 1997). Species with the highest indicator values for each plant association were used for naming each plant association.

The strength of the plant association groups were tested using the Multiple Response Permutation Procedures (MRPP) program available in the PC-ORD (McCune and Mefford 1999) software package. MRPP, a non-parametric procedure, was used because
it requires no assumptions about underlying data structure and the data need not be normally distributed or without outliers (Biondini et al. 1988).

I combined the TWINSPLAN classification with an ordination of the samples and species to better understand the distribution of *Botrychium* species and their habitat preferences (Hill 1979, ter Braak in Jongman et al. 1995, Grossman et al. 1998). The causal environmental factors in plant species distribution can be inferred from ordination outputs (Jongman et al. 1995). Plant species and samples are displayed along mathematically generated axes, with the most similar species and samples grouped near to each other. The most dissimilar samples are placed far apart on the ordination axes. This graphic display in two-dimensional space allowed me to form hypotheses about the underlying abiotic factors that are reflected in the ordination of plant species and samples (plots).

The *Botrychium* Ecodata plots were analyzed using the eigenanalysis ordination programs Detrended Correspondence Analysis (DCA), and Canonical Correspondence Analysis (CCA) available in the CANONical Community Ordination (CANOCO) (ter Braak 1988) software package. Eigenanalysis techniques take a species and sample data matrix through numerous iterations to eventually close in on an answer to explain species and sample distribution (Palmer 1999). CCA is a direct ordination method that reproduces an environmental gradient displaying the relationship between species and samples to the measured environmental variables. DCA is an indirect ordination method in which the abiotic factors influencing the arrangement of samples or species on the axes
can only be inferred, because no site variables are entered into the program. The significance of the first ordination axis and the sum of all canonical eigenvalues were tested using the Monte Carlo Permutation Test available in the CANOCO (ter Braak 1988) software package.

3.4 French Creek *Botrychium* Permanent Monitoring Methods

I resampled the French Creek permanent *Botrychium* monitoring plots in 1997 and 1998. In 1995, 13-1m² plots were established to monitor the effects of logging disturbance over time on populations of *Botrychium montanum* and *B. minganense* in the French Creek drainage, on the Troy Ranger District (Vanderhorst 1997). Two of the three transects consisting of a total 10 plots were located in a proposed timber sale unit in the French Mud Pickin’s Timber Sale. The third transect consisting of three plots was established as a control in a no treatment area (Vanderhorst 1997). The timber harvest unit containing the two transects was subsequently removed from the timber sale (Vanderhorst 1997). The dropped timber harvest unit containing the *Botrychium* transects has again been rescheduled for timber harvest (Ferguson pers. comm.). The plots were measured in mid July, and the first week of September in 1995, and 1996 by Jim Vanderhorst and Mike Arvidson (Vanderhorst 1997). Two transects were measured in 1997 and 1998 during the first week of August and the first week of September. The third transect could not be relocated. The two sampling dates each year were utilized due to the staggered phenology of *Botrychium* populations. Staggered phenology or continuous initiation has previously been documented in *B. montanum* (Rust and Burnett 1994), and in *B. mormo* (Johnson-Groh 1998).
The intent of the French Creek plots was to determine demographic populations trends and the effects of logging for both *B. montanum* and *B. minganense* over time (Vanderhorst 1997). Each plant was mapped and labeled on a piece of grid paper. This mapping technique was found to be insufficient to identify the different individual plants in each plot in 1997 (pers. obs.). There was no permanent monumentation of the corners of each m$^2$ plot. Only each transects' end points were permanently marked. Thus, plot placement from year to year could vary slightly making identification of individual plants from year to year very difficult. The often-clumped distribution of the *Botrychium* plants added to the confusion about whether a plant was new or one from the previous year.

The greatest number of individual *Botrychium* plants was 66/m$^2$ in 1997. Harper (1977) notes, “some form of marking individuals is required for making a proper census” of plants. Johnson-Groh (1998) uses metal tags attached to a piece of wire placed in the ground beside individual *Botrychium* plants to track the plants from year to year in the permanent monitoring plots she has established. The lack of adequate marking of individual plants did not allow calculation of demographic parameters such as recruitment and longevity of individuals in the French Creek Monitoring Plots.

My objective in continuing to measure these plots was to examine broad population trends, the total number of plants observed, the rate of continuous initiation, and herbivory (%) observed each year. Herbivory was defined as any plant that had any portion of its aboveground leaf removed. The measurement of these plots was not
continued long enough to get accurate demographic trends for plants such as *Botrychium*
that exhibit periods of prolonged dormancy (Lesica and Steele 1994).
CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The KNF botany team documented 124 *Botrychium* locations on the KNF by the end of the 1999 field season (Appendix 8). KNF *Botrychium* sites often support rich diverse *Botrychium* genus communities. In addition to the rare species, the more common species *B. lanceolatum* (S. G. Gmelin) Angstrom, *B. lunaria* (Linnaeus) Swartz, *B. multifidum* (S. G. Gmelin) Ruprecht, Bemerk, *B. pinnatum* H. St. John, and *B. virginianum* (Linnaeus) Swartz also occur at KNF *Botrychium* locations. Sixty-six of the 124 KNF *Botrychium* locations were sampled with Ecodata plots. I used the TWINSPAN classification of the *Botrychium* Ecodata plots to recognize eight discreet *Botrychium* plant associations. The geographic range, environment, successional status, and *Botrychium* constancy for each plant association are described based upon the site variables measured at the Ecodata plots and literature review. In addition, the results of the French Creek permanent *Botrychium* monitoring plots are discussed.

4.2 *Botrychium* Field Surveys 1997-1999

I documented three additional species of *Botrychium* on the Fortine Ranger District of the KNF. *Botrychium hesperium* (Maxon and Clausen) Wagner and Lellinger, *B. pallidum* W. H. Wagner, and *Botrychium michiganense* in ed. were collected on the KNF in 1999 at Davis Creek, and verified by Dr. W. H. Wagner. Two plants of *Botrychium michiganense* in ed. were also collected in 1998 at Wigwam River and verified by Dr. W. H. Wagner. In addition, two plants I collected at Spring Creek on the Troy Ranger
District and identified as *B. hesperium* were tentatively identified as *B. venulosum* in ed. by Dr. W. H. Wagner. *B. hesperium* is considered sensitive in Region One by the US Forest Service (USFS R1 1999). *B. pallidum* is not listed as sensitive in Region One by the USFS because it had not previously been documented on Forest Service land.

### 4.2.1 *Botrychium ascendens* W. H. Wagner

I documented eight populations of *Botrychium ascendens* with 76 plants (Table 4.1). All populations occur on roadsides and old roads. Eight of the 11 total occurrences of *B. ascendens* in Montana are on the KNF (Appendix 1).

#### Table 4.1. *Botrychium ascendens* populations on the Kootenai National Forest.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>KNF DISTRICT</th>
<th>ELEMENT OCCURRENCE</th>
<th>NUMBER OF PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLICK GULCH</td>
<td>EUREKA</td>
<td>NEW 1999</td>
<td>1</td>
</tr>
<tr>
<td>WATER TROUGH DRAW</td>
<td>EUREKA</td>
<td>NEW 1999</td>
<td>1</td>
</tr>
<tr>
<td>DAVIS CREEK</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>33</td>
</tr>
<tr>
<td>GRAVE CREEK</td>
<td>FORTINE</td>
<td>NEW 1999</td>
<td>5</td>
</tr>
<tr>
<td>LAKE CREEK</td>
<td>FORTINE</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>TWIN MEADOW CREEK MOUTH</td>
<td>FORTINE</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>DRY FORK CREEK MOUTH</td>
<td>LIBBY</td>
<td>NEW 1999</td>
<td>1</td>
</tr>
<tr>
<td>WEST FORK YAAK RIVER</td>
<td>TROY</td>
<td>NEW 1998</td>
<td>1</td>
</tr>
</tbody>
</table>

#### 4.2.2 *Botrychium crenulatum* W. H. Wagner

I documented 22 new populations of *Botrychium crenulatum* with 1193 plants (Table 4.2). The total number of *B. crenulatum* plants on the KNF is 2047. Four of the 33 *B. crenulatum* occurrences on the KNF are not represented by a voucher specimen and have

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1 Element Occurrence Numbers are the unique numbers used by the MTNHP to record each species at each location for their database.
not been relocated in subsequent years of searching the location. These four sites, Rock Creek (EO #2), Sutton Creek (EO #3), West Fisher River (EO #25), and Upper Boulder Creek (EO #21) are displayed in Table 4.2 with a zero for number of plants. Thirty-three of the 41 total *B. crenulatum* occurrences in Montana are on the KNF (Appendix 2).

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>KNF DISTRICT</th>
<th>ELEMENT OCCURRENCE #</th>
<th>NUMBER OF PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCK CREEK</td>
<td>CABINET</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>SUTTON CREEK</td>
<td>EUREKA</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>UPPER BOULDER CREEK #1</td>
<td>EUREKA</td>
<td>21</td>
<td>0(^2)</td>
</tr>
<tr>
<td>WATER TROUGH DRAW</td>
<td>EUREKA</td>
<td>12</td>
<td>106</td>
</tr>
<tr>
<td>SLICK GULCH</td>
<td>EUREKA</td>
<td>NEW 1999</td>
<td>4*</td>
</tr>
<tr>
<td>ZELLER CREEK</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>27*</td>
</tr>
<tr>
<td>UPPER SUNDAY CREEK #1</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>75*</td>
</tr>
<tr>
<td>STEWART CREEK WEST</td>
<td>FORTINE</td>
<td>19</td>
<td>59</td>
</tr>
<tr>
<td>UPPER SUNDAY CREEK #2</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>75*</td>
</tr>
<tr>
<td>BEAVER CREEK</td>
<td>FORTINE</td>
<td>7</td>
<td>106</td>
</tr>
<tr>
<td>DAVIS CREEK</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>82*</td>
</tr>
<tr>
<td>LOWER BASIN CREEK EAST</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>100*</td>
</tr>
<tr>
<td>TWIN MEADOWS CREEK</td>
<td>FORTINE</td>
<td>31</td>
<td>150*</td>
</tr>
<tr>
<td>LIME CREEK</td>
<td>FORTINE</td>
<td>17</td>
<td>400</td>
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<tr>
<td>SKILLET CREEK</td>
<td>FORTINE</td>
<td>32</td>
<td>50*</td>
</tr>
<tr>
<td>GRAVE CREEK</td>
<td>FORTINE</td>
<td>NEW 1999</td>
<td>2*</td>
</tr>
<tr>
<td>LOWER TWIN MEADOW CREEK</td>
<td>FORTINE</td>
<td>NEW 1999</td>
<td>27*</td>
</tr>
<tr>
<td>UPPER BASIN CREEK</td>
<td>FORTINE</td>
<td>33</td>
<td>10*</td>
</tr>
<tr>
<td>SWAMP CREEK</td>
<td>FORTINE</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>STEWART CREEK EAST</td>
<td>FORTINE</td>
<td>22</td>
<td>4*</td>
</tr>
<tr>
<td>WHITE CREEK FEN</td>
<td>FORTINE</td>
<td>35</td>
<td>4*</td>
</tr>
<tr>
<td>LOWER BASIN CREEK WEST</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>10*</td>
</tr>
<tr>
<td>UPPER FORTINE CREEK</td>
<td>FORTINE</td>
<td>34</td>
<td>12*</td>
</tr>
<tr>
<td>LAKE CREEK</td>
<td>FORTINE</td>
<td>36</td>
<td>59*</td>
</tr>
<tr>
<td>ALEXANDER CREEK</td>
<td>LIBBY</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

\(^2\) Signifies that I documented the population during this study.
4.2.3 *Botrychium minganense* Victorin

I documented 38 new populations of *Botrychium minganense* with 1309 plants (Table 4.3). The total number of *B. minganense* plants on the KNF is 3077. Three of the 89 *B. minganense* occurrences on the KNF have not been relocated in subsequent years. These three sites, North Fork Dodge Creek (EO #41), Warland Creek (EO #35), Pete Creek (EO #32) are displayed in Table 4.3 with a 0 for number of plants. Eighty-nine of the 112 total *B. minganense* occurrences in Montana are on the KNF (Appendix 3).

**Table 4.3. *Botrychium minganense* populations on the Kootenai National Forest.**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>KNF DISTRICT</th>
<th>ELEMENT OCCURRENCE #</th>
<th>NUMBER OF PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BULL RIVER</td>
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<td>47</td>
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<td>50*3</td>
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<tr>
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<td>EUREKA</td>
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<td>1*</td>
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<td>LOWER BOULDER CREEK</td>
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<td>65*</td>
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<tr>
<td>NORTH FORK DODGE CREEK</td>
<td>EUREKA</td>
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<td>0</td>
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<tr>
<td>PARSNIP CREEK</td>
<td>EUREKA</td>
<td>59</td>
<td>105</td>
</tr>
<tr>
<td>SOUTH FORK BIG CREEK</td>
<td>EUREKA</td>
<td>46</td>
<td>50</td>
</tr>
<tr>
<td>SUTTON CREEK</td>
<td>EUREKA</td>
<td>49</td>
<td>238</td>
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<td>EUREKA</td>
<td>70</td>
<td>29*</td>
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1 * Signifies that I documented the population during this study.
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<td>E U R E K A</td>
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<td>83</td>
<td>6*</td>
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<td>69</td>
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<td>BUNKER HILL CREEK</td>
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<td>50</td>
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<td>38</td>
<td>150</td>
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<td>TROY</td>
<td>73</td>
<td>7*</td>
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43

4.2.4 *Botrychium montanum* W. H. Wagner

I documented 15 new populations of *Botrychium montanum* with 858 plants (Table 4.4).

The total number of *B. montanum* plants on the KNF is 3077. Of the 51 total *B. montanum* occurrences in Montana 39 are on the KNF (Appendix 4).

**Table 4.4. *Botrychium montanum* populations on the Kootenai National Forest.**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>KNF DISTRICT</th>
<th>ELEMENT OCCURRENCE</th>
<th>NUMBER OF PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BERRAY MOUNTAIN</td>
<td>CABINET</td>
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<td>7</td>
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<tr>
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<td>PARSNIP CREEK</td>
<td>EUREKA</td>
<td>29</td>
<td>50</td>
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<tr>
<td>SOUTH FORK BIG CREEK</td>
<td>EUREKA</td>
<td>24</td>
<td>24</td>
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* Signifies that I documented the population during this study.
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<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
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<tbody>
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<td>34</td>
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<tr>
<td>BASIN CREEK MID</td>
<td>TROY</td>
<td>38</td>
<td>18*</td>
</tr>
<tr>
<td>BEETLE CREEK</td>
<td>TROY</td>
<td>31</td>
<td>39</td>
</tr>
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<td>CAN CREEK</td>
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<td>11</td>
<td>150</td>
</tr>
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<td>CLAY MOUNTAIN</td>
<td>TROY</td>
<td>19</td>
<td>15</td>
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<td>TROY</td>
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<td>500</td>
</tr>
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</tr>
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<td>150</td>
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<td>18</td>
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<td>RABBIT CREEK</td>
<td>TROY</td>
<td>42</td>
<td>10*</td>
</tr>
<tr>
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<td>TROY</td>
<td>22</td>
<td>50</td>
</tr>
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<td>RODERICK BUTTE</td>
<td>TROY</td>
<td>18</td>
<td>55</td>
</tr>
<tr>
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<td>UPPER WHITETAIL CREEK</td>
<td>TROY</td>
<td>37</td>
<td>29*</td>
</tr>
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<td>ZULU CREEK</td>
<td>TROY</td>
<td>15</td>
<td>5</td>
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### 4.2.5 *Botrychium paradoxum* W. H. Wagner

The seven documented *B. paradoxum* locations on the KNF are probably another species of *Botrychium*, except perhaps at Bluebird Lake. *B. paradoxum* typically occurs in meadow habitats throughout its range (Wagner and Wagner 1993). *B. paradoxum* occurs in bunch grass dominated meadows with a substantial forb component in Glacier National Park and on the Beaverhead-Deerlodge National Forest, Montana (pers. obs.). The *Thuja plicata* plant associations where *B. paradoxum* plants have most often been
found on the KNF do not fit this relationship. The Subalpine Meadow plant association found at Bluebird Lake has the greatest potential for *B. paradoxum* on the KNF.

*Botrychium* plants sometimes produce a second sporophore branch on the trophophore axis (pers. obs.). If the trophophore is then removed through herbivory or damage the plant will have the two sporophores that are diagnostic of *B. paradoxum*. Wagner (pers. comm.) agrees that this is the most likely explanation given the atypical habitat where *B. paradoxum* has been found on the KNF. Zika et al. (1995) note that some shaded specimens of *B. minganense* and *B. montanum* sometimes simulate *B. paradoxum* with a reduced etiolated trophophore with marginal sporangia. The *B. paradoxum* plants at Zulu Creek, Can Creek, and Upper Can Creek Drainage have been searched for in subsequent years and not relocated (Vanderhorst 1997). All *B. paradoxum* occurrences on the KNF consist of only one to two plants. These small samples make their identification equally dubious.

I documented four new populations of *Botrychium paradoxum* (Table 4.5). Three of these locations are questionable based on the habitat, the potential for other *Botrychium* species to mimic the morphology of *B. paradoxum*, and they are represented by only one plant. The questionable *B. paradoxum* populations are not considered extant and are displayed in table 4.5 with a 0 for number of plants. The total number of *B. paradoxum* plants on the KNF is two. Seven of the 19 documented occurrences of *B. paradoxum* in Montana are on the KNF (Appendix 5).
Table 4.5. *Botrychium paradoxum* populations on the Kootenai National Forest.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>KNF DISTRICT</th>
<th>ELEMENT OCCURRENCE #</th>
<th>NUMBER OF PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLUEBIRD LAKE</td>
<td>FORTINE</td>
<td>17</td>
<td>2*5</td>
</tr>
<tr>
<td>DAVIS CREEK</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>0*</td>
</tr>
<tr>
<td>EDNA CREEK</td>
<td>FORTINE</td>
<td>16</td>
<td>0*</td>
</tr>
<tr>
<td>LAKE CREEK</td>
<td>FORTINE</td>
<td>18</td>
<td>0*</td>
</tr>
<tr>
<td>CAN CREEK</td>
<td>TROY</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>UPPER CAN CREEK</td>
<td>TROY</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>DRAINAGE</td>
<td>TROY</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

4.2.6 *Botrychium pedunculosum* W. H. Wagner

I documented five new populations of *Botrychium pedunculosum* with 155 plants (Table 4.6). The total number of *B. pedunculosum* plants on the KNF is 205. Ten of the 11 total *B. pedunculosum* occurrences in Montana are on the KNF (Appendix 6).

Table 4.6. *Botrychium pedunculosum* populations on the Kootenai National Forest.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>KNF DISTRICT</th>
<th>ELEMENT OCCURRENCE #</th>
<th>NUMBER OF PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOXON RAPIDS DAM</td>
<td>CABINET</td>
<td>NEW 1999</td>
<td>1*5</td>
</tr>
<tr>
<td>BIG CREEK</td>
<td>EUREKA</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>PARSNIP CREEK</td>
<td>EUREKA</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>SOUTH FORK BIG CREEK</td>
<td>EUREKA</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>SUTTON CREEK</td>
<td>EUREKA</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>DAVIS CREEK</td>
<td>FORTINE</td>
<td>NEW 1998</td>
<td>13*</td>
</tr>
<tr>
<td>TWIN MEADOW CREEK MOUTH</td>
<td>FORTINE</td>
<td>NEW 1999</td>
<td>2*</td>
</tr>
<tr>
<td>CEDAR CREEK</td>
<td>LIBBY</td>
<td>7</td>
<td>14*</td>
</tr>
<tr>
<td>W. FORK QUARTZ CR.</td>
<td>LIBBY</td>
<td>8</td>
<td>125*</td>
</tr>
<tr>
<td>KEELER CREEK</td>
<td>TROY</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* Signifies that I documented the population during this study.
4.3 French Creek *Botrychium* Permanent Monitoring Plots Results

Figures 4.1 and 4.2 display the total *B. minganense* and *B. montanum* plants, respectively, observed over the four years of monitoring the French Creek plots. Both species exhibit similar trends from year to year. The similarity of the population trends for both *B. montanum* and *B. minganense* at French Creek indicate that both species are probably responding to the same environmental conditions or demographic parameters.

Annual fluctuations in *Botrychium* populations are very common in monitoring studies but the populations tend to be stable over longer periods of time (Johnson-Groh 1998). Field (1993 unpublished study) reported that both *B. paradoxum* and *B. lunaria* showed the same annual variations in population size over six years at Our Lake, Lewis and Clark National Forest, Montana. Johnson-Groh and Farrar (1993) monitored *Botrychium simplex*, *B. gallicomontanum*, and *B. campestre* over seven years in permanent plots in Iowa and Minnesota. They found that these three *Botrychium* species had similar patterns of occurrence and response to fire, drought, and other environmental disturbances.

In 1998, *B. minganense* and *B. montanum* plants were only 43% and 50%, respectively of their initial count on the French Creek monitoring plots. These declines may be partially due to variable rates of dormancy from year to year and the probable short-lived nature of these species. Several studies (Lesica and Steele 1994, Montgomery 1990, Johnson-Groh and Farrar 1993, Muller 1993, Kelly 1994) have reported that the total number of *Botrychium* plants observed each year is an underestimate of the total number of sporophytes present because of the prolonged dormancy common in *Botrychium*. 
However, the observed rates of population decline for *B. minganense* and *B. montanum* at French Creek are greater than the reported dormancy rates of 12% to 38% found by Lesica and Ahlenslager (1996), and 47% for *B. mormo* in Minnesota (Johnson-Groh 1998). The apparent large population declines at French Creek differ from the other published *Botrychium* monitoring results. Lesica and Ahlenslager (1996), Gehring and Potash (1996), Muller (1993), and Montgomery (1990) all found the *Botrychium* populations that they studied were rather stable over time, with recruitment of new individuals usually exceeding death of individuals. The standard deviation varied from 2.6-3.2 for *B. minganense* and 36.9-52.9 for *B. montanum* over the four years of monitoring.

Figure 4.1. Annual census (1995-1998) of total *Botrychium minganense* plants at French Creek on the KNF, Montana.
Figure 4.2. Annual census (1995-1998) of total *Botrychium montanum* plants at French Creek on the KNF, Montana.

It appears that both *Botrychium montanum* and *B. mingenense* are short-lived perennials based on the population decreases observed at French Creek, as are the other studied species in the *Botrychium* subgenus (Johnson-Groh 1998, Lesica and Ahlenslager 1996, Muller 1993). Johnson-Groh (1998) found that *B. campestrum* and *B. gallicomontanum* both have an aboveground longevity of about four to five years. Johnson-Groh also estimated a longevity of one to two years for *B. mormo*, the possible eastern geographic sister taxa of *B. montanum* (Farrar 1998, Wagner and Wagner 1993). Lesica and Ahlenslager (1996) calculated an average half-life for *B. hesperium*, *B. paradoxum*, and *B. X watertonense* of about three years or less. Muller (1993) found that *B. matricariifolium* had a life span of two to four years. The French Creek monitoring data indicates a higher mortality rate than recruitment over the brief four-year life of the plots.

It is impossible to make any determinations of long-term population trends due to the short duration of this study and the limited sample size of *Botrychium mingenense* on the
French Creek monitoring plots. The observed decline in both *B. mingenense* and *B. montanum* may be countered by large populations increases in subsequent years. The observed population declines cannot be interpreted to be the trend for *Botrychium* species throughout the KNF; they may be due to localized environmental or demographic conditions. More monitoring with marked individuals is required to better understand population trends of *Botrychium* on the KNF. The planned logging of the timber sale unit containing the two relocated French Creek monitoring transects provides an excellent opportunity to examine the effects of logging on these two species.

The other documented (published and unpublished) studies of *Botrychium* populations all dealt with different species of *Botrychium* than *B. montanum* and *B. mingenense*, except for the Nooksack Study (Gehring and Potash 1996). The Nooksack *Botrychium* genus community included two to three *B. mingenense* plants, too small a sample to make any determinations of population trends. The results of these other monitoring studies may not be applicable to different species of *Botrychium*.

### 4.3.1 Herbivory

*Botrychium montanum* and *B. mingenense* had similar annual herbivory trends (Figure 4.3). It is unknown what effect these higher levels of herbivory in 1996 may have on these populations. However, Montgomery (1990) in his eleven-year study of *B. dissectum* found that plants could survive having the aboveground leaf removed for three years or more and still persist. The removal of the aboveground *Botrychium* leaf through herbivory, fire, or collection has been found to have no effect on the subsequent
emergence of the sporophyte aboveground the following year (Johnson-Groh 1998). The standard deviation varied from 17.1-20.7 for *B. minganense* and 7.7-9.6 for *B. montanum* over the four years of monitoring herbivory.

![Figure 4.3 Annual rates (1995-1998) of herbivory for *Botrychium minganense* and *B. montanum* at French Creek KNF, Montana.](image)

4.3.2 Staggered Phenology

*B. montanum* and *B. minganense* exhibited staggered emergence of new plants throughout the growing season (Figure 4.4). *B. minganense* with its small sample size had the highest percent (52%) of new plants emerging later in the year in 1997. Both species averaged 25% later emerging plants annually for the four-year duration of the French Creek monitoring. Thus, one-time censuses of *Botrychium* populations in cedar/hemlock forests could underestimate the total aboveground plant population by 10%-52% based on the French Creek monitoring results.

The continuous emergence of *Botrychium* plants is not reported from the other monitoring studies (Kelly 1994, Montgomery 1990, Lesica and Ahlenslager 1996, and
Muller 1993), with the exception of Johnson-Groh's (1998) monitoring of *B. mormo*. The other study sites, excluding *B. mormo*, are all located in open non-forested plant communities. These sites have greater solar input due to their lack of tree cover. Thus, the ground dries out through the growing season, and the site becomes inhospitable for the emergence of new *Botrychium* plants. Johnson-Groh (1998) found continuous emergence of monitored *B. mormo* populations in northern hardwood forests in Minnesota. It is only in the cedar/hemlock forests and northern hardwood forests where high soil moisture levels are often maintained through the growing season, which are favorable for the emergence of new sporophytes throughout the growing season. The roadside *Botrychium* sites on the KNF probably have little late emergence of new sporophytes due to the drying of the soil later in the growing season. The standard deviation varied from 17.2-20.8 for *B. minganense* and 4.7-5.4 for *B. montanum* over the four years of monitoring late emergence.

![Figure 4.4 Percent of total annual *Botrychium minganense* and *B. montanum* plants not present at the first census visit (July, August) at French Creek KNF, Montana.](image)
4.4 Classification And Ordination Results

4.4.1 TWINSPAN Classification Results

I described eight *Botrychium* plant associations based upon the TWINSPAN classification of the Ecodata plots. A dichotomous key to *Botrychium* plant associations based upon the TWINSPAN classification was developed (Appendix 7). This key will aid field workers in recognizing potential *Botrychium* habitats, and understanding the vegetation similarities and distinguishing characteristics between *Botrychium* plant associations.

Using TWINSPAN I found that 33 of the sample plots grouped into a vegetation alliance with 20% or greater coverage of *Thuja plicata* (Table 4.7). These plots represent the *Tsuga heterophylla* - *Thuja plicata* forest alliance (TSUHET – THUPLI FA). The first TWINSPAN division of the TSUHET – THUPLI FA is at level 3, where three plots are separated based on the presence of *Carex disperma* and *Cinna latifolia*. These three plots are placed in the middle of the TWINSPAN table (Table 4.7), between the TSUHET – THUPLI FA and the Shrub Wetland plant association (PA) plots. The relative position of these three TSUHET - THUPLI FA plots indicates their shared affinities with the Shrub Wetland plant association. These three plots are referred to as Transitional or Intermediate between the TSUHET - THUPLI FA and Shrub Wetland PA. These plant associations often occur adjacent to and intergrading into each other.
Table 4.7. TWINSPLAN classification of *Botrychium* Ecodata plots.
The TSUHET - THUPLI FA is further divided by the TWINSpan classification into two community types based on variability of understory vegetation. This fifth level division is based on the occurrence of *Oplopanax horridum* coverage of 10%, *Gymnocarpium dryopteris* coverage of 5%, *Athyrium filix-femina* coverage of 10%, *Tiarella trifoliata* coverage of 10%, and *Cinna latifolia* coverage of 1%. This plant association is referred to as the *Thuja plicata*/*Oplopanax horridum*/*Gymnocarpium dryopteris*/*Tiarella trifoliata* PA (THUPLI/OPLHOR/GYMDRY/TIATRI PA), or the THUPLI with Understory PA. The occurrence of these mesic site plant species separated out seven plots from the remaining 30 plots in the TSUHET - THUPLI FA. Three additional plots that were not placed in the THUPLI with Understory PA by the TWINSpan classification have greater floristic affinity for this PA than for the THUPLI Depauperate PA. This conclusion is based on examination of the TWINSpan output table (Table 4.7) and comparison of the plot cover similarity percentages generated from Wineco (Table 4.8). Plots 13, 19, and 46 all have greater cover similarity to the THUPLI with Understory PA than to the THUPLI Depauperate PA.

**Table 4.8. Cover similarity between plots 13, 19, and 46 to the two THUPLI plant associations.**

<table>
<thead>
<tr>
<th>Plot number</th>
<th>Cover similarity to the THUPLI With Understory PA</th>
<th>Cover similarity to the THUPLI Depauperate PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>58.1</td>
<td>52.3</td>
</tr>
<tr>
<td>19</td>
<td>57.9</td>
<td>47.5</td>
</tr>
<tr>
<td>46</td>
<td>59.9</td>
<td>52.1</td>
</tr>
</tbody>
</table>
The three plots misplaced by TWINSPAN in the THUPLI Depauperate PA have four of the five differential species that characterize the THUPLI with Understory PA. They lack only *Cinna latifolia*, which is one of the differential species of lesser importance. They also have one of the other indicator species in the next lower coverage class. The differentiation of coverage classes can be based on as little as 1% difference in coverage. Thus, the differentiation of plots based on one coverage class can be very small, arbitrary, and based on observer bias. The TWINSPAN placement of these three plots in the THUPLI Depauperate PA was thus determined to be incorrect. These plots have greater affinity for the THUPLI with Understory PA. No classification is perfect but it is a numerical approximation of plant communities based upon observed plant coverages. This approximation can be further refined based on observations of the ecologist. The small size of the *Botrychium* data set allows one familiar with the plots to further refine the classification.

Two plots were removed from the analysis. One plot located at Othorp-Morgan Lake is an extreme outlier in the data set. Its inclusion in the analysis caused an extreme compression of the gradient. The Othorp-Morgan Lake plot would not cluster with any other plots. The second plot dropped from the analysis is located at Swamp Creek. This plot is placed in the Lower Subalpine Forest PA by the TWINSPAN classification. The Swamp Creek plot is located in an aspen dominated riparian area. The Swamp Creek plot was deleted based on examination of the TWINSPAN table and its low cover similarity to any PA.
4.4.2 Multiple Response Permutation Procedures (MRPP) Results

The TWINSPLAN generated plant association groups were compared with moving the three plots from the THUPLI Depauperate PA to the THUPLI with Understory PA using MRPP. The modification of the TWINSPLAN classification slightly decreased the average within group distance by moving the three plots to the THUPLI with Understory PA (Table 4.9). The plots within the THUPLI PAs are closer together in Euclidean space with the movement of these three plots. The test statistic, an indicator of the separation between groups (McCune and Mefford 1999), is greater for the modified TWINSPLAN plot grouping (Table 4.10). The small decrease in within group distance and the small increase in separation between groups gained by the movement of these three plots, are not statistically significant. The movement of the three plots to the THUPLI with Understory PA does result in greater within group homogeneity and greater between group distances. The MRPP results provide validation for both classifications. The P-value for both groupings (Table 4.10) is very low. Thus, at the 95% confidence level there is less than 1% chance that there is not any difference between the PA groups.

Table 4.9. Comparison of MRPP produced within group distances, for TWINSPLAN produced plot grouping and modified plot grouping.

<table>
<thead>
<tr>
<th>PLANT ASSOCIATION</th>
<th>THUPLI WITH UNDERSTORY MODIFIED</th>
<th>THUPLI WITH UNDERSTORY TWINSPLAN</th>
<th>THUPLI DEPAUPERATE MODIFIED</th>
<th>THUPLI DEPAUPERATE TWINSPLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG WITHIN GROUP DISTANCE</td>
<td>44.903567</td>
<td>48.171301</td>
<td>34.768459</td>
<td>34.189370</td>
</tr>
<tr>
<td>SAMPLE SIZE</td>
<td>10</td>
<td>7</td>
<td>20</td>
<td>23</td>
</tr>
</tbody>
</table>
Table 4.10. Comparison of the test statistic for TWINSPLAN produced plot grouping and modified plot grouping.

<table>
<thead>
<tr>
<th></th>
<th>TWINSPAN GENERATED PAS</th>
<th>MODIFIED PAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST STATISTIC (T)</td>
<td>-17.304273</td>
<td>-17.081922</td>
</tr>
<tr>
<td>OBSERVED DELTA</td>
<td>46.784184</td>
<td>47.109969</td>
</tr>
<tr>
<td>EXPECTED DELTA</td>
<td>68.068650</td>
<td>68.068650</td>
</tr>
<tr>
<td>VARIANCE OF DELTA</td>
<td>1.5129299</td>
<td>1.5054087</td>
</tr>
<tr>
<td>CHANCE-CORRECTED WITHIN GROUP AGREEMENT (A)</td>
<td>0.31269118</td>
<td>0.30790505</td>
</tr>
<tr>
<td>PROBABILITY OF SMALLER OR EQUAL DELTA (P)</td>
<td>0.00000000</td>
<td>0.00000000</td>
</tr>
</tbody>
</table>

4.4.3 DCA Results

The DCA ordination output shows a clear separation of the eight *Botrychium* plant associations that were produced by the TWINSPLAN classification of the *Botrychium* plots (Figure 4.5). The *Tsuga heterophylla - Thuja plicata* forest alliance (TSUHET – THUPLI FA) plots are grouped on the left hand side of the ordination (Figure 4.5). The *Thuja plicata* with Understory PA is primarily on the lower end of the TSUHET – THUPLI FA plot swarm. The *Thuja plicata* Depauperate PA plots are on the upper portion of the TSUHET – THUPLI FA plot swarm. There is some overlap of the two TSUHET – THUPLI PAs indicative of the intergradations of the two PAs. The next PA displayed moving to the right on the DCA ordination, is the Transitional PA (Figure 4.5). The DCA placement of the Transitional PA between the TSUHET – THUPLI FA and the Shrub Wetland PA plots again demonstrates the intermediate nature of the Transitional PA between these two PAs. The Subalpine Meadow PA is located on the extreme left
hand side of the ordination. The latent environmental gradient produced by the DCA ordination moves from warm moist PAs on the left, to the higher elevation cold moist PAs on the right.

4.4.4 CCA Results

The most significant environmental variable on the first CCA axis is elevation. This is based on elevation having the highest Inter set correlation value for environmental variables on the first axis (Table 4.11). This is illustrated in Figure 4.6 where elevation has the longest arrow on the CCA scatter plot, indicating it has the greatest influence. The arrows also point in the direction of greatest variation in that environmental variable (ter Braak 1988). Thus, the arrow for elevation is pointing in the quadrant where the Upper Subalpine Forest PA and the Subalpine Meadow PA are located (Figure 4.6). Higher elevation is important for the development of these plant communities.

The strongest environmental variable on the second axis is old growth (OG) based on the Inter set correlations (Table 4.11). There was a highly negative correlation between Recent disturbance (REC) and Old Growth (OG) (Table 4.11). Thus, the second axis is a gradient based on successional status, which is the time since the last major disturbance.
Botrychium Plant Associations
- Thuya plicata with Understory
- Thuya plicata Depauperate
- Transitional
- Shrub Wetland
- Lower Subalpine Forest
- Upper Subalpine Forest
- Roadside
- Subalpine Meadow

LANDFORM CODES
- MS = MOUNTAIN SLOPE
- MB = MOUNTAIN BENCH
- MT = MOUNTAIN SUMMIT
- MW = MOUNTAIN SWALE
- VM = VALLEY MORAIN
- VW = VALLEY SWALE
- VI = VALLEY TERRACE

SOIL-PARENT MATERIAL CODES
- GLAC = GLACIAL TILL
- ALLU = ALLUVIUM
- CALC = CALCAREOUS

DISTURBANCE CODES
- OG = OLD GROWTH
- MAT = MATURE
- REC = RECENT
The stand age of each plot was transformed into a nominal variable based on length of time since last major disturbance. The categories are: Recent (REC) last major disturbance 0-50 years, Mid-Seral (MID) last major disturbance 51-100, Mature (MAT) last major disturbance 101-199 years ago, and Old Growth (OG) last major disturbance over 200 years ago. Each class of a nominal environmental variable is displayed at the centroid of the sample scores belonging to the class on the ordination axes (ter Braak 1988). Thus, the OG and MAT centroids are in the upper left hand quadrant, within the TSUHET – THUPLI FA plots (Figure 4.6). The recent (REC) centroid is located in the lower right quadrant of the ordination (Figure 4.6), squarely within the Roadside PA plots. These ordination results show the preference for TSUHET – THUPLI FA plant associations to develop on relatively undisturbed areas. The Roadside PA occurs in areas of recent disturbance. The MID disturbance class was deleted to avoid multicollinearity of the variable. One class of each nominal environmental variable should be deleted to avoid multicollinearity (ter Braak 1988).

The other two continuous environmental variables in the ordination are the percent ground surface occupied by bare soil and moss cover. Both bare soil and moss coverage had small influence on the ordination results as evidenced by the shortness of their respective arrow (Figure 4.6) and by their low Inter set correlation values (Table 4.11). Although these variables have little effect on the ordination, they do provide some understanding of the plant associations’ environment. The arrow for percent soil coverage in the lower right quadrant of the ordination (Figure 4.6) reinforces the importance of disturbance to the Roadside PA. Bare soil had the greatest percent
Coverage in the Roadside PA. The higher percent coverages of gravels and bare soil are not the causal factors of the Roadside PA. These are instead the result of the ground clearing for the roadway. The arrow for moss coverage in the lower left quadrant (Figure 4.6) indicates the relatively higher coverage of mosses in the Shrub Wetland PA. The lack of tree canopy coverage and high water table in this PA are highly favorable for moss growth. Moss is actually not an environmental variable but a biological variable. It was included in the ordination because of its indicator value of environmental conditions. All mosses were deleted from the species data set. Thus, moss cover can be used as a surrogate environmental variable an independent variable, because it is not entered as species data a dependant variable.

Table 4.11. Inter set correlations of environmental variables by axis for the CCA ordination of Botrychium Ecodata plots.

<table>
<thead>
<tr>
<th>CorE: Inter set correlations of environmental variables with axes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AXIS 1</strong></td>
</tr>
<tr>
<td>FF EXTRACTED=0.186</td>
</tr>
<tr>
<td>ELEVATION</td>
</tr>
<tr>
<td>34</td>
</tr>
<tr>
<td>PET</td>
</tr>
<tr>
<td>44</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>MW</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>PET</td>
</tr>
<tr>
<td>44</td>
</tr>
<tr>
<td>ALL</td>
</tr>
<tr>
<td>&lt;4</td>
</tr>
<tr>
<td>ALLO</td>
</tr>
<tr>
<td>47</td>
</tr>
<tr>
<td>MESS</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>PET</td>
</tr>
<tr>
<td>44</td>
</tr>
<tr>
<td>ALL</td>
</tr>
<tr>
<td>&lt;4</td>
</tr>
<tr>
<td>ALLO</td>
</tr>
<tr>
<td>47</td>
</tr>
<tr>
<td>MESS</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>PET</td>
</tr>
<tr>
<td>44</td>
</tr>
<tr>
<td>ALL</td>
</tr>
<tr>
<td>&lt;4</td>
</tr>
<tr>
<td>ALLO</td>
</tr>
<tr>
<td>47</td>
</tr>
</tbody>
</table>
Explanation of environmental variable abbreviations

Landform Codes
- MS = Mountain Slope
- MB = Mountain Bench
- MT = Mountain Terrace
- MW = Mountain Swale
- VM = Valley Moraine
- VW = Valley Swale
- VT = Valley Terrace

Soil Parent Material Codes
- GLAC = Glacial till
- ALLU = Alluvium
- CALC = Calcareous

Disturbance Codes
- OG = Old Growth
- MAT = Mature
- REC = Recent

I found the P-Value for both the test of significance of the first CCA axis and the overall test was .01 (Table 4.12) using the Monte Carlo Permutation Test available in the CANOCO software package (ter Braak 1988). This indicates that the placement of samples and species in the CCA ordination are not random. There is some underlying environmental gradient driving the placement of samples and species in the CCA ordination.

Table 4.12. Monte Carlo Test of significance of the first canonical axis and of all canonical eigenvalues for the CCA ordination of Botrychium Ecological plots.

<table>
<thead>
<tr>
<th>TEST VARIABLE</th>
<th>P-VALUE</th>
<th>F RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST AXIS</td>
<td>0.01</td>
<td>4.54</td>
</tr>
<tr>
<td>OVERALL TEST</td>
<td>0.01</td>
<td>2.19</td>
</tr>
</tbody>
</table>

There were not many measured environmental variables at the Ecological plots to use in the ordination. All available environmental variables were tried in the CCA program either
with the forward selection option in CANOCO or by exploratory runs of the data set. The CCA ordination (Figure 4.6) represents the subset of environmental variables that best explained the sample data as determined by comparing the eigenvalues and the percent of species environment relation explained. Most of the measured environmental variables that were available for input had little influence on the ordination. They produced low Inter set correlation values and did not greatly increase the percentage variance explained in the species environment relation. The lack of explanatory power of the environmental variables is due in some cases to the homogeneity of the plots for those variables. For example, slope is relatively flat on all plots and therefore has little influence on the distribution of plots across the ordination. The lack of slope also precludes the highly variable aspect of the plots from exerting any influence over the species and sample distribution.

The landform classes are present in the final CCA ordination output, but have little influence on the ordination of samples and species, based on their low Inter set correlation scores (Table 4.11). The landtype variables were left in the ordination both for display of which landforms the PAs occur upon, and to maintain some environmental complexity in the data set. If there is only one environmental variable in the data set the Inter set correlation will be 1 and the one environmental variable will perfectly explain the sample and species distribution.

Soil parent material provides some strong correlations with the axes based on their Inter set correlations (Table 4.11). Glacial till parent material has a moderately strong negative
correlation with the first axis. The placement of the glacial till parent material (GLAC) centroid in the upper left quadrant of the ordination (Figure 4.6), graphically displays its association with the TSUHET – THUPLI FA plots. Calcareous parent material had a strong negative correlation to the second axis (Table 4.11). The placement of the Calcareous Parent Material (CALC) centroid in the lower half of the ordination diagram (Figure 4.6) demonstrates the greater likelihood for both the Roadside PA and the Shrub Wetland PA to develop on calcareous parent material. The calcareous parent material centroid is located approximately midway between these two PAs.

4.4.5 *Botrychium* Species Preference in the CCA Ordination

CCA produces centroids for each species that are displayed on the ordination axes. These species centroids can be thought of as species optima (the summit of the species’ Gaussian curve), where the species will be most abundant (Jongman et al. 1995). The species centroids for the *Botrychium* species in the analysis are shown in Figure 4.7. The *Botrychium* species centroids are actually based on presence or absence, not on species abundance. No *Botrychium* species exceeded 1% coverage on any plot because they are very small and few in number. Thus, the species centroids are not an accurate portrayal for *Botrychium* species that occur in more than one plant association, i.e. *B. manganense*, and *B. virginianum*. Figure 4.7 does provide an accurate picture of species optima for those species that occur in only one to two PAs. The centroid for *B. ascendens* is located squarely in the Roadside PA indicating its preference for these disturbed seral habitats. *Botrychium crenulatum*’s centroid is located in between the Shrub Wetland PA and the Roadside PA indicating its preference for the two PAs. The three centroids for *B. pedunculosum*, *B. montanum*, and *B. paradoxum* (may be based on misidentification, see
pages 44-45), are all tightly clustered in the *Thuja plicata* Depauperate PA. The centroids for the cosmopolitan species *B. minganense* and *B. virginianum* are not representative of these species' optima. The placement of their centroid near the center of the ordination axes is indicative of *B. minganense* and *B. virginianum* wide distribution.

### 4.4.6 Overlap of *Botrychium* Plant Associations in the CCA Ordination

Six of the eight *Botrychium* plant associations displayed on the CCA ordination axes (Figure 4.6) show some overlap. Only two of the PAs, the Upper Subalpine Forest PA and the Subalpine Meadow PA are completely discreet entities. The strongest environmental variables determining the ordination axes are elevation on the X-axis and frequency of disturbance on the Y-axis. The environmental variables determining the axes and thus the placement of the plots on the ordination are not unique for each PA. Elevation and frequency of disturbance do not separate out the THUPLI with Understory PA, THUPLI Depauperate PA, the Transitional PA, or the upper portion of the Shrub Wetland PA. These four PAs occupy relatively the same horizontal position on the ordination axes (Figure 4.6). These four PAs do separate out somewhat on the Y-axis based on differences in frequency of disturbance. The THUPLI with Understory PA is the oldest PA on average. The Shrub Wetland is the youngest PA of the four.
Figure 4.7. CCA biplot ordination of *Botrychium* Ecodata plots and *Botrychium* species.
The second area of overlap in the *Botrychium* PAs occurs in the lower half of the CCA ordination diagram (Figure 4.6). The Shrub Wetland PA, the Roadside PA, and the Lower Subalpine Forest PA overlap in this area. These three PAs differ only slightly in elevation. The Shrub Wetland PA has the greatest elevational range of these three PAs. The overlap of these three PAs is much less on the Y-axis. The Shrub Wetland PA and the Upper Subalpine Forest PA are both in the Mid disturbance frequency class. These two PAs separate out on the X-axis due to the higher elevation of the Lower Subalpine Forest PA. The Roadside PA has a similar elevation to the Lower Subalpine Forest PA but they separate out on the Y-axis based on disturbance frequency. The Roadside PA has had more recent disturbance. Two of the Shrub Wetland PA plots are placed in the Roadside PA space in the CCA ordination (Figure 4.6). One of these plots is located at Doak Creek on a roadside. The second Shrub Wetland plot placed in the Roadside space is located at West Fisher River. TWINSPAN placed both of these plots in the Shrub Wetland PA based on plant composition. The plot at West Fisher River had been recently flooded with much soil and gravel deposition. The recent disturbance and high bare soil ground coverage placed the West Fisher River plot in the Roadside PA space in the CCA ordination. The two Lower Subalpine Forest PA plots that are placed in close proximity to the Roadside PA space are both located in forest stands that have been logged about 30 years ago. These recent disturbances placed these plots in close proximity to the Roadside PA. The overlap of the plots from different *Botrychium* plant associations emphasizes the similarities between these PAs, and the intergradations that often occur between them.
4.4.7 A Comparison of the DCA and CCA Ordinations

The CCA ordination of the *Botrychium* plots produced relatively high eigenvalues (Table 4.13). The high eigenvalues produced by CCA contrasts with the relatively low percentage variance of the species environment relation explained by the axes (Table 4.14). The first two axes explained only 37.1% of the species environment relation (Table 4.14). Both the DCA (Figure 4.5) and CCA (Figure 4.6) ordinations produced essentially the same ordering of the *Botrychium* plant associations. The comparison of indirect and direct ordination results can provide confirmation that the direct ordination results are correct, when the configuration of plots is congruent (Okland 1996). Thus, it appears that the CCA ordination has captured the environmental gradient but perhaps the most important environmental variable driving the gradient was not measured.

Table 4.13. Comparison of eigenvalues for CCA and DCA ordinations of the *Botrychium* Ecodata plots.

<table>
<thead>
<tr>
<th>ORDINATION METHOD</th>
<th>EIGENVALUE</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AXIS 1</td>
<td>AXIS 2</td>
<td>AXIS 3</td>
<td>AXIS 4</td>
</tr>
<tr>
<td>DCA</td>
<td>0.781</td>
<td>0.399</td>
<td>0.334</td>
<td>0.273</td>
</tr>
<tr>
<td>CCA</td>
<td>0.739</td>
<td>0.588</td>
<td>0.397</td>
<td>0.373</td>
</tr>
</tbody>
</table>

Table 4.14. Cumulative percentage variance of species-environment relation explained for the *Botrychium* Ecodata plots by the four CCA ordination axes.

<table>
<thead>
<tr>
<th>ORDINATION METHOD</th>
<th>AXIS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>CCA</td>
<td>20.6</td>
<td>37.1</td>
<td>48.2</td>
<td>58.6</td>
</tr>
</tbody>
</table>
4.5 Detailed Descriptions of Botrychium Plant Associations

4.5.1 Thuja plicata/Oplopanax horridum/Gymnocarpium dryopteris/Tiarella trifoliata Plant Association (THUPLI With Understory PA)

A. Range The THUPLI with Understory PA is most common on the Troy Ranger District (RD) in the northwestern portion of the Kootenai National Forest (KNF), where seven out of ten of the plots occur (Figure 4.8). Two plots are found in the northwestern portion of the Libby RD, and one plot is on the western portion of the Fortine RD. The geographic distribution of the THUPLI with Understory PA follows climate. The requirement for this PA, abundant moisture at lower elevations where *Thuja plicata* occurs, is most common on the western portion of the forest (KNF Precipitation Map 1999).

B. Environmental Description The THUPLI with Understory PA occurs primarily in valleys adjacent to streams (60% of the plots). It also occurs on benches, swales, and terraces. These relatively flat areas are conducive to the pooling of water and raising the water table, which favors the formation of this plant association. The soils of this plant association are formed from glacial till and alluvium parent material (Kuennen and Nielsen-Gerhardt 1995). These are rich productive soils typically overlain with a volcanic ash cap (Kuennen and Nielsen-Gerhardt 1995) increasing soil productivity. Aspect is unimportant in the distribution of this PA due to the lack of slope that characterizes its occurrence (Table 4.15).
condition and closely approximated by the vegetation descriptions for these habitat types (Cooper et al. 1991, Pfister et al. 1977). The presence of *Oplopanax horridum* indicates that these sites are located in stream bottoms having a high water table and cold air drainage (Cooper et al. 1991). Pfister et al. (1977) describe their THPL/OPHO habitat type as a topo-edaphic habitat found only in wet bottoms and toe-slope seepy areas.

**Table 4.15. Slope, tree age, basal area, and elevation for each *Botrychium* plant association.**

<table>
<thead>
<tr>
<th>Plant Association</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>THUPLI with Understory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>15</td>
<td>0</td>
<td>40</td>
<td>13.4</td>
</tr>
<tr>
<td>Tree Age</td>
<td>301</td>
<td>98</td>
<td>630</td>
<td>166.9</td>
</tr>
<tr>
<td>Live Basal Area&lt;sup&gt;1&lt;/sup&gt;</td>
<td>406</td>
<td>140</td>
<td>640</td>
<td>142.3</td>
</tr>
<tr>
<td>Elevation</td>
<td>4021</td>
<td>2908</td>
<td>4781</td>
<td>672.0</td>
</tr>
<tr>
<td><strong>THUPLI Depauperate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>8</td>
<td>0</td>
<td>36</td>
<td>9.2</td>
</tr>
<tr>
<td>Tree Age</td>
<td>158</td>
<td>50</td>
<td>350</td>
<td>86.3</td>
</tr>
<tr>
<td>Live Basal Area</td>
<td>282</td>
<td>140</td>
<td>560</td>
<td>105.2</td>
</tr>
<tr>
<td>Elevation</td>
<td>3798</td>
<td>2560</td>
<td>4737</td>
<td>621.9</td>
</tr>
<tr>
<td><strong>Transitional</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>7</td>
<td>0</td>
<td>10</td>
<td>5.7</td>
</tr>
<tr>
<td>Tree Age</td>
<td>68</td>
<td>49</td>
<td>80</td>
<td>16.6</td>
</tr>
<tr>
<td>Live Basal Area</td>
<td>113</td>
<td>80</td>
<td>140</td>
<td>30.5</td>
</tr>
<tr>
<td>Elevation</td>
<td>3590</td>
<td>3137</td>
<td>4100</td>
<td>484.0</td>
</tr>
<tr>
<td><strong>Shrub Wetland</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>4</td>
<td>0</td>
<td>11</td>
<td>4.5</td>
</tr>
<tr>
<td>Tree Age</td>
<td>73.42</td>
<td>0</td>
<td>180</td>
<td>56.7</td>
</tr>
<tr>
<td>Live Basal Area</td>
<td>51</td>
<td>0</td>
<td>140</td>
<td>47.7</td>
</tr>
<tr>
<td>Elevation</td>
<td>3611</td>
<td>2639</td>
<td>4400</td>
<td>496.6</td>
</tr>
<tr>
<td><strong>Lower Subalpine Forest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>7</td>
<td>2</td>
<td>13</td>
<td>4.6</td>
</tr>
<tr>
<td>Tree Age</td>
<td>62</td>
<td>30</td>
<td>96</td>
<td>34.3</td>
</tr>
<tr>
<td>Live Basal Area</td>
<td>75</td>
<td>15</td>
<td>150</td>
<td>56.7</td>
</tr>
</tbody>
</table>

<sup>1</sup> Live Basal Area is recorded in square feet/acre.
Figure 4.9 THUPLI with Understory plant association at North Fork of Meadow Creek, Troy Ranger District.

C. Successional Status/History Natural disturbances include very light fire, flooding, wind, and drought. These are the oldest stands in the Botrychium data set (Table 4.15), with an average age of 301 years. The most common disturbance to these stands is occasional wind throw of trees creating gaps in the forest canopy. The high water table
associated with these sites promotes shallow conifer rooting depth and thus trees are more susceptible to being wind thrown. These stands have down course woody debris averaging 4.4% of the total ground cover. The higher rate of wind thrown trees allows more sunlight to reach lower vegetation levels increasing the coverage of shrubs, ferns, and forbs in this plant association. These gaps in the tree canopy can also allow tree seedlings to become established which enables some new recruitment to the overstory old growth. Fire is a very rare occurrence in this PA due to the abundant moisture. Cooper et al. (1991) note little evidence of past fire in the THPL/OPHO h.t. and THPL/ATFI h.t. stands they sampled, except for sporadic, cool, ground fires. Flooding is an occasional occurrence for stands located beside streams. Flooding provides deposition of silts and fine soil particles. This increases soil productivity. Flooding also has the potential to carry *Botrychium* spores downstream to favorable germination sites. This will allow the propagation of new *Botrychium* populations.

### D. *Botrychium* Constancy in the THUPLI With Understory PA

*Botrychium minganense* is both the most frequent and the most abundant *Botrychium* species in the THUPLI with Understory PA (Appendix 9F). The very mesic, seepy, high water table conditions that characterize this PA seem to be more favorable for *B. minganense*. The common associate of *B. minganense* in these mesic cedar plant associations: *B. montanum* seems to prefer slightly more xeric conditions. *B. montanum* has its greatest constancy in the *Thuja plicata* Depauperate PA and the Transitional PA. Neither *B. crenulatum* nor *B. ascendens* occur in this plant association. Either this may be due to their need for more recent disturbance or their requiring soils derived from calcareous
parent material. The ever-present "weedy" *Botrychium virginianum* occurs on only 50% of the plots in this plant association. Figure 4.10 displays all KNF *Botrychium* occurrences by PA. The *Thuja plicata* PAs are lumped together as “Cedar”.

![Diagram of Botrychium species by plant association on the KNF.](image)

**Figure 4.10.** Sensitive *Botrychium* species populations by plant association on the KNF.

### 4.5.2 *Thuja plicata* Depauperate Plant Association (THUPLI Depauperate PA)

**A. Range** The THUPLI Depauperate PA plots are most common in the northwestern portion of the KNF (Figure 4.11). These plots occur where the precipitation is the
highest on the KNF (KNF precipitation map 1999) and at lower elevations that support mesic *Thuja plicata* forests (Cooper et al 1991).

---

Figure 4.11. Location of *Thuja plicata* Depauperate PA plots on the KNF.
B. **Environmental Description** The THUPLI Depauperate PA occurs primarily in valley stream bottoms, and with lesser frequency on valley swales, valley terraces, and mountain benches. The soils are formed from noncalcareous glacial till (65%), alluvium (25%), and calcareous glacial till (10%) (Kuennen and Nielsen-Gerhardt 1995). A layer of volcanic ash deposition makes these soils highly productive (Kuennen and Nielsen-Gerhardt 1995). Aspect is not important in the distribution of this PA due to the lack of slope that characterizes its occurrence (Table 4.15).

The THUPLI Depauperate PA is floristically similar to the THUPLI with Understory PA (cover similarity of 62.7%, Table 4.16), but differs by increased average tree canopy coverage and decreased average coverages of shrubs and ferns of 16% and 22%, respectively (Figures 4.12 and 4.13). The greater tree canopy coverage of this plant association reduces the amount of solar radiation reaching the forest floor. This reduces the available light for the growth of understory plant species.

C. **Successional Status/History** Natural disturbances include fire, flooding, wind, and drought. The plots in this PA are on average 143 years younger in age than those in the THUPLI with Understory PA (Table 4.15). These stands may eventually resemble those in the THUPLI with Understory PA, as more trees fall down creating openings and stimulating the growth of understory plant species. Both *Athyrium filix-femina* and *Gymnocarpium dryopteris* (two of the TWINSSPAN differential species for the THUPLI with Understory PA) are present on over 50% of the plots in the *Thuja plicata* Depauperate PA.
with Understory PA) are present on over 50% of the plots in the *Thuja plicata* Depauperate PA.

![Image of forest](image)

**Figure 4.12.** *Thuja plicata* Depauperate PA at Roderick Butte, Troy Ranger District.

Fire intensity is generally low in this PA due to the mesic nature of these sites and close proximity to surface water. Flooding is an occasional occurrence for those stands that are located on streams in the floodplain. Flooding provides deposition of silts and fine soil particles, increasing soil productivity. *Botrychium* spores can also be carried downstream to favorable germination sites by floods, promoting the establishment of new *Botrychium* populations.
Table 4.16. Percent cover similarity between *Botrychium* plant associations on the Kootenai National Forest.

<table>
<thead>
<tr>
<th>Plant Association</th>
<th>THUPLI With Understory</th>
<th>THUPLI Depauperate</th>
<th>Transitional</th>
<th>Shrub Wetland</th>
<th>Lower Subalpine Forest</th>
<th>Upper Subalpine Forest</th>
<th>Roadside</th>
<th>Subalpine Meadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>THUPLI With Understory</td>
<td>100</td>
<td>62.7</td>
<td>46.0</td>
<td>32.6</td>
<td>23.2</td>
<td>16.7</td>
<td>20.6</td>
<td>5.0</td>
</tr>
<tr>
<td>THUPLI Depauperate</td>
<td></td>
<td>62.7</td>
<td>100</td>
<td>40.7</td>
<td>36.7</td>
<td>24.6</td>
<td>16.8</td>
<td>23.6</td>
</tr>
<tr>
<td>Transitional</td>
<td>46.0</td>
<td>40.7</td>
<td>100</td>
<td>51.9</td>
<td>32.0</td>
<td>10.5</td>
<td>18.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Shrub Wetland</td>
<td>32.6</td>
<td>36.7</td>
<td>51.9</td>
<td>100</td>
<td>37.5</td>
<td>13.4</td>
<td>32.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Lower Subalpine Forest</td>
<td>23.2</td>
<td>24.6</td>
<td>32.0</td>
<td>37.5</td>
<td>100</td>
<td>23.1</td>
<td>38.2</td>
<td>17.0</td>
</tr>
<tr>
<td>Upper Subalpine Forest</td>
<td>16.7</td>
<td>16.8</td>
<td>10.5</td>
<td>13.4</td>
<td>23.1</td>
<td>100</td>
<td>15.4</td>
<td>18.4</td>
</tr>
<tr>
<td>Roadside</td>
<td>20.6</td>
<td>23.6</td>
<td>18.6</td>
<td>32.2</td>
<td>38.2</td>
<td>15.4</td>
<td>100</td>
<td>12.1</td>
</tr>
<tr>
<td>Subalpine Meadow</td>
<td>5.0</td>
<td>4.6</td>
<td>3.4</td>
<td>4.8</td>
<td>17.0</td>
<td>18.4</td>
<td>12.1</td>
<td>100</td>
</tr>
</tbody>
</table>
D. *Botrychium* Constancy in the *Thuja plicata* Depauperate Plant Association

*Botrychium montanum* has the greatest constancy (85%) of any *Botrychium* in this plant association (Appendix 10F). The higher constancy of *B. montanum* in this PA over the THUPLI with Understory PA is indicative of *B. montanum*’s preference for somewhat dryer sites than the THUPLI with Understory PA locations. There are no occurrences of *B. ascendens* and *B. crenulatum* in this plant association. This may be due to the lack of calcareous parent material or the lack of more recent disturbance in this PA.

Figure 4.13. Mean life form coverages (%) by plant association for *Botrychium* Ecodata plots on the KNF.
4.5.3 Thuja Plicata/Circaea alpina/Cinna latifolia - Carex disperma Plant Association (Transitional PA)

A. Range All three plots in the Transitional PA are located on the northwestern portion of the KNF, at French Creek on the Troy Ranger District, and Pipe Creek, and Cedar Creek on the Libby Ranger District (Figure 4.14). The small sample size is indicative of the relatively minor occurrence of this plant association.

B. Environmental Description The Transitional PA is intermediate between the Tsuga heterophylla - Thuja plicata forest alliance (TSEHET – THUPLI FA) plots and the Shrub Wetland PA. The Transitional plots were the first to be separated out from the TSEHET – THUPLI FA plot group by TWINSPLAN based on the presence of Cinna latifolia and Carex disperma. These grass species are indicative of the mesic, more open conditions that characterize this PA. The Transitional plots varied from the Tsuga heterophylla - Thuja plicata FA plots by having only 37% average total tree cover (Figure 4.13). The more open overstory favors the growth of grasses, forbs, and shrubs by allowing more solar radiation to reach the lower vegetation strata.

The Transitional PA occurs on mountain benches, valley terraces, and mountain swales. It does not occur on valley streamside sites. Soil parent material is glacial till overlain with volcanic ash (Kuennen and Nielsen-Gerhardt 1995). The habitat type for all plots in this PA is Thuja plicata/Athyrium filix-femina. This habitat type is indicative of the abundant soil moisture available for the growth of mesophytic fern species. Aspect is
unimportant in the distribution of this PA because of the lack of slope that characterizes this PA (Table 4.15).

Figure 4.14. Location of Transitional plant association plots on the KNF.

C. Successional Status/History These are the youngest plant communities in the TSEHET – THUPLI FA, with an average age of 68 years (Table 4.15). As discussed
below in the Shrub Wetland PA Description, this plant association may be a successional intermediary between the Shrub Wetland PA and the TSEHET – THUPLI FA. Natural disturbances in this community type include wind, fire, and drought. Fire is probably very infrequent and low intensity when it occurs. The Dome Mountain Fire on the Libby Ranger District in 1998 burned within about 300 feet of the Cedar Creek site but did not burn the Transitional PA. Drought probably has little effect in this PA due to the high water table and abundant surface water.

The one plot in this PA with *B. pedunculosum* is located in the Cedar Creek drainage, southwest of Libby, MT. This site is the location of an old cabin from the early 1900’s and the first fish hatchery in the region (White pers. comm.). The homestead included a cultivated hay meadow with raised mounds that were apparently constructed to maintain water irrigation to the hay meadow from a nearby seepage area (White pers. comm.). The current plant community at the site is a shrub-dominated wetland bearing little resemblance to a hay meadow. The *B. pedunculosum* at this site are growing only on raised hummocks that are regularly spaced through the shrub wetland. Most of this site is inundated with standing water due to this water development and is not suitable *Botrychium* habitat. This is an atypical *B. pedunculosum* location with greater similarity to the Shrub Wetland PA. The occurrence of *Botrychium* on naturally occurring raised hummocks in shrub-dominated wetlands is common. It is unusual to find *Botrychium* on human constructed hummocks. Although, human manipulation of the environment has been observed to create favorable *Botrychium* habitats on roadsides and old roads on the KNF (pers. obs.). Wagner (pers. comm.) also states that old home sites and town sites are good habitats for *Botrychium*.
D. *Botrychium* Constancy in the *Thuja plicata/Circaea alpina/Cinna latifolia - Carex disperma* Transitional PA The Transitional plant association is within the TSEHET – THUPLI forest alliance. The *Botrychium* species with the greatest constancy in the TSEHET – THUPLI FA also have the highest constancies in this PA (i.e. *B. minganense* and *B. montanum*) (Figure 4.10 and Appendix 11F).

4.5.4 *Cornus stolonifera - Symphoricarpos albus - Rhamnus alnifolia* Plant Association (Shrub Wetland PA)

A. Range This plant association occurs on the central and eastern portions of the KNF (Figure 4.15), and is represented by 12 plots. This plant association is not abundant on the forest, representing only 10% of the 124 total *Botrychium* locations on the KNF. The sample size of this plant association has been relatively large due to the occurrence of one of the less common species: *B. crenulatum* in natural habitats.

B. Environmental Description The Shrub Wetland plant association occurs only in valleys, and 75% of the occurrences are on streamside locations. The remainder are in valley swales and valley terraces. High water tables with standing surface water characterize these sites. The Shrub Wetland PA had the highest average ground coverage by water at 6.1%. The higher water table drowns conifer regeneration allowing shrubs to dominate (Figure 4.16). Standing water was generally avoided in locating *Botrychium* plots, since *Botrychium* do not grow from standing water, and the plots were laid out to include the greatest number of *Botrychium* plants. The *Botrychium* in this PA occur on
the raised hummocks, or areas that seasonally dry out within these wetland sites. Aspect is unimportant due to the lack of slope (Table 4.15).

Figure 4.15. Location of the Shrub Wetland plant association plots on the KNF.
Figure 4.16. Shrub Wetland plant association at Jackson Creek, Libby Ranger District.

The lack of heavy tree cover (Figure 4.13) in the Shrub Wetland PA allows greater growth of understory vegetation. The habitat type of these sites was highly variable. Some sites supported coniferous trees, and thus fit one of the forest habitat types. Other locations required the use of Hansen et al. (1995) to determine potential vegetation. The most common soil parent material of the Shrub Wetland PA is calcareous glacial till (58%) (Kuennen and Nielsen-Gerhardt 1995). Noncalcareous glacial till accounts for 25% of the soil parent material and alluvium makes up the remaining 17% (Kuennen and Nielsen-Gerhardt 1995).
The intergradation of *Botrychium* plant associations is again exemplified by the placement of the plot at Parsnip Creek in the Shrub Wetland PA by the TWINSPAN classification. The CCA (Figure 4.6) and DCA (Figure 4.5) ordinations corroborate its placement in the Shrub Wetland PA. The Parsnip Creek site is a large *Botrychium* genus community extending over approximately 50 acres. Plots placed elsewhere at this site would classify out in the TSUHET – THUPLI FA. Located just beyond the plot boundaries are the THUPLI Depauperate PA, and upstream a short distance more *B. pedunculosum* occur in the THUPLI with Understory PA. Thus, more than one plant association can occur at the same *Botrychium* location.

C. Successional Status/History It is unknown if the Shrub Wetland PA is a seral or climax plant community. The Shrub Wetland sites that were sampled had a range of average tree age from 50-180 years old. The average age was 73 years (Table 4.15), much less than the average age of the TSUHET - THUPLI forest alliance of 158 years. It is possible that the Shrub Wetland PA will succeed to the Transitional PA and then progress to the TSUHET - THUPLI forest alliance. These shrub wetlands may be seral plant communities that are slowly becoming forested. If trees become established at Shrub Wetland PA sites, they may gradually lower the water table by increased water uptake, and build up soils with litter deposition. This may make the area even more conducive to conifer seedling establishment, and slowly convert the Shrub Wetland PA to forest.
Tree coverages were great enough to place most Shrub Wetland sites into coniferous dominated habitat types. Most sites had the requisite 10 or more trees per acre not restricted to microsites (Cooper et al. 1991, Pfister et al. 1977, and Hansen et al. 1995). These coniferous habitat type determinations indicate that these sites do support coniferous trees, and should succeed to coniferous forest. Four of the sampled Shrub Wetland sites did not have enough trees present to be placed into coniferous habitat types. These sites typed out as Alnus sinuata and Cornus stolonifera Community Types (Hansen et al. 1995). Cooper et al. (1991) describe a similar habitat type for Northern Idaho as Alnus sinuata/Montia cordifolia (ALSI/MOCO) h.t. Cooper et al. describe the ALSI/MOCO h.t. as long-lived mid seral to climax plant community, maintained by high water tables and seasonal flooding that drowns conifer regeneration. Thus, the longevity of the Shrub Wetland PA is unsure.

Natural disturbances in this PA include fire, flooding, wind, and drought. Fire and drought effects are probably minimal due to very mesic conditions and abundant surface water present. Flooding can be beneficial by reducing coverage of competing plants, deposition of silts to improve soil fertility, and transport of Botrychium spores to new safe sites for establishment of new populations.

D. Botrychium Constancy in the Cornus stolonifera - Symphoricarpos albus -

*Rhamnus alnifolia* Shrub Wetland Plant Association Botrychium crenulatum has the greatest constancy (58%) of the sensitive species of Botrychium in the Shrub Wetland plant association (Appendix 12F). Both *B. minganense* and *B. montanum* are less
frequent in this PA. *B. pedunculosum* occurs in one plot in this PA at Parsnip Creek as discussed above. Perhaps the calcareous soil parent material or the more frequent disturbance favors *B. crenulatum* more than *B. minganense* and *B. montanum* in this PA. The occurrence of *B. montanum* and *B. pedunculosum* in this PA are perhaps incidental. The populations of *B. montanum* and *B. pedunculosum* consist of only a few plants of each species where they occur in this PA. The largest populations of *B. pedunculosum* and *B. montanum* occur in the TSUHET - THUPLI forest alliance. This is probably the preferred habitat for the two species on the KNF. *B. virginianum* has the greatest constancy of all *Botrychium* for this PA at 83%.

4.5.5 *Picea* spp./*Ribes lacustre/Senecio pseudoaureus* Plant Association (Lower Subalpine Forest PA)

**A. Range** The Lower Subalpine Forest PA occurs on the northeastern portion of the KNF (Figure 4.17). Two plots are located in the Weigel Mountain area. on the Libby RD. One plot is at Boulder Creek on the Eureka RD, with one plot at Wigwam River, Fortine RD. This is not a common PA for *Botrychium* on the KNF. Only 6% of the total KNF *Botrychium* locations are in the Lower Subalpine Forest PA.

**B. Environmental Description** The Lower Subalpine Forest PA occurs in valleys along streams and on valley terraces. The most common habitat type is *Abies lasiocarpa/Calamagrostis canadensis* (ABLA/CACA) (75% of plots). *Abies lasiocarpa/Streptopus amplexifolius* (ABLA/STAM) habitat type occurs on 25% of the plots. Cooper et al. (1991) describe the ABLA/CACA Habitat Type as occurring on "toe-
slopes with seeps and sites with perched water tables - in general poorly drained, seasonally saturated sites.” This plant association shares the high water table and abundant surface water found in the TSUHET - THUPLI FA and Shrub Wetland PA. Soil parent material is noncalcareous glacial till on 75% of the plots and alluvium on 25% of the plots (Kuennen and Nielsen-Gerhardt 1995). These are open forests (average tree coverage of 25%) due to logging manipulation with high coverages of forbs and grasses (Figure 4.13 and 4.18).

C. Successional Status/History All plots in the Lower Subalpine Forest PA have had some recent logging activity. Both the stands at Wigwam River and at Boulder Creek were clear-cut 30-35 years ago. These stands are currently stocked with small pole size trees (DBH 5-7 inches). The other two stands in the Weigel Mountain area are midseral stands approximately 90 years old. Both have had some selective logging in the past. The logging-created openings in this PA have likely improved the habitat for Botrychium. B. minganense was only found in the openings and around the edges of the openings. No B. minganense were observed in the more dense surrounding forest. The preference for early seral stand conditions and recent disturbance seems incongruous with the mature to old growth cedar/hemlock forest PAs favored by B. minganense.

Natural Disturbances in this PA include wind, fire, and drought. This PA is located in the valleys near streams, but above the flood plain. Wind was not observed to currently affect these stands due to their early successional status. Fire in this PA would be infrequent and low intensity due to the mesic site characteristics. The site at Boulder
D. *Botrychium* Constancy in the *Picea* spp./*Ribes lacustre*/*Senecio pseudaureus*

**Lower Subalpine Forest Plant Association** The only sensitive species of *Botrychium* to occur in the Lower Subalpine Forest PA is *B. minganense* (Appendix 13F). The populations of *B. minganense* in this PA are relatively small, ranging from 2-29 plants. These smaller populations seem to indicate the Lower Subalpine Forest sites are not the optimal habitat for *B. minganense* on the KNF. These higher elevation cooler sites may be too cold for *B. pedunculosum* and *B. montanum*. Both species are only found in the TSUHET - THUPLI FA and the Shrub Wetland PA. *B. crenulatum* has not been found in this PA perhaps due to its preference for calcareous parent material.
4.5.6 *Abies lasiocarpa/Luzula hitchcockii/Angelica dawsonii* - *Parnassia fimbriata*

**Plant Association (Upper Subalpine Forest PA)**

**A. Range** The Upper Subalpine Forest PA is not common on the KNF (Figure 4.19).

Only two of the three total locations on the KNF were sampled with Ecodata plots. All locations are in the Ten Lakes Scenic Area, on the Fortine RD. This is an uncommon *Botrychium* PA accounting for only 2% of the total KNF *Botrychium* locations.

**B. Environmental Description** The Upper Subalpine Forest plant association occurs in mountain swales near seepage areas or troughs of seasonal runoff. These are mature, late seral, forested stands with openings promoting the growth of forbs and grasses (Figure 4.20). The habitat type is *Abies lasiocarpa/Streptopus amplexifolius*. This habitat type indicates seeps and subirrigated alluvial terraces of the subalpine zone (Cooper et. al 1991). TWINSPLAN split the Upper Subalpine Forest PA plots from the Shrub Wetland PA based on the presence of *Luzula hitchcockii*, an indicator of cold environments where snow stays late (Lackschewitz 1991). This PA shares the high water table and at least seasonally surface water with all the previous plant associations. The Upper Subalpine Forest PA differs from the Lower Subalpine Forest PA by greater elevation, stand age (Table 4.15), forb coverage, and reduced coverages of grasses and shrubs (Figure 4.13). Soil parent material at these two sites is glacial till and weathered metasedimentary rock (Kuennen and Nielsen-Gerhardt 1995).
C. Successional Status/History The plots in this PA have had disturbance from trail construction at the Paradise Lake Trail site and very selective logging at the Big Therriault Lake site. These disturbances create openings in the forest and improve
habitat for *Botrychium*. At the Paradise Lake Trail site *Botrychium* are presently growing from the side of the trail. A similar occurrence is reported at the trail to Mount Aeneas (EO # 1), in the Jewel Basin Hiking Area on the Flathead NF, where *B. mingsanense* occurs on the side of the trail (Wagner pers. comm.). Natural disturbances in this PA include fire, wind, and drought. The effects of fire and drought in this PA should be minor due to the abundance of soil moisture from seeps and late season snow pack.

![Figure 4.20. Upper Subalpine Forest plant association at Big Therriault Lake, Fortine Ranger District.](image)

**D. *Botrychium* Constancy in the *Abies lasiocarpa/Luzula hitchcockii/ Angelica dawsonii - Parnassia fimbriata* Upper Subalpine Forest Plant Association** These high elevation sites support a very limited *Botrychium* flora. *Botrychium mingsanense* is the only sensitive species of *Botrychium* found in this PA (Figure 4.10 and Appendix 14F).
have also observed *B. lunaria*, *B. pinnatum*, and *B. virginianum* in the Upper Subalpine Forest PA. Cooler temperatures do not appear to limit the occurrence of *B. crenulatum* and *B. ascendens* in the Upper Subalpine Forest PA. The Roadside PA sites where both *B. crenulatum* and *B. ascendens* have their greatest constancy often have *Vaccinium caespitosum* present indicating a frost pocket or cold air drainage (Cooper et al. 1991, Pfister et al. 1977). The more frequent disturbance and calcareous parent material present on the roadsides may favor *B. crenulatum* and *B. ascendens* in the Roadside PA.

### 4.5.7 *Trifolium repens* - *Plantago major* - *Prunella vulgaris* Plant Association (Roadside PA)

**A. Range** Nine of the ten Roadside PA plots are located in the northeastern portion of the forest, primarily in the Upper Fortine Creek area, on the Fortine RD (Figure 4.21), and one plot is located at Basin Creek on the Troy RD. There are 29 total *Botrychium* locations on roadsides on the KNF, representing 23% of the total KNF *Botrychium* locations. Sixty-two percent of these are in the Upper Fortine Creek area.

**B. Environmental Description** This PA includes sites located on open roadsides and closed roads. These are disturbed plant communities often with high coverages of nonnative and native weedy plants. The plots are open with very little tree cover and high coverages of grasses and forbs (Figures 4.13 and 4.22). Ferns that were a major component of the THUPLI with Understory PA are rare here. *Equisetum arvense* is the only fern ally with high constancy (70%) in this PA. The Roadside PA plots are located in valleys (80%) and mountain swales. Of the valley plots 50% were on valley terraces.
20% on valley streams, and 10% on valley moraines. The remaining 20% of the Roadside PA plots occur on mountain swales. Calcareous glacial till is the most common soil parent material for this community type at 50% (Kuennen and Nielsen-Gerhardt 1995). Noncalcareous glacial till accounts for 20% of the sites’ soil parent material and alluvium the remaining 30% (Kuennen and Nielsen-Gerhardt 1995). It unknown if this alluvium is calcareous or not.

Site characteristics are somewhat variable for the Roadside PA. Eighty percent of the habitat types for plots in this PA are in the *Abies lasiocarpa* series. The remaining 20% are *Thuja plicata/Clintonia uniflora* habitat type. The most common habitat type is *Abies lasiocarpa/Clintonia uniflora* (40%). Sixty percent of all plots in this PA are in the *Clintonia* understory union. These sites are therefore somewhat dryer than the locations where the Subalpine Forest PAs occur. Surface water is still in close proximity (approximately 400 feet) to all Roadside plot locations.

C. **Successional Status/History** The Roadside PA sites are the youngest plots in the *Botrychium* dataset with an average age of 25-35 years; however, these sites are not pioneer plant communities. The average tree age (Table 4.15) for this PA is not representative of the site conditions because it is based on surrounding trees not on trees found on the fixed radius Ecodata plot. These trees are present on the variable radius plot used to sample trees. Ecodata plot methodology uses a variable radius plot to sample tress in addition to the fixed radius plot used to sample plant composition (Jensen and
Hann 1992). Some of the roadsides occur adjacent to old growth forests increasing the plots' tree age.

Natural disturbances in this PA include fire, drought, and wind. Fires in this PA would be light surface fires due to fuel consisting of only cured forbs and grasses. The fuel model for this PA is Fuel Model 1 (Anderson 1982). While these roadsides are close to surface water, they are generally not directly on the stream or in the flood plain. Drought could have its greatest effects in this PA. These are the driest sites in the Botrychium data set.

The Roadside PA is a human created environment. These are very disturbed sites and are often subjected to ongoing human perturbations. Human induced disturbances in the Roadside PA include road maintenance, mechanical blading and grading, herbicide spraying, grazing, and parking. The majority of the KNF locations for this PA are within grazing leases. The previous road construction in this PA often creates cut slopes down to an impermeable layer from which water often flows out into roadside ditches. Thus, the road construction promotes pooling of water in the ditches, and decreases water infiltration by increased soil compaction. The accumulation of water in the upper portion of the soil profile would provide a medium for the sperm to swim in, facilitating the fertilization of Botrychium gametophytes.
D. *Botrychium* Constancy in the *Trifolium repens* - *Plantago major* - *Prunella vulgaris* Roadside Plant Association

*Botrychium crenulatum* is the most frequent species of *Botrychium* in the Roadside PA, having a constancy of 90% (Appendix 15F). The ever-present *B. virginianum* has a constancy of only 50%. The more frequent disturbance and higher light intensity of these open habitats probably make these sites poor habitat for *B. montanum*. Some problematic plants tentatively identified as *B. paradoxum* have been found in this PA, at Lake Creek, and at Davis Creek on the Fortune
RD. Only a single specimen was found at each location. These may be another Botrychium species that had their trophophores damaged stimulating the growth of a second sporophore (see pages 45-46). The Roadside PA and the Subalpine Meadow PA probably have the greatest potential for B. paradoxum on the KNF, based on B. paradoxum’s preference for meadow habitats (Wagner and Wagner 1993). Roadsides are human created approximations of meadows.

Figure 4.22. Roadside plant association at Water Trough Draw, Eureka Ranger District.
4.5.8 *Ranunculus eschscholtzii - Potentilla diversifolia - Phleum alpinum - Poa alpina*

Plant Association (Subalpine Meadow PA)

A. Range All three plots in the Subalpine Meadow PA are located in the Ten Lakes Scenic Area on the Fortine RD (Figure 4.23). This does not appear to be a common *Botrychium* plant association on the KNF. There are only six total locations on the KNF accounting for 5% of the total KNF *Botrychium* locations. This PA could be separated into two plant associations. One plant association would be the rich forb subalpine meadows. The second would be the alpine summit locations at Green Mountain and Saint Paul Peak. The ordination outputs of CCA and DCA show the separation of the alpine summit plot at Green Mountain from the lower subalpine meadow sites. The separation was very slight in the CCA ordination (Figure 4.6). In contrast, the DCA ordination (Figure 4.5) shows a great distance between the alpine summit at Green Mountain and the lower subalpine meadow sites. The three plots are left together as a single PA for this analysis as the TWINSPAN table grouped them. The two groups may be better differentiated with a larger sample.

B. Environmental Description These are open high elevation sites. These meadows are characterized by high coverages of forbs and grasses and very low coverages of trees and shrubs (Figures 4.13 and 4.24). The *Botrychium* at these sites are growing below the grass/forb layer, often hidden in a mat of herbaceous vegetation. The dense herbaceous and graminoid vegetation provides some insulation and increases the boundary layer around the *Botrychium* plants reducing the effects of extreme cold and decreasing transpirational water loss.
This PA occurs in the mountains in swales and on summits. It differs from the other *Botrychium* PAs in its greater distance from surface water. These are the highest precipitation sites in the *Botrychium* data set based on the KNF precipitation map (Kootenai National Forest 1999). The higher precipitation rate at these sites negates the need for surface water to provide mesic conditions favorable for *Botrychium*. All sites have soil parent material formed from weathered, metasedimentary rock and friable glacial till (Kuennen and Nielsen-Gerhardt 1995). The habitat type did not actually reflect site potential vegetation because sites are not forested. Habitat guides to forested plant communities did not fit.

**C. Successional Status/History** It is unknown if these meadows are seral plant communities that will eventually be seeded in with conifers, and become a forest. A few tree seedlings were noted at all locations. The upper elevation alpine summits may be unsuitable for conifer establishment due to the high winds that characterize these sites. Although conifer seedlings are present, they rarely grow to tree size.
Figure 4.23. Location of Subalpine Meadow plant association plots on the KNF.
Figure 4.24. Subalpine Meadow plant association at Bluebird Basin, Fortine Ranger District, KNF.

D. *Botrychium* Constancy in the *Ranunculus eschscholtzii - Potentilla diversifolia - Phleum alpinum - Poa alpina* Subalpine Meadow PA *Botrychium minganense* is the only sensitive species of *Botrychium* that occurs in this PA (Figure 4.10 and Appendix 16F). It is amazing that *B. minganense* has the physiological amplitude to occur in the darkest cedar forest stands at low elevations and in the wind and sun blasted environments of alpine summits. The *B. minganense* in these alpine environments differ morphologically from the *B. minganense* occurring at lower elevations. The alpine *B. minganense* tend to be much smaller (height 3-6 cm.) with only 2-4 pinnac pairs and thicker, more leathery texture. The thicker epidermis of the alpine *B. minganense* would reduce transpirational water loss and provide additional insulation against the cold. The
Botrychium minganense from the Subalpine Meadow PA also show some isozyme
differentiation from B. minganense collected at lower elevation sites on the KNF (Farrar
1998). The isozyme differences probably correspond to different enzyme systems for
physiologically tolerating the harsh site characteristics of the Subalpine Meadow PA.
The Subalpine Meadow PA supports relatively large vigorous populations of B.
inganense. Population size varied from 50 plants at Green Mountain and Saint Paul
Peak to 125 B. minganense at Upper Bluebird Basin.

4.5.9 Discussion of Shared Attributes of all Botrychium Plant Associations
All Botrychium locations sampled have the following shared attributes lack of slope,
close proximity to surface water (excluding the Subalpine Meadow PA), and the presence
of mesophytic plant species. The lack of slope accounts for the great variation in aspect
within each PA. The relative flatness of all these locations ameliorates the effects of
aspect on vegetation. Solar insolation is relatively constant regardless of aspect when
slope is negligible and latitude is constant. Constancy tables indicate the strong
association between the occurrence of the common species of Botrychium and the
sensitive species of Botrychium. In particular, Botrychium virginianum has 61% total
constancy for the entire data set. Botrychium virginianum is a good indicator of the
potential habitat for the sensitive species of Botrychium except for in the Subalpine
Meadow PA, where no B. virginianum was observed.
4.5.10 Other *Botrychium* Plant Associations not Described

Not all *Botrychium* plant associations were sampled with enough repetitions to obtain a detailed characterization. The plots at Othorp-Morgan Lake (*B. minganense* EO # 66) and at Swamp Creek (*B. minganense* EO #45 and *B. crenulatum* EO # 8) were dropped from the analysis because they were outliers. Their floristic composition was very different from the eight plant associations described in this report. The research for this report tried to quantify the more common and important *Botrychium* plant associations. Only three of the 124 total KNF *Botrychium* sites do not appear to fit into the eight described *Botrychium* plant associations. In addition to the two noted above the site at Brush Creek (*B. minganense* EO # 42) on the Libby Ranger District does not appear to fit in any of the eight described *Botrychium* plant associations. These three sites support only small populations of *Botrychium* plants and are perhaps at the limits of the species’ environmental tolerance.
CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Botrychium Status Recommendations for Montana and the US Forest Service

5.1.1 Introduction

The KNF is blessed with a large diverse Botrychium flora. The world center for Botrychium diversity is the Columbia River Basin of the Northwestern United States (Wagner pers. comm.). There are three distinct centers of Botrychium diversity within this larger physiognomic unit. The three regional centers of Botrychium diversity within the Columbia Basin are the Wallowa Mountains of Northeastern Oregon, the Colville National Forest in Eastern Washington, and Northwestern Montana. The importance of the Kootenai National Forest Botrychium resource to the global distribution of these species cannot be ignored, and thus supports strong conservation measures for maintaining these populations.

I present my status recommendations for each of the sensitive species of Botrychium to insure the maintenance of viable populations of Botrychium in Montana and on the KNF. My recommendations are based upon rarity, habitat, and threats for each sensitive species of Botrychium. In addition, I review the status of B. hesperium, B. pallidum, and B. simplex. Site-specific management recommendations are formulated to maintain viable Botrychium populations at locations that are determined to be of conservation concern. Management recommendations are directed at Botrychium locations not at individual species due to the tendency for different Botrychium species to occur together.
Botrychium monitoring recommendations are also made to assess the success of my proposed management recommendations.

5.1.2 Botrychium ascendens W. H. Wagner

Botrychium ascendens has been identified at only 11 locations in Montana (MTNHP 1999, KNF Database). Eight of the eleven occurrences in Montana are on the KNF (Table 5.1). Botrychium ascendens has been found exclusively on disturbed roadsides and old roads on the KNF. Elsewhere in Montana B. ascendens occurs in a campground on the Flathead National Forest, on an old road in the Swan Valley, and at the base of the Chinese Wall in the Bob Marshall Wilderness (MTNHP 1999). Threats to B. ascendens include road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, fire suppression, fire line construction, misidentification as a more common species of Botrychium, trail construction, and encroachment of woody plant species.

Four of the eight populations of B. ascendens on the KNF consist of only a single plant. Berlin et al. (1998) found that B. mormo populations of less than five individuals were vulnerable to extirpation through stochastic events alone in the stage-based stochastic models they constructed for B. mormo populations. Thus, 50% of the population of B. ascendens on the KNF may be susceptible to extirpation due to stochastic events alone. The roadside habitats of B. ascendens on the KNF are transient plant communities. These sites will succeed to brush and tree dominated plant communities without active management of these sites. The small number of sites, low population numbers for B. ascendens, and the transient nature of the habitats where this species occurs on the KNF,
Table 5.1. *Botrychium* occurrences in Montana by county.

<table>
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<tr>
<th>County</th>
<th>B. ascendens</th>
<th>B. crenulatum</th>
<th>B. minganense</th>
<th>B. montanum</th>
<th>B. paradoxum</th>
<th>B. pedunculosum</th>
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</tr>
<tr>
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<td>29(^*)</td>
<td>87(^*)</td>
<td>38(^*)</td>
<td>7(^*)</td>
<td>9(^*)</td>
</tr>
<tr>
<td>Mineral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Missoula</td>
<td></td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pondera</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanders</td>
<td>1(^*)</td>
<td>2(^*)</td>
<td>1(^*)</td>
<td></td>
<td>1(^*)</td>
<td></td>
</tr>
<tr>
<td>Teton</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Occurrences</td>
<td>11</td>
<td>41</td>
<td>112</td>
<td>51</td>
<td>19</td>
<td>11</td>
</tr>
</tbody>
</table>

\(^1\) Three of the eight occurrences in Flathead County are on the KNF.
\(^2\) * Indicates that occurrences are on the KNF.
makes these populations susceptible to extirpation. It is recommended that the Montana State Status of S1 be retained for *Botrychium ascendens*, and Region One Forest Service Sensitive status be retained for the species.

### 5.1.3 *Botrychium crenulatum* W. H. Wagner

There are 41 known *Botrychium crenulatum* locations in Montana (MTNHP 1999, KNF Database) and 80% of the sites are located on the KNF (Table 5.1). Four of the 33 occurrences on the KNF are not represented by a voucher specimen and have not been relocated in subsequent years. These four sites, Rock Creek (EO #2), Sutton Creek (EO #3), West Fisher River (EO #25), and Upper Boulder Creek (EO #21) will not be considered as extant populations in this analysis. Thus, there are 37 extant occurrences of *B. crenulatum* in Montana, with 29 occurring on the KNF. Six of the *B. crenulatum* populations on the KNF (21%) consist of five or fewer individuals. These very small populations may be susceptible to extirpation from stochastic events alone (Berlin et al. 1998). This leaves 23 potentially viable populations of *B. crenulatum* on the KNF. *B. crenulatum* occurs only on roadsides and in shrub-dominated wetlands on the KNF, except for one small population at Swamp Creek, (Fortine Ranger District) which occurs in an atypical aspen dominated wetland. Of the total extant *B. crenulatum* occurrences on the KNF 69% are in the Roadside plant association (PA), 28% are located in Shrub Wetland PA, and 3% are in Subalpine Forest PA. Thus, the majority of *B. crenulatum* on the KNF are located in transient plant communities on old roads and roadsides. The roadside PA will eventually succeed to tree and shrub dominated plant communities with little light available for the understory species without active management. These sites
will become unfavorable habitat for \textit{B. crenulatum} as plant succession progresses. It is unknown if the Shrub Wetland PA is a long-lived plant community or a seral plant community (see discussion above in the description of the Shrub Wetland PA). Threats to \textit{B. crenulatum} include road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, changes in hydrological regime, fire line construction, misidentification as a more common species of \textit{Botrychium}, trail construction, and encroachment of woody plant species. It is recommended that the Montana Natural Heritage Program change the state rank for \textit{Botrychium crenulatum} from S2 to S3 based on the number of occurrences. Tracking of \textit{B. crenulatum} should continue due to the transient nature of the plant communities (roadsides) at 69\% of the sites where it occurs on the KNF.

5.1.4 \textit{Botrychium minganense} Victorin

There are 112 known sites of \textit{Botrychium minganense} in Montana (MTNHP 1999, KNF Database) with 79\% located on the KNF (Table 5.1). Two of these occurrences at North Fork of Dodge Creek (EO # 41) and Warland Creek (EO # 35) are historical and have not been relocated on subsequent searches (Vanderhorst 1997). Thus, there are 87 extant populations of \textit{B. minganense} on the KNF. Twenty-six of the extant populations of \textit{B. minganense} (30\%) consist of five or fewer plants. These small populations may be vulnerable to extirpation through stochastic events alone (Berlin et al. 1998). This leaves 61 potentially viable populations of \textit{B. minganense} on the KNF.
Botrychium minganense has the greatest habitat breadth of any species of Botrychium on the KNF. This includes even the more common Botrychium species such as the “weedy” B. virginianum. B. minganense occurs in all eight Botrychium PAs that have been described for the KNF. This habitat breadth is quite remarkable. B. minganense occurs in dense mature cedar/hemlock forests, open roadsides, subalpine forests, and on alpine summits. The largest populations of B. minganense on the KNF occur in cedar/hemlock forests. In addition, two alpine meadow sites have large populations of over 100 plants.

Botrychium minganense was removed from the Montana State Plant Species of Concern List and the Forest Service Region One Sensitive Plant List for Montana during the course of completing this Conservation Strategy (MTNHP 2000, USFS 1999). B. minganense was found to be more abundant than previously thought, partially through the survey work completed during the course of this project. B. minganense remains on the Idaho State Plants of Concern List, and the Region One Forest Service Sensitive Plant List for Idaho. B. minganense is now a watch species on the Montana State Plant Species of Concern List (MTNHP 2000).

There has been ongoing controversy as to whether B. minganense may be made up of more than one “cryptic species” (Hauk 1995, Wagner pers. comm.). Botrychium minganense is a highly morphologically diverse species, as it is currently regarded. Farrar’s (1998) isozyme analysis of numerous samples of B. minganense throughout the western United States has not detected enough isozyme variability among samples to designate more than one species from the B. minganense he has sampled. Isozymes are
but one means of determining genetic relationships among and between species that looks at genetic byproducts and not the genome itself. It is possible that different genetic analysis techniques will find that additional species are presently being lumped together as *B. minganense*.

*Botrychium minganense* often occurs growing with other species of *Botrychium* in genus communities as most species of *Botrychium* do. Forty-six percent of the total *B. minganense* occurrences on the KNF are also locations for other sensitive species of *Botrychium*. Fifty percent of the *B. ascendens* occurrences and 80% of the *B. pedunculosum* occurrences on the KNF are at *B. minganense* locations. *B. pedunculosum* and *B. ascendens* are the least common sensitive *Botrychium* species on the KNF.

The subtle morphological differences that distinguish species of *Botrychium* often cause species to be misidentified. *B. crenulatum*, *B. ascendens*, and *B. pedunculosum* can at times resemble the highly morphologically variable *B. minganense*. All three species have been confused with *B. minganense* on the KNF at different times. Threats to *B. minganense* include timber harvest, road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, changes in hydrological regime, fire line construction, trail construction, and encroachment of woody plant species on roadsides and meadows.

*Botrychium minganense* does not warrant the conservation concern that many less common plant species in Montana deserve, due to the number of populations (nine of
which on the KNF consist of greater than 100 plants), and its great habitat breadth. Still, the somewhat muddled taxonomic picture, difficulties in distinguishing *Botrychium* species, and *B. minganense*’s potential to indicate habitat for other rare species of *Botrychium* argue for some consideration for *B. minganense*. I concur with the move of *B. minganense* to the State Plant Watch List. *B. minganense* should be retained as a Category 4 species (Species of Forest Concern) on the KNF. It should be tracked, but not all populations should be managed for. Not all populations are required to maintain the species’ viability. *B. minganense* should still be tracked in case additional species are described from it in the future, and to aid in the location of other sensitive species of *Botrychium*. *B. minganense* is still an uncommon plant with 112 occurrences in Montana.

5.1.5 *Botrychium montanum* W. H. Wagner

There are 51 known sites of *Botrychium montanum* in Montana (MTNHP 1999, KNF Database), 39 of which are on the KNF (Table 5.1). Seven of the *B. montanum* sites on the KNF consist of five or fewer plants. These very small populations may be susceptible to extirpation from stochastic events alone (Berlin et al. 1998). Thus, there are thirty-two potentially viable populations of *B. montanum* on the KNF. All *B. montanum* occurrences on the KNF are closely associated with mature cedar/hemlock forests and surface water. *B. montanum* occurs most often along streams or near seepage areas on the KNF. *B. montanum* has not been documented in any open sunny areas on the KNF. *Botrychium montanum* has been documented in four of the *Botrychium* plant associations described on the KNF. *B. montanum* occurrences in the Shrub Wetland PA are in areas
with cedar/hemlock forest adjacent to the sites. *B. montanum* plants tend to be more abundant in the surrounding cedar/hemlock forest than in the Shrub Wetland PA at these sites. These Shrub Wetland sites may be successional to cedar/hemlock forest. Thus, *B. montanum* has one of the most limited habitat requirements of any sensitive species of *Botrychium* on the KNF.

Threats to *B. montanum* include timber harvest, road construction and maintenance, fire line construction, trail construction, and changes in hydrological regime. It is recommended that the state rank of S3 and Forest Service Region One Sensitive Status for *Botrychium montanum* be maintained. The great habitat specificity of *B. montanum* makes the species more vulnerable to extirpation. Plant species with great habitat specificity are more susceptible to extirpation than species with broad habitat preferences (Primack 1993, Given 1994). Foresters also prize the cedar/hemlock forest habitats favored by *B. montanum* as timber harvest areas. These cedar/hemlock forests have the highest basal area of any *Botrychium* plant associations sampled on the KNF. The habitat specificity and potential for detrimental disturbances to these habitats provide strong support for maintaining *B. montanum*’s sensitive status, even with relatively strong population numbers.

### 5.1.6 *Botrychium paradoxum* W. H. Wagner

Seven of the 19 occurrences of *B. paradoxum* in Montana (MTNHP 1999, KNF Database) are located on the KNF (Table 5.1). The seven locations for *B. paradoxum* on the KNF are probably another species of *Botrychium*, except perhaps at Bluebird Lake
(see discussion pages 45-46). *Botrychium paradoxum* occurs most often in mesic meadows throughout its range (Wagner and Wagner 1993). There is very little good meadow habitat for *Botrychium paradoxum* on the KNF. The abundant precipitation, relatively mild temperatures, and deep fertile volcanic ash covered soils on the KNF favors the development of conifer-dominated forests. There are very few occurrences of natural meadows on the KNF. The best potential habitat for *B. paradoxum* on the KNF are the subalpine/alpine meadows in the Ten Lakes area, and perhaps in the temporary meadow like openings created on the roadsides.

Threats to *B. paradoxum* include road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, fire suppression, fire line construction, trail construction, and encroachment of woody plant species. It is recommended that both the State Status of S2 and Region One Sensitive plant status be maintained *B. paradoxum*, one of the globally least common species of *Botrychium*.

### 5.1.7 Botrychium pedunculosum W. H. Wagner

There are 11 occurrences of *Botrychium pedunculosum* in Montana (MTNHP 1999, KNF Database), 10 of which are on the KNF (Table 5.1). In Montana, *B. pedunculosum* is most commonly found in mature to old growth cedar/hemlock forest. These atypical mature forest habitats for the species produce a morphological variation of *B. pedunculosum*, with the trophophore reduced and skeletonized (the shade form of the species). *B. pedunculosum* has also been found in the Shrub Wetland PA on the KNF at Parsnip Creek. The Shrub Wetland PA is only one of the *Botrychium* PAs present at the
Parsnip Creek site. *B. pedunculosum* also occurs in *Thuja plicata* PAs at Parsnip Creek. In 1998, *B. pedunculosum* was first documented in a Roadside PA on the KNF. *B. pedunculosum* has subsequently been documented at two more Roadside PAs on the KNF. The *B. pedunculosum* plants found on the roadsides vary morphologically from those found in the cedar/hemlock forests by having greater expansion of their trophophores, more typical of the species’ morphology throughout its range. The roadsides of the KNF mimic the natural grass forb meadows where *B. pedunculosum* is most commonly found.

Threats to *B. pedunculosum* include timber harvest, road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, fire suppression, changes in hydrological regime, fire line construction, misidentification as a more common species of *Botrychium*, trail construction, and encroachment of woody plant species at roadside and meadow occurrences. It is recommended that Montana State Status of S1 and Forest Service Region One Sensitive Status be maintained for this very rare species of *Botrychium*.

5.2 Other *Botrychium* Species

5.2.1 *Botrychium hesperium* (Maxon & R. T. Clausen) W. H. Wagner & Lellinger

There are nine occurrences of *B. hesperium* in Montana (MTNHP 2000). *B. hesperium* was documented for the first time in 1999 on an old road and beneath a powerline corridor at Davis Creek, on the Fortine RD, KNF. *B. hesperium* has been found in mesic bunch grass dominated meadows and on old roads and roadsides in Montana (pers. obs.).
Threats to *B. hesperium* include: road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, fire suppression, fire line construction, misidentification as a more common species of *Botrychium*, trail construction, and encroachment of woody plant species. It is recommended that *B. hesperium* be added to the Sensitive Plant list for the KNF. Currently *B. hesperium* is on the Forest Service Region One Sensitive Plant List and tracked by the MTNHP with a state rank of S2. It is recommended that these rankings be retained.

### 5.2.2 *Botrychium pallidum* W. H. Wagner

There are three occurrences of *Botrychium pallidum* in Montana, one of which is on the KNF. A single plant of *B. pallidum* was documented on an old road at Davis Creek on the Fortine Ranger District, KNF, in 1999. *B. pallidum* has been found in mesic bunch grass and forb meadows in Glacier National Park (pers. obs.). Threats to *B. pallidum* include: road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, fire suppression, fire line construction, misidentification as a more common species of *Botrychium*, and encroachment of woody plant species. It is recommended that State Sensitive Status of S1 be retained for this extremely rare species of *Botrychium*. It is also recommended that *B. pallidum* be added to the Region One Sensitive Plant List.

### 5.2.3 *Botrychium simplex* E. Hitchcock

There are eight populations of *Botrychium simplex* on the KNF. The Herbarium at The University of Montana contains only five collections of *B. simplex*, from only four locations in Montana. It is unknown how many occurrences there are throughout
Montana. *B. simplex* is tracked with a State rank of S1 in both Idaho and North Dakota. *Botrychium simplex* occurs in dry fields, marshes, bogs, swamps, and roadside ditches throughout its range (Wagner and Wagner 1993). In California, *B. simplex* occurs only in open grassy areas that are more or less marshy (Wagner and Devine 1989). *B. simplex* has been found on old roads, roadsides, a powerline corridor, and on the edge of a wet meadow, on the KNF (Table 5.2).

### Table 5.2. *Botrychium simplex* locations on the Kootenai National Forest.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DISTRICT</th>
<th>HABITAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Creek</td>
<td>Fortine</td>
<td>Edge of wet meadow</td>
</tr>
<tr>
<td>Dry Fork*</td>
<td>Libby</td>
<td>Old road</td>
</tr>
<tr>
<td>Brush Creek*</td>
<td>Libby</td>
<td>Old road</td>
</tr>
<tr>
<td>Parmenter Creek*</td>
<td>Libby</td>
<td>Trail side</td>
</tr>
<tr>
<td>Noxon Rapids Dam*</td>
<td>Cabinet</td>
<td>Powerline corridor</td>
</tr>
<tr>
<td>Yaak River Road*</td>
<td>Troy</td>
<td>Roadside</td>
</tr>
<tr>
<td>Lap Creek*</td>
<td>Troy</td>
<td>Roadside</td>
</tr>
<tr>
<td>Bull River (3 sites, probably one population)*</td>
<td>Troy</td>
<td>Old Roads</td>
</tr>
</tbody>
</table>

Threats to *B. simplex* include road construction and maintenance, overgrazing, vehicular traffic, herbicide spraying, fire suppression, fire line construction, trail construction, and encroachment of woody plant species. It is recommended that *B. simplex* be added to the KNF Sensitive Plant List as a Category Four Species (Species of Forest Concern). This recommendation is based on the few documented occurrences of the species, and the potential threats to these transient plant communities. It is also recommended that the MTNHP review the abundance of *B. simplex* throughout the state of Montana for possible inclusion on the State Plant Species of Concern List.

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* Indicates that the site was located during this study.
5.3 Management Recommendations

5.3.1 Conservation Criteria

The 124 Botrychium locations (Appendix 8) on the Kootenai National Forest were evaluated based on conservation concern for the sites. Genetic diversity was not used as a criterion for determining conservation priorities due to the lack of genetic variation found in Botrychium populations from the isozyme analysis of Farrar (1998). Sites of greatest conservation concern are 1) any locations where the six least common Botrychium species (B. ascendens, B. hesperium, B. pallidum, B. pedunculosum, B. venulosum in ed., and B michiganense in ed.) occur, 2) locations important in maintaining the geographic distribution of the other sensitive species of Botrychium, and 3) large core populations consisting of 50 or more individuals, which have the greatest potential viability. Management concerns and recommendations are based on the Botrychium plant association (PA) present at the Botrychium locations. Thuja plicata forested sites on the eastern and southern portions of the KNF are peripheral and thus important to the geographic distribution of these sites. Roadsides and Shrub Wetland sites located on the western and southern portion of the KNF are peripheral and thus important to the geographic distribution of these sites. Sixty KNF Botrychium locations were found to meet at least one of the conservation criteria and thus be of significant conservation concern (Table 5.3).
Table 5.3. *Botrychium* Conservation Concern Sites on the Kootenai National Forest.

<table>
<thead>
<tr>
<th>BOTRYCHIUM PLANT ASSOCIATION</th>
<th>RATIONAL FOR CONSERVATION CONCERN</th>
<th>MANAGEMENT AREA</th>
<th>LOCATION</th>
<th>DISTRICT</th>
<th>ELEMENT OCCURRENCE #</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>THUJA Plicata</em></td>
<td>PERIPHERAL</td>
<td>21</td>
<td>BERRY MOUNTAIN CEDARS</td>
<td>CABINET</td>
<td>MON: 17</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>RARE SPECIES</td>
<td>2</td>
<td>BIG CREEK</td>
<td>EUREKA</td>
<td>MIN: 60, PED: 5</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>PERIPHERAL</td>
<td>15</td>
<td>LOWER BOULDER CREEK</td>
<td>EUREKA</td>
<td>MIN: 70</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE AND RARE SPECIES</td>
<td>2</td>
<td>SOUTH FORK BIG CREEK</td>
<td>EUREKA</td>
<td>MIN: 46, MON: 29, PED: 1</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE AND RARE SPECIES</td>
<td>13</td>
<td>SUTTON CREEK</td>
<td>EUREKA</td>
<td>CRE: 3, MIN: 49, MON: 24, PED: 4</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>13</td>
<td>YOUNG CREEK</td>
<td>EUREKA</td>
<td>MIN: 71, MON: 36</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>13</td>
<td>CEDAR CREEK D3</td>
<td>FORTINE</td>
<td>MIN: 86, MON: 46</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>15</td>
<td>EDNA CREEK</td>
<td>FORTINE</td>
<td>MON: 43, PAR: 16</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>21</td>
<td>STERLING CREEK</td>
<td>FORTINE</td>
<td>MIN: 67, MON: 28</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>PERIPHERAL</td>
<td>13</td>
<td>HOODOO CREEK</td>
<td>LIBBY</td>
<td>MIN: 82, MON: 45</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>13</td>
<td>WEST PIPE CREEK</td>
<td>LIBBY</td>
<td>MIN: 26, MON: 13</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE AND RARE SPECIES</td>
<td>13</td>
<td>W. FK. QUARTZ CR.</td>
<td>LIBBY</td>
<td>MIN: 81, MON: 44, PED: 8</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>12</td>
<td>BEETLE CREEK</td>
<td>TROY</td>
<td>MIN: 33, MON: 31</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>13</td>
<td>BUNKER HILL CREEK</td>
<td>TROY</td>
<td>MIN: 17</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>12</td>
<td>CAN CREEK</td>
<td>TROY</td>
<td>MIN: 44, MON: 11, PAR: 9</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>RARE SPECIES</td>
<td>13</td>
<td>KEELER CREEK</td>
<td>TROY</td>
<td>MON: 27, PED: 3</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>12</td>
<td>KELSEY CREEK</td>
<td>TROY</td>
<td>MIN: 25, MON: 12</td>
</tr>
<tr>
<td><em>THUJA Plicata</em></td>
<td>CORE</td>
<td>13</td>
<td>RED TOP CREEK</td>
<td>TROY</td>
<td>MIN: 38, MON: 22</td>
</tr>
<tr>
<td>Thuja Plicata</td>
<td>Description</td>
<td>No.</td>
<td>Location</td>
<td>City, Province</td>
<td>Date</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
<td>-----</td>
<td>----------</td>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td>THUJA PLICATA</td>
<td>Core</td>
<td>11</td>
<td>Roderick Butte</td>
<td>Troy, New</td>
<td>Min: 73, Mon: 18</td>
</tr>
<tr>
<td>THUJA PLICATA</td>
<td>Peripheral</td>
<td>21</td>
<td>Ross Creek Cedar Grove</td>
<td>Troy, New</td>
<td>Min: 10</td>
</tr>
<tr>
<td>THUJA PLICATA</td>
<td>Peripheral</td>
<td>8</td>
<td>Spar Creek Trail</td>
<td>Troy, New</td>
<td>Mon: New 1998</td>
</tr>
<tr>
<td>THUJA PLICATA</td>
<td>Core</td>
<td>12</td>
<td>Upper Can Creek Drainage</td>
<td>Troy, New</td>
<td>Min: 18, Par: 8, Mon: 9</td>
</tr>
<tr>
<td>THUJA PLICATA</td>
<td>Core</td>
<td>13</td>
<td>Zulu Creek</td>
<td>Troy, New</td>
<td>Min: 28, Mon: 15, Par: 10</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Rare Species</td>
<td>11</td>
<td>Noxon Rapids Dam</td>
<td>Cabinet, New</td>
<td>Ped: New 1999</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Rare Species</td>
<td>15</td>
<td>Slick Gulch</td>
<td>Eureka, New</td>
<td>Asc: New/1999, Cre: New/1999</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core and Rare Species</td>
<td>15</td>
<td>Water Trough Draw</td>
<td>Eureka, New</td>
<td>Asc: New/1999, Cre: 12</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Rare Species</td>
<td>14</td>
<td>Grave Creek</td>
<td>Fortine, New</td>
<td>Asc: New/1999, Cre: New/1999</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core and Rare Species</td>
<td>15</td>
<td>Lake Creek</td>
<td>Fortine, New</td>
<td>Asc: 4, Cre: 36, Par: 18, Min: 85</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core</td>
<td>15</td>
<td>Lime Creek</td>
<td>Fortine, New</td>
<td>Cre: 17</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core</td>
<td>13</td>
<td>Lower Basin Creek East</td>
<td>Fortine, New</td>
<td>Cre: New 1998</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core</td>
<td>15</td>
<td>Skillet Creek</td>
<td>Fortine, New</td>
<td>Cre: 32</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core</td>
<td>15</td>
<td>Stewart Creek West</td>
<td>Fortine, New</td>
<td>Cre: 19</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core</td>
<td>13</td>
<td>Twin Meadows Creek</td>
<td>Fortine, New</td>
<td>Cre: 31</td>
</tr>
<tr>
<td>Roadsides</td>
<td>Core</td>
<td>12</td>
<td>Upper Sunday Creek #1</td>
<td>Fortine, New</td>
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</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>------------------------</td>
<td>---------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td>ROADSIDE</td>
<td>RARE SPECIES</td>
<td>WIGWAM RIVER</td>
<td>FORTINE</td>
<td>MIN: 79, MIC: NEW 1998</td>
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<td>TROY</td>
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<td>RARE SPECIES</td>
<td>SPRING CREEK</td>
<td>TROY</td>
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<tr>
<td>ROADSIDE</td>
<td>RARE SPECIES</td>
<td>WEST FORK YAAK RIVER</td>
<td>TROY</td>
<td>MIN: 88, ASC: NEW 1998</td>
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</tr>
<tr>
<td>SHRUB WETLAND</td>
<td>CORE AND RARE SPECIES</td>
<td>PARSNIP CREEK</td>
<td>EUREKA</td>
<td>MIN: 59, MON: 30, PED: 2</td>
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<td>SHRUB WETLAND</td>
<td>CORE</td>
<td>BEAVER CREEK</td>
<td>FORTINE</td>
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<tr>
<td>SHRUB WETLAND</td>
<td>CORE</td>
<td>ALEXANDER MOUNTAIN</td>
<td>LIBBY</td>
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<tr>
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<td>PERIPHERAL</td>
<td>BRUSH CREEK WETLAND</td>
<td>LIBBY</td>
<td>MIN: NEW 1998</td>
<td></td>
</tr>
<tr>
<td>SHRUB WETLAND</td>
<td>PERIPHERAL</td>
<td>CHIEF CREEK</td>
<td>LIBBY</td>
<td>CRE: 9</td>
<td></td>
</tr>
<tr>
<td>SHRUB WETLAND</td>
<td>CORE</td>
<td>DOAK CREEK</td>
<td>LIBBY</td>
<td>CRE: NEW1997, MIN: 53</td>
<td></td>
</tr>
<tr>
<td>SHRUB WETLAND</td>
<td>CORE</td>
<td>JACKSON CREEK</td>
<td>LIBBY</td>
<td>CRE: 23; MON: 40; MIN: 74</td>
<td></td>
</tr>
<tr>
<td>SHRUB WETLAND</td>
<td>PERIPHERAL</td>
<td>WEST FISHER CREEK</td>
<td>LIBBY</td>
<td>CRE: 25; MIN: 34</td>
<td></td>
</tr>
<tr>
<td>SHRUB WETLAND</td>
<td>PERIPHERAL</td>
<td>WILLIAMS CREEK</td>
<td>LIBBY</td>
<td>CRE: 24</td>
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</tr>
<tr>
<td>SUBALPINE MEADOW</td>
<td>CORE</td>
<td>SAINT PAUL PEAK</td>
<td>CABINET</td>
<td>MIN: NEW 1998</td>
<td></td>
</tr>
<tr>
<td>SUBALPINE MEADOW</td>
<td>CORE</td>
<td>BLUEBIRD BASIN</td>
<td>FORTINE</td>
<td>MIN: NEW 1998</td>
<td></td>
</tr>
<tr>
<td>SUBALPINE MEADOW</td>
<td>CORE</td>
<td>BLUEBIRD LAKE</td>
<td>FORTINE</td>
<td>CRE: 15, MIN: 77</td>
<td></td>
</tr>
<tr>
<td>SUBALPINE MEADOW</td>
<td>CORE</td>
<td>GREEN MOUNTAIN</td>
<td>FORTINE</td>
<td>CRE: 16, MIN: NEW 1998</td>
<td></td>
</tr>
</tbody>
</table>
5.3.2 Blanket Management Recommendations Applicable to all *Botrychium*

**Conservation Concern Sites**

**Fire**

All *Botrychium* Conservation Concern sites should be designated and accurately mapped in the Fire Management Action Plans for these areas. These *Botrychium* locations should be avoided during fire line construction and any slash piling from fire line construction or fire line rehabilitation. Fire line construction and rehabilitation has the potential to directly remove *Botrychium* plants. These very mesic sites have low potential to carry a high intensity catastrophic fire. Thus, there is no need to aggressively try to keep fires from these sites.
Trail Construction

All *Botrychium* Conservation Concern sites should be avoided in trail construction or maintenance. Eight of the *Botrychium* Conservation Concern sites (Cedar Creek Libby RD, Spar Creek Trail, West Fork of Quartz Creek, Ross Creek Cedar Grove, Baree Creek, Bluebird Lake, and Bluebird Basin) are located in close proximity to existing recreational trails. These locations should be entered into the trial system database as areas to avoid during trial construction and maintenance. District botanists should survey areas of proposed trial construction and maintenance in mesic cedar/hemlock forest, shrub wetlands, old roads, and mesic subalpine meadows for additional populations of *Botrychium*. There is potential for some old roads to be converted to recreational trails. This conversion should not be allowed in areas where *Botrychium* plants inhabit old roads to avoid trampling the plants with the increased recreational traffic.

Misidentification as a More Common Species of *Botrychium*

Different species of *Botrychium* often occur together in genus communities (Wagner and Wagner 1983). It is recommended that newly discovered *Botrychium* populations’ species determinations be verified by comparison with the numerous *Botrychium* specimens present in the KNF Herbarium, or by sending a sample to an acknowledged expert in the genus to verify species determination. *Botrychium* species are differentiated based on subtle morphological differences. Botanists unfamiliar with the genus should not make species determinations without consultation with the KNF Herbarium and/or taxonomic experts. When the more common species of *Botrychium* are found the area should be thoroughly searched for the often co-occurring but less common species of
It may be necessary to search the area a second time during a more favorable time for additional species of *Botrychium* that were not above ground during the initial survey.

### 5.3.3 Maintenance of *Thuja plicata* and Transitional PA Sites

**Timber Management**

Twenty-six of the *Botrychium* Conservation Concern sites on the KNF are in *Thuja plicata* dominated plant associations (PA) (Table 5.3). This includes two locations that are in the Transitional PA. It is imperative to preserve the dense conifer dominated canopy coverage to maintain the cool moist microclimate conditions favorable for the *Botrychium* species at these sites. Eighteen of the 26 *Thuja plicata* conservation concern sites are in management areas where timber harvest is not allowed and thus these sites do not need any additional management recommendations to limit logging. Only eight of the *Thuja plicata* Conservation Concern Sites (Roderick Butte, Beetle Creek, Kelsey Creek, Upper Can Creek Drainage, Can Creek, French Creek, Lower Boulder Creek, and Edna Creek) are in areas where logging is allowed under the KNF (1987) Forest Plan. Three of these *Botrychium* locations (Beetle Creek, Can Creek, and Lower Boulder Creek) are in old growth *Thuja plicata* forest (Vanderhorst 1997, and pers. obs.). It is recommended that the Management Area for these three sites be changed to MA 13 (Old Growth Unsuitable for Timber) to preserve the forest canopy coverage and maintain suitable *Botrychium* habitat. The other five *Thuja plicata* sites are mature forests with average stand age ranging from 120-140 years. Four of these locations (Roderick Butte, Kelsey Creek, Upper Can Creek Drainage, and Edna Creek) should be excluded from
timber harvest with a recommended designation as Special Interest Areas (SIA) MA 21. A portion of the Kelsey Creek *Botrychium* location is in a designated SIA (Vanderhorst 1997). Protection should be extended to the entire *Botrychium* populations at Kelsey Creek. The total acreage withdrawn from the KNF suitable timber base for these seven *Botrychium* sites is 43 acres.

**Domestic Livestock Grazing**

Forage production is very low and domestic stock usage is minimal in these heavily forested sites. Only a few sites are within existing grazing leases. Thus, no special recommendations are required to avoid adverse impacts of livestock grazing in these PAs.

**5.3.4 Maintenance of Shrub Wetland PA Sites**

**Timber Management**

Ten of the *Botrychium* Conservation Concern Sites on the KNF are in the Shrub Wetland PA (Table 5.3). The Shrub Wetland PA is most common on the eastern portion of the KNF. One of the 10 Shrub Wetland Conservation Concern Sites is located on state owned land, at Beaver Creek (*B. crenulatum* EO # 7). Thus, management recommendations will be directed at only nine of the Shrub Wetland Conservation Concern Sites except for fire recommendations that will include Beaver Creek because it is within the fire protection of the KNF. Two of the Shrub Wetland sites (Chief Creek and Parsnip Creek) are in management areas that are unsuitable for timber harvest.
The Shrub Wetland Conservation Concern Sites are not heavily forested. Tree canopy coverage averaged 16% and basal area averaged only 51 square feet/acre in this PA. The maintenance of these Shrub Wetland PAs does not appear to be dependant on overstory tree canopy. *Botrychium* present in this PA appear to be more dependant on the shade provided by the abundant brush and forb coverages. Any timber harvest in the Shrub Wetland PA should not result in any ground disturbance that may cause soil compaction, changes in site hydrology, or decrease the total coverage of shrub or forb species. The abundant surface water at these locations should preclude any ground disturbing activities to maintain the hydrologic regime favorable for sensitive species of *Botrychium*. Any selective timber harvest that does occurs at *Botrychium* locations in the Shrub Wetland Conservation Concern Sites should be accomplished with helicopter logging to avoid ground disturbance.

**Road Construction and Maintenance**

All Shrub Wetland *Botrychium* Conservation Concern sites should be avoided in any new road construction to avoid adverse modification of the habitat. Most Shrub Wetland Conservation Concern Sites are not in close enough proximity to existing roads to be impacted by road maintenance, with the exception of the Doak Creek site. *Botrychium crenulatum* grows on the roadside and in the ditch at Doak Creek. The site is a roadside but the associated plant species have greater affinity to the Shrub Wetland PA than to the Roadside PA. Any road maintenance of the Doak Creek Spur Road (#4753A) should avoid ground disturbance to the approximately 400 feet of roadside and ditch where the *B. crenulatum* occurs.
Domestic Livestock Grazing

None of the Shrub Wetland Conservation Concern Sites is within existing grazing leases. Any new proposed grazing leases that include these Conservation Concern Sites should evaluate the effects of the proposed leases on these Botrychium locations. The Shrub Wetland Sites have the potential to be over utilized by grazing livestock if not closely regulated because of their abundant surface water, and high shrub and forb coverages.

5.3.5 Maintenance of Roadside PA Sites

This is the most significant PA for Botrychium on the KNF from a conservation perspective, although the 29 Roadside locations represent only 23% of the 124 Botrychium locations on the KNF. This is the PA where some of the least common species of Botrychium are found. All occurrences of B. ascendens, B. pallidum, B. hesperium, 20% of B. pedunculosum occurrences, and 69% of extant B. crenulatum occurrences on the KNF are on roadsides.

There are 19 Roadside Botrychium Conservation Concern Sites on the KNF (Table 5.3). One of these Roadsides is located at Spring Creek on the Troy District on private land. Thus, management recommendations will apply to only the 18 Roadside Conservation Concern Sites that are located on Forest Service land. The species of Botrychium that occur on roadsides are adapted to ephemeral habitats and are dependent on recolonizing new seral habitats as occupied sites become forested and local subpopulations go extinct. This fits the concept of a metapopulation: geographically isolated patches of individuals
interconnected through patterns of gene flow, recolonization, and extinction (Lande and Barrowclough 1987). The short-lived perennial life cycle and long distance spore dispersal characteristic of the subgenus *Botrychium* also suggests these species are adapted to local extinctions, and recolonization of seral habitats. Perhaps vehicles serve as vectors of spore dispersal at roadside *Botrychium* locations. Vehicles passing over or beside *Botrychium* plants as spores are dispersed could perhaps carry the spores on to a new safe germination site. Vehicles do increase localized wind currents near ground level as they pass which could aid spore dispersal for roadside *Botrychium* plants.

The current management emphasis on Forest Service land is to construct virtually no new roads and to increase road obliterations and closures. These policies will reduce the creation of new roadside habitats and may limit facilitation of spore dispersal by vehicles at these sites. The *Botrychium* populations on abandoned roads may be completely isolated genetically from other subpopulations. Thus, roadside *Botrychium* subpopulations adapted to local extinctions as plant succession occurs then migrating to a newly disturbed site, may not have this option available. The maintenance of the existing Roadside *Botrychium* locations is imperative for the persistence of these rare plant populations. It is unknown if a species adapted to colonizing newly disturbed areas can be successfully maintained at the same location.

The Roadside *Botrychium* Conservation Concern sites include three different current road management conditions: 1) road is open to public, 2) road is closed to public use (gated) but open for administrative use, and 3) road is closed to public and administrative use and
thus are roads that are being abandoned (Table 5.4). Some *Botrychium* sites include more than one class of road management. *Botrychium* plants are sometimes located on more than a single road at one location. The variable current management status at these *Botrychium* roadsides requires differing management strategies to maintain the current *Botrychium* habitat. Plant succession must be arrested; the seral plant community must be sustained to maintain suitable *Botrychium* habitat at all roadside locations on the KNF (Wagner pers. comm.).

**Table 5.4. Road management statuses at *Botrychium* Roadside Conservation Concern Sites.**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DISTRICT</th>
<th>ROAD STATUS</th>
<th>ROAD #</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOXON RAPIDS DAM</td>
<td>CABINET</td>
<td>OPEN</td>
<td>?</td>
</tr>
<tr>
<td>SLICK GULCH</td>
<td>EUREKA</td>
<td>CLOSED</td>
<td>7912</td>
</tr>
<tr>
<td>WATER TROUGH DRAW</td>
<td>EUREKA</td>
<td>OPEN</td>
<td>?²</td>
</tr>
<tr>
<td>DAVIS CREEK</td>
<td>FORTINE</td>
<td>OPEN AND CLOSED*</td>
<td>3531, 3531A,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and ?</td>
</tr>
<tr>
<td>GRAVE CREEK</td>
<td>FORTINE</td>
<td>CLOSED</td>
<td>?</td>
</tr>
<tr>
<td>LAKE CREEK</td>
<td>FORTINE</td>
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<td>3550</td>
</tr>
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<td>FORTINE</td>
<td>CLOSED</td>
<td>?</td>
</tr>
<tr>
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<td>FORTINE</td>
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<tr>
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<td>FORTINE</td>
<td>OPEN</td>
<td>3518</td>
</tr>
<tr>
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<td>FORTINE</td>
<td>OPEN</td>
<td>3732</td>
</tr>
<tr>
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<td>FORTINE</td>
<td>OPEN</td>
<td>36</td>
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<tr>
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<td>FORTINE</td>
<td>OPEN</td>
<td>3520</td>
</tr>
<tr>
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<td>FORTINE</td>
<td>OPEN AND CLOSED</td>
<td>315, and ?</td>
</tr>
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<td>FORTINE</td>
<td>OPEN AND CLOSED*</td>
<td>3520, 3520A</td>
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² ? Indicates that road number is not shown on KNF Travel Plan.
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<tr>
<th>WIGWAM RIVER</th>
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<th>7086, 7091</th>
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<tr>
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</tr>
<tr>
<td>BASIN CREEK NORTH</td>
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<td>OPEN</td>
<td>337</td>
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<td>TROY</td>
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</tr>
<tr>
<td>WEST FORK YAAK RIVER</td>
<td>TROY</td>
<td>OPEN</td>
<td>92</td>
</tr>
</tbody>
</table>

**Timber Management**

The Roadside *Botrychium* Conservation Concern Sites have little tree canopy coverage. Tree coverage averaged 7% at the Ecodata plot locations in this PA. These sites have the capacity to support coniferous forests. The surrounding vegetation at these roadside sites is conifer-dominated forest. Conifer seedlings and saplings are present at all *Botrychium* roadside locations. These sites will revert to forest without human intervention to maintain the open character of these sites. The dense shade of coniferous forests will not support the *Botrychium* species that favor the open habitats currently present at these roadside locations. Management emphasis is often to restore old roads that are no longer in use to forested conditions. This management direction will be detrimental to *Botrychium* plants growing on abandoned roads that are to be restored to forest.

**Road Construction and Maintenance**

All Roadside *Botrychium* Conservation Priority Sites should be avoided in any new road construction and road maintenance to avoid adverse modification of the habitat. These locations should be entered into the KNF road system database as areas to avoid during construction and maintenance.

* = Gated road closed to the public but open to management.
DOMESTIC LIVESTOCK GRAZING

Many of the Roadside PA Conservation Priority sites are within existing grazing leases, particularly in the upper Fortine Creek area. The grazed *Botrychium* roadsides in the Upper Fortine Creek area are in good condition with moderate grazing utilization (pers. obs.). Livestock usage removes competing shrubs, forbs, and grasses at these roadsides helping to maintain conditions that are more open and favorable for *Botrychium*.

The one Roadside *Botrychium* location with excessive grazing utilization is the old road at Water Trough Draw, on the Eureka Ranger District. The *Botrychium* plants at the Water Trough Draw site grow mostly on the road surface and are most abundant where the road crosses a small seepage area. The cattle have heavily utilized this seep area for water, overgrazing the roadway, trampling plants, and creating compacted eroded trails from the road down to the seepage area. It is recommended that an off-site water tank be added to reduce the cattle utilization of the seepage area and reduce adverse impacts to the *Botrychium* plants at this site. If the off-site water tank is not sufficient to keep the cattle from overusing the seepage area, it may be necessary to fence the seepage area to avoid adverse impacts from the cattle. Cattle grazing should not be eliminated from the Water Trough Draw site. Grazing should only be reduced to avoid adverse impacts to the *Botrychium* plants.

The Water Trough Draw *Botrychium* roadside is an old road. Although it has a small kelly hump at its terminus the road is still driven. On July 23, 1998 I observed signs someone had driven this road for firewood collection. The firewood had apparently been
sawed up into stove size pieces on the roadbed and large pieces of bark, piles of sawdust, and wood chips remained on the road. I observed some *B. crenulatum* plants that were buried below the pieces of bark. The emergent *B. crenulatum* plants were bent over and chlorotic due to the lack of sunlight penetrating through the bark pieces. Drainage ditches were also installed on this old road in 1999 (Lofts pers. comm.). No attempt was made to avoid *Botrychium* plants when these drainage ditches were installed (Lofts pers. comm.). It is recommended that this approximately ½ mile of spur road be permanently closed with a gate or barrier to keep people from driving on top of *Botrychium* plants or burying them beneath a pile of firewood debris.

Some level of grazing at these open roadside locations helps to reduce the cover of competing plants that could produce shade detrimental to these *Botrychium* plants that prefer more open habitats. *Botrychium* of meadow habitats are adapted to some grazing having coevolved with native ungulates. Two roadside *Botrychium* locations that are not grazed are located at Basin Creek on the Troy Ranger District and Doak Creek on the Libby Ranger District. At these two sites nonnative grass species such as *Poa pratensis*, *Bromus inermis*, *Festuca pratensis*, and *Phleum pratense* form dense stands, often reaching heights of three to five feet. These dense grass stands were observed to overtop the *Botrychium* plants when the grasses had completed flowering. The dense shade provided by the grass overstory at these two nongrazed roadside locations is probably detrimental to *Botrychium crenulatum*. It is recommended that some reduction of the grass overstory would be beneficial to the *B. crenulatum* at these two locations. Muller (1993) observed that populations of *B. matricariifolium* declined in hay meadows where
the harvest of hay had been stopped in the Bitcherland in France. Whereas, B. *matricariifolium* populations were observed to be stable in the hay meadows where hay harvest was continued (Muller 1993). It is recommended that the *Botrychium* roadside locations at Doak Creek and at Basin Creek (Troy District) should have the grass mowed annually to a height of about one foot to reduce the heavy grass canopy coverage at these sites, allowing more light to reach the *Botrychium* plants. The mowing should occur in June before the *Botrychium* plants have reached maturity. A mower with side mounted cutting unit could drive down these roads and cut the grass on the roadside where the *Botrychium* plants occur without running directly over the *Botrychium* plants. The cut grass should be pulled or raked up and deposited off site to avoid having the cut grass bury the *Botrychium* plants or creating a fuel build up.

**Herbicide Spraying**

The effects of herbicide spraying on *Botrychium* species are not known. *B. crenulatum* sprayed with herbicide in July 1999 at Lower Basin Creek on the Fortine District had above ground leaves that were twisted and brown (pers. obs.). It appeared that the aboveground leaf of the year had been killed. *B. pinnatum* that had been sprayed with herbicides was observed at the Wigwam River roadside on August 9, 1998, where it grows with *B. minganense* and *B. michiganense* in ed. The herbicide sprayed *B. pinnatum* had dead brown sporophytes with twisted sporophores. It is unknown if the below ground portion of the sprayed *Botrychium* plants survived the herbicide spraying. One should take the conservative approach that herbicide spraying is detrimental to species of *Botrychium* until there is documented evidence to the contrary.
It is imperative that roadsides scheduled for herbicide application in suitable *Botrychium* habitat are surveyed by a botanist for sensitive *Botrychium* species to avoid adverse impacts to these species. *Botrychium* sometimes occur growing from thick mats of the noxious weed *Hieracium aurantiacum* on roadsides of the KNF. Botanists should become familiar with the roadside habitats favored by species of *Botrychium*. A detailed description of the roadside habitat is available in the Roadside PA description above. Not all roadsides are potential *Botrychium* habitat. All *Botrychium* Roadside locations share the characteristics of close proximity to surface water (usually within 400 feet) and the presence of mesophytic vegetation (Appendix Table 15E). Roadsides in close proximity to surface water and supporting mesophytic vegetation should be intensively searched for *Botrychium* before applying herbicides to the area to avoid adversely affecting sensitive *Botrychium* species.

A map of all known roadside locations of sensitive *Botrychium* species should be given to the herbicide application crews. These areas should not be sprayed with herbicides. If a roadside *Botrychium* location is within a proposed herbicide treatment area, the district botanist should flag the *Botrychium* plants as an area for the herbicide crew not to spray with herbicide.
5.3.6 Maintenance of Subalpine Meadow PA and Upper Subalpine Forest PA Sites

Timber Management and Domestic Livestock Grazing

All five of the Subalpine Meadow PA and Upper Subalpine Forest PA *Botrychium* Conservation Concern Sites are located in existing wilderness areas or in a congressionally designated wilderness study area. Timber harvest and domestic livestock grazing are not allowed in either of these two management areas. Thus, there is no need for management recommendations regarding timber harvest or domestic livestock grazing at these sites.

5.4 Monitoring Recommendations

5.4.1 Monitoring Needs

Many questions remain concerning species of *Botrychium*. Are *Botrychium* plants 99% self fertilized as the isozyme results indicate? Alternatively, are there higher rate of sexual reproduction occurring as indicated by other methods of genetic analysis? The findings of Camacho (1999) of the diverse fungal community dominated by septate fungi present in the roots of sampled of *B. pumicola*, contradicts previous research that showed that aseptate endo-mycorrhizal fungi were the dominant mycorrhizal associates of *Botrychium*. The most important question concerning *Botrychium* in this report is are these populations of *Botrychium* on the Kootenai National Forest viable? The least common species of *Botrychium* occurring on the KNF prefer disturbed seral roadsides. These sites are human manufactured habitats of which few new sites will be created due to the changing management direction on US Forest Service lands. Can short-lived perennial *Botrychium* species adapted to local extinctions and colonizing new sites be
maintained at the sites where they presently occur? Will plant succession at these sites create conditions unfavorable for Botrychium?

The only method to determine if these relatively large populations of Botrychium will persist over time is a strong monitoring program. The monitoring of rare plant populations is essential to provide a scientific basis for management decisions concerning these populations (Davy and Jefferies 1981). Monitoring provides a characterization of rare plant population structure and function, which is required to competently manage these populations (Davy and Jefferies 1981, Owen and Rosentreter 1992).

One set of Botrychium monitoring plots is already established at French Creek, in a timber harvest area. I recommend that these plots continue to be monitored to determine the effects of canopy removal in a Thuja plicata dominated PA on species of Botrychium. It is recommended that a second Thuja plicata site also be monitored to increase the sample size of Botrychium populations in Thuja plicata PAs. The second location will also provide a control, an area of no treatment, to compare with the timber harvest occurring at French Creek. It is recommended that the Thuja plicata dominated PA site at West Fork of Quartz Creek be monitored. This site has the largest population of B. pedunculosum in the state. It is also an old growth forest site and may allow us to answer the following question. Do species of Botrychium adapted to colonizing new sites persist for long periods in these relatively stable environments?
A minimum of two Shrub Wetland PA sites and two Subalpine Meadow PA sites should be monitored to determine if these Shrub Wetlands and Subalpine Meadows support long-lived plant communities. Do species of *Botrychium* persist for long periods in these habitats? Jackson Creek and Alexander Mountain have the largest *B. crenulatum* populations of all Shrub Wetland sites on the KNF. These would be good choices for the two Shrub Wetland monitoring locations. Bluebird Basin and Saint Paul Peak would be excellent choices for monitoring *Botrychium* in the Subalpine Meadow PA. These two sites both have large *B. minganense* populations, they are spatially separated by approximately 65 air miles, and the Saint Paul Peak location is in an area that may be impacted by the proposed Rock Creek copper and silver mine.

The greatest *Botrychium* monitoring priority is the Roadside PA sites. These are the sites where the least common species of *Botrychium* occur. The persistence of these habitats and these populations is unknown. The Roadsides are the *Botrychium* locations of greatest conservation concern, and should be intensively monitored. In addition, these habitats are not regarded as rare plant habitat by most botanists. They tend to be overlooked and their importance minimized. These are areas of ongoing human disturbances. These sites are regularly sprayed with herbicides and routinely bladed with a cat tractor as part of routine road maintenance.

It is recommended that a stratified sample of Roadside *Botrychium* sites be sampled with permanent monitoring plots to understand the persistence of these populations and habitats. Stratification should be based on road management (open, closed, and
abandoned, Table 5.4), habitat type, and include the least common species of *Botrychium* (*B. ascendens*, *B. hesperium*, *B. pallidum*, and *B. pedunculosum*). Effects of management at these roadside locations should also be monitored. The *B. crenulatum* at Basin Creek (Fortine District) sprayed with herbicide in 1999 should be monitored to determine the effects of herbicide spraying on *Botrychium*. The recommended mowing of overstory grasses at Basin Creek (Troy District), and Doak Creek should be monitored at one of these sites to determine effects of grass mowing at Roadside *Botrychium* locations. The proposed recommendations to limit cattle over usage at the Water Trough Draw Roadside should be monitored to determine success.

### 5.4.2 Monitoring Techniques Recommendations

*Botrychium* population monitoring should utilize a modified belt transect method (Lesica 1987). Modifications should include selective location of plots to obtain an adequate sample of *Botrychium* plants but not too large so that individuals cannot be distinguished in the meter-by-meter plots. Large clumps of plants should be avoided when locating plots. Lesica (1987) recommends a density of 0.2 to 10 individuals/plot. The very small population size of all *Botrychium ascendens* occurrences on the KNF may necessitate permanently tagging all plants at these monitoring locations and not using plots. The two largest populations of *B. ascendens* occur at Davis Creek (33 plants) and at Lake Creek (20 plants). Monitoring all individuals in these small populations will be required to obtain an adequate sample of plants from which to determine population trends. Each monitoring plot should have its corners permanently marked with 8-inch duff nails. Nails can then be relocated each year using a metal detector. Permanently marked plot corners
will greatly improve the accuracy of plot relocation from year to year. Each *Botrychium* plant should be marked on the ground with a metal tag attached to a wire placed in the ground next to each plant, in addition to mapping the location of each plant. This will greatly improve the accuracy of tracking individuals from year to year, and obtaining a better understanding of population demographics. Johnson-Groh (1998) has found no adverse effects comparing plots with tagged plants and plots without tagged plants.

Permanent plots should include ocular estimates of coverage values for all plant species present. This will allow a quantification of the plant succession occurring at these sites, and provide insights into *Botrychium* populations’ response to plant succession. Permanent photographic points should also be established to provide a visual record of plant succession occurring at these monitoring sites.

Plots located in *Thuja plicata* forest and Shrub Wetland sites should be read twice during the growing season to obtain an accurate population census given *Botrychium’s* propensity for continuous initiation throughout the growing season. These very mesic sites have conditions favorable for *Botrychium* initiation throughout the growing season. In contrast, the Roadsides and Subalpine Meadow sites are somewhat dryer and one can probably obtain an accurate census reading these plots once at the height of the growing season each year. It is recommended that plots be read annually to determine population trends and plant succession rates.
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Appendix 1 *Botrychium ascendens* populations by size class on the KNF, 1999.
Appendix 2 *Botrychium crenulatum* populations by size class on the KNF, 1999.

B. crenulatum
Populations by Size Class
- 0 plants
- 1-5 plants
- 6-10 plants
- 11-25 plants
- 26-50 plants
- 51-99 plants
- 100+ plants
+ Cities

Major Highways
KNF Districts
Major Streams
MT Counties
Appendix 3 *Botrychium minganense* populations by size class on the KNF, 1999.
Appendix 4 *Botrychium montanum* populations by size class on the KNF, 1999.
Appendix 5 *Botrychium paradoxum* populations by size class on the KNF, 1999.
Appendix 6 *Botrychium pedunculosum* populations by size class on the KNF, 1999.

'B. pedunculosum' Populations by Size Class
- 0 plants
- 1-5 plants
- 6-10 plants
- 11-25 plants
- 100+ plants

+ Cities

▲ Major Highways

KNF Districts

▲ Major Streams

MT Counties
Appendix 7 Key to Botrychium Plant Associations on the Kootenai National Forest.

Note: This key is for use only where Botrychium species are present on the Kootenai National Forest.

1. *Thuja plicata* with at least 20% coverage. Lead 2 *TSUGA HETEROPHYLLA - THUJA PLICATA FOREST ALLIANCE.*

1. *Thuja plicata* with less than 20% coverage. Lead 4

2. *Circaea alpina, Carex disperma,* and *Cinna latifolia* present and tree coverage < 40%. *THUJA PLICATA/CIRCAEA ALPINA/CAREX DISPERMA - CINNA LATIFOLIA (TRANSITIONAL) PA*

2. Not as above. Lead 3

3. *Athyrium filix-femina, Gymnocarpium dryopteris, Oplopanax horridum* and *Tiarella trifoliata* each with ≥ 5% coverage.

*THUJA PLICATA/OPLOPANAX HORRIDUM/GYMNOCARPIUM DRYOPTERIS/TIARELLA TRIFOLIATA (THUJA PLICATA WITH UNDERSTORY) PA*

3. Not as above

*THUJA PLICATA DEPAUPERATE PA*

4. *Fragaria virginiana, Trifolium repens* with ≥ 5% coverage, and both *Plantago major* and *Prunella vulgaris* present. Located on old roads or roadsides.
TRIFOLIUM REPENS - PLANTAGO MAJOR - PRUNELLA VULGARIS (ROADSIDE)

PA

4. Not as above. Lead 5

5. At least three of the following species: *Cornus stolonifera*, *Symphoricarpos albus*, *Alnus incana*, *Acer glabrum*, *Alnus sinuata*, and *Rhamnus alnifolia* in combination with \( \geq 20\% \) coverage.

*CORNUS STOLONIFERA - SYMPHORICARPOS ALBUS - RHAMNUS ALNIFOLIA* (SHRUB WETLAND) PA

5. Not as above. Lead 6

6. Areas with \(< 10\% \) tree coverage and *Ranunculus eschscholtzii*. 

*Potentilla diversifolia*, *Phleum alpinum*, *Poa alpina*, all present.

*RANUNCULUS ESCHSCHOLTZII - POTENTILLA DIVERSIFOLIA/PHLEUM ALPINUM - POA ALPINA* (SUBALPINE MEADOW) PA

6. Not as above. Lead 7 *ABIES LASIOCARPA* FOREST ALLIANCE

7. *Luzula hitchcockii* with \( \geq 5\% \) coverage, and both *Angelica dawsonii*, and *Parnassia fimbriata* present.

*ABIES LASIOCARPA/LUZULA HITCHCOCKII/ANGELICA DAWSONII – PARNASSIA FIMBRIATA* (UPPER SUBALPINE FOREST) PA
7. Not as above, both *Senecio pseudaureus* and *Ribes lacustre* present.

**PICEA SPP./RIBES LACUSTRE/SENECIO PSEUDAUREUS**  
(LOWER SUBALPINE FOREST) PA

Appendix 8 All Sensitive *Botrychium* locations on the KNF 1999.
APPENDICES TABLES: SUMMARIZING THE BIOLOGICAL AND ENVIRONMENTAL ATTRIBUTES MEASURED AT SAMPLE PLOTS

9. **THUJA P LICATA/OPLOPANAX HORRIDUM/GYMNOCARPrium**

**DRO YOPTERIS/TIARELLA TRIFOLIATA PLANT ASSOCIATION**

(CEDAR WITH UNDERSTORY PA)

9A. ENVIRONMENTAL SITE CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
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<tbody>
<tr>
<td>SLOPE (percent)</td>
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<td>40</td>
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<tr>
<td>ASPECT (degrees)</td>
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</tr>
<tr>
<td>ELEVATION (feet)</td>
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<td>2908</td>
<td>4781</td>
<td>672.09</td>
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<tr>
<td>DUFF DEPTH (inches)</td>
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<td>1.5</td>
<td>12</td>
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<tr>
<td>FUEL DEPTH (feet)</td>
<td>2.35</td>
<td>1</td>
<td>4.2</td>
<td>1.24</td>
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<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>HABITAT TYPE</td>
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<tr>
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9B. VEGETATION PERCENT COVERAGE BY LIFE FORM

<table>
<thead>
<tr>
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<td>TREE</td>
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<td>0.53</td>
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<td>FORB</td>
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<td>40</td>
<td>13.5</td>
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<td>FERN</td>
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<tr>
<td>MOSS LICHER</td>
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9C. OVERSTORY TREE DATA

<table>
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<tbody>
<tr>
<td>LIVE BASAL AREA</td>
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<td>406</td>
<td>640</td>
<td>142.38</td>
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<tr>
<td>(square feet/acre)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIVE DBH (inches)</td>
<td>28.5</td>
<td>14</td>
<td>42</td>
<td>8.57</td>
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<tr>
<td>LIVE HEIGHT (feet)</td>
<td>106</td>
<td>40</td>
<td>135</td>
<td>26.75</td>
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9D. GROUND COVER DATA

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<td>60</td>
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<td>WOOD</td>
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<td>2.95</td>
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<tr>
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<td>1</td>
<td>20</td>
<td>8.17</td>
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<tr>
<td>BASAL VEG</td>
<td>4.7</td>
<td>1</td>
<td>10</td>
<td>3.86</td>
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<tr>
<td>WATER</td>
<td>1.9</td>
<td>0</td>
<td>10</td>
<td>3.07</td>
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9E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

<table>
<thead>
<tr>
<th>PLANT ASSOCIATION</th>
<th>CEDAR WITH UNDERSTORY</th>
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<tbody>
<tr>
<td>Sample size</td>
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<tr>
<td>SPECIES</td>
<td>INDEX VALUE AVG COVER CONSTANCY</td>
</tr>
<tr>
<td>TREES</td>
<td></td>
</tr>
<tr>
<td>Picea spp.</td>
<td>12 6 90</td>
</tr>
<tr>
<td>Thuja plicata</td>
<td>65 57 100</td>
</tr>
<tr>
<td>Tsuga heterophylla</td>
<td>13 9 80</td>
</tr>
<tr>
<td>SHRUBS</td>
<td></td>
</tr>
<tr>
<td>Oplopanax horridum</td>
<td>93 19 100</td>
</tr>
<tr>
<td>Taxus brevifolia</td>
<td>14 1 30</td>
</tr>
<tr>
<td>Vaccinium membranaceum</td>
<td>40 2 50</td>
</tr>
<tr>
<td>FORBS</td>
<td></td>
</tr>
<tr>
<td>Actaea rubra</td>
<td>18 1 80</td>
</tr>
<tr>
<td>Adenocaulon bicolor</td>
<td>10 1 40</td>
</tr>
<tr>
<td>Calypso bulbosa</td>
<td>10 1 10</td>
</tr>
<tr>
<td>Clintonia uniflora</td>
<td>32 3 100</td>
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<tr>
<td>Corallorhiza spp.</td>
<td>10 1 10</td>
</tr>
<tr>
<td>Disporum hookeri</td>
<td>39 3 50</td>
</tr>
<tr>
<td>Galium triflorum</td>
<td>18 2 100</td>
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<td>Goodyera oblongifolia</td>
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</tr>
<tr>
<td>Listera cordata</td>
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</tr>
<tr>
<td>Listera spp.</td>
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<td>Montia cordifolia</td>
<td>10 1 10</td>
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<td>Pyrola uniflora</td>
<td>13 1 30</td>
</tr>
<tr>
<td>Streptopus amplexifolius</td>
<td>26 1 80</td>
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<tr>
<td>Tiarella trofoliata</td>
<td>65 7 100</td>
</tr>
</tbody>
</table>
Trautvetteria caroliniensis | 10 | 1 | 10
Trillium ovatum | 23 | 1 | 90

GRASSES
Bromus spp. | 10 | 1 | 10
Luzula parviflora | 20 | 1 | 20

FERNS
Athyrium filix-femina | 40 | 14 | 100
Botrychium lanceolatum | 13 | 1 | 40
Botrychium minganense | 11 | 1 | 80
Cystopteris fragilis | 14 | 1 | 30
Dryopteris austriaca | 14 | 2 | 20
Dryopteris carthusiana | 10 | 3 | 10
Gymnocarpium dryopteris | 60 | 10 | 100

9F. *BOTRYCHIUM* CONSTANCY IN THE THUPLI WITH UNDERSTORY PA

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>% CONSTANCY</th>
<th>SPECIES</th>
<th>% CONSTANCY</th>
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<tr>
<td>B. ASCENDENS</td>
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<td>B. MULTIFIDUM</td>
<td>0</td>
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<tr>
<td>B. CRENULATUM</td>
<td>0</td>
<td>B. PARADOXUM</td>
<td>0</td>
</tr>
<tr>
<td>B. LANCEOLATUM</td>
<td>40</td>
<td>B. PEDUNCULOSUM</td>
<td>20</td>
</tr>
<tr>
<td>B. LUNARIA</td>
<td>0</td>
<td>B. PINNATUM</td>
<td>10</td>
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<tr>
<td>B. MINGANENSE</td>
<td>80</td>
<td>B. VIRGINIANUM</td>
<td>50</td>
</tr>
<tr>
<td>B. MONTANUM</td>
<td>40</td>
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<td></td>
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10. *THUJA Plicata* DEPAUPERATE PLANT ASSOCIATION
(THUPLI DEPAUPERATE PA)

10A. ENVIRONMENTAL SITE CHARACTERISTICS

<table>
<thead>
<tr>
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<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
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</thead>
<tbody>
<tr>
<td>SLOPE (percent)</td>
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<td>36</td>
<td>9.23</td>
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<tr>
<td>ASPECT (degrees)</td>
<td>91.7</td>
<td>0</td>
<td>300</td>
<td>108.65</td>
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<tr>
<td>ELEVATION (feet)</td>
<td>3798</td>
<td>2560</td>
<td>4737</td>
<td>621.92</td>
</tr>
<tr>
<td>DUFF DEPTH (inches)</td>
<td>6.37</td>
<td>1</td>
<td>30</td>
<td>7.22</td>
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<tr>
<td>FUEL DEPTH (feet)</td>
<td>1.58</td>
<td>0.4</td>
<td>3.5</td>
<td>0.95</td>
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<tr>
<td>FUEL MODEL</td>
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<td></td>
</tr>
<tr>
<td>HABITAT TYPE</td>
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### 10B. VEGETATION PERCENT COVERAGE BY LIFE FORM

<table>
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<tr>
<th>Life Form</th>
<th>Average</th>
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<th>Maximum</th>
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<tr>
<td>Tree</td>
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<td>60</td>
<td>90</td>
<td>10.26</td>
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<td>8</td>
<td>1</td>
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<td>Grass</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0.6</td>
</tr>
<tr>
<td>Forb</td>
<td>13</td>
<td>3</td>
<td>50</td>
<td>12.16</td>
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<tr>
<td>Fern</td>
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<tr>
<td>Moss Lichen</td>
<td>12</td>
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<td>40</td>
<td>12.38</td>
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### 10C. OVERSTORY TREE DATA

<table>
<thead>
<tr>
<th>Data Description</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. Dev.</th>
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</thead>
<tbody>
<tr>
<td>Live Basal Area (square feet/acre)</td>
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<td>140</td>
<td>560</td>
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<td>Live DBH (inches)</td>
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<td>5.46</td>
</tr>
<tr>
<td>Live Height (feet)</td>
<td>91</td>
<td>65</td>
<td>125</td>
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<tr>
<td>Live Age</td>
<td>158</td>
<td>50</td>
<td>350</td>
<td>86.37</td>
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<tr>
<td>Dead Basal Area (square feet/acre)</td>
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<td>100</td>
<td>27.73</td>
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### 10D. GROUND COVER DATA

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<th>Average</th>
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<tr>
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<td>0.41</td>
</tr>
<tr>
<td>Rock</td>
<td>0.65</td>
<td>0</td>
<td>3</td>
<td>0.93</td>
</tr>
<tr>
<td>Litter</td>
<td>73</td>
<td>40</td>
<td>90</td>
<td>14.9</td>
</tr>
<tr>
<td>Wood</td>
<td>10.2</td>
<td>1</td>
<td>30</td>
<td>7.94</td>
</tr>
<tr>
<td>Moss, Lichen</td>
<td>12.6</td>
<td>0</td>
<td>40</td>
<td>12.99</td>
</tr>
<tr>
<td>Basal Veg</td>
<td>3.45</td>
<td>1</td>
<td>10</td>
<td>3.17</td>
</tr>
<tr>
<td>Water</td>
<td>0.6</td>
<td>0</td>
<td>5</td>
<td>1.27</td>
</tr>
</tbody>
</table>

### 10E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

<table>
<thead>
<tr>
<th>Plant Association</th>
<th>Sample Size</th>
<th>Indicator Value</th>
<th>Average Cover</th>
<th>Constancy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CEDAR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abies grandis</td>
<td>20</td>
<td>11</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Pseudotsuga menziesii</td>
<td>14</td>
<td>4</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Thuja plicata</td>
<td>41</td>
<td>64</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Tsuga heterophylla</td>
<td>24</td>
<td>10</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>
### SHRUBS

<table>
<thead>
<tr>
<th>Species</th>
<th>% Constancy</th>
<th>Species</th>
<th>% Constancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimaphila umbellata</td>
<td>34</td>
<td>Linnaea borealis</td>
<td>20</td>
</tr>
<tr>
<td>Pachistima myrsinites</td>
<td>16</td>
<td>Vaccinium myrtillus</td>
<td>11</td>
</tr>
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</table>

### FORBS

<table>
<thead>
<tr>
<th>Species</th>
<th>% Constancy</th>
<th>Species</th>
<th>% Constancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clintonia uniflora</td>
<td>30</td>
<td>Coptis occidentalis</td>
<td>11</td>
</tr>
<tr>
<td>Corallorhiza trifida</td>
<td>10</td>
<td>Goodyera oblongifolia</td>
<td>27</td>
</tr>
<tr>
<td>Osmorhiza chilensis</td>
<td>10</td>
<td>Pyrola secunda</td>
<td>16</td>
</tr>
<tr>
<td>Tiarella trofoliata</td>
<td>16</td>
<td>Trillium ovatum</td>
<td>15</td>
</tr>
</tbody>
</table>

### GRASSES

<table>
<thead>
<tr>
<th>Species</th>
<th>% Constancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botrychium minganense</td>
<td>10</td>
</tr>
<tr>
<td>Botrychium montanum</td>
<td>33</td>
</tr>
<tr>
<td>Botrychium paradoxum</td>
<td>15</td>
</tr>
<tr>
<td>Lycopodium annotium</td>
<td>11</td>
</tr>
</tbody>
</table>

### FERNS

<table>
<thead>
<tr>
<th>Species</th>
<th>% Constancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botrychium minganense</td>
<td>10</td>
</tr>
<tr>
<td>Botrychium montanum</td>
<td>33</td>
</tr>
<tr>
<td>Botrychium paradoxum</td>
<td>15</td>
</tr>
<tr>
<td>Lycopodium annotium</td>
<td>11</td>
</tr>
</tbody>
</table>

### 10F. BOTRYCHIUM CONSTANCY IN THE THUJA PLICATA DEPAUPERATE PLANT ASSOCIATION

<table>
<thead>
<tr>
<th>Species</th>
<th>% Constancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. ASCENDENS</td>
<td>0</td>
</tr>
<tr>
<td>B. CREMULATUM</td>
<td>0</td>
</tr>
<tr>
<td>B. LANCEOLATUM</td>
<td>10</td>
</tr>
<tr>
<td>B. LUNARIA</td>
<td>5</td>
</tr>
<tr>
<td>B. MINGANENSE</td>
<td>75</td>
</tr>
<tr>
<td>B. MONTANUM</td>
<td>85</td>
</tr>
<tr>
<td>B. MULTIFIDUM</td>
<td>0</td>
</tr>
<tr>
<td>B. PARADOXUM</td>
<td>15</td>
</tr>
<tr>
<td>B. PEDUNCULOSUM</td>
<td>15</td>
</tr>
<tr>
<td>B. VIRGINIANUM</td>
<td>55</td>
</tr>
</tbody>
</table>
11. THUJA PLICATA/CIRCAEA ALPINA/CINNA LATIFOLIA - CAREX

DISPERMA PLANT ASSOCIATION (TRANSITIONAL PA)

11A. ENVIRONMENTAL SITE CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE (percent)</td>
<td>7</td>
<td>0</td>
<td>10</td>
<td>5.77</td>
</tr>
<tr>
<td>ASPECT (degrees)</td>
<td>119</td>
<td>68</td>
<td>180</td>
<td>56.58</td>
</tr>
<tr>
<td>ELEVATION (feet)</td>
<td>3590</td>
<td>3137</td>
<td>4100</td>
<td>484.08</td>
</tr>
<tr>
<td>DUFF DEPTH (inches)</td>
<td>1.57</td>
<td>0.5</td>
<td>3</td>
<td>1.29</td>
</tr>
<tr>
<td>FUEL DEPTH (feet)</td>
<td>2.67</td>
<td>2</td>
<td>3</td>
<td>0.58</td>
</tr>
<tr>
<td>FUEL MODEL</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HABITAT TYPE</td>
<td>THPL/ATFI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANDTYPE</td>
<td>352</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

11B. VEGETATION PERCENT COVERAGE BY LIFE FORM

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREE</td>
<td>37</td>
<td>30</td>
<td>40</td>
<td>5.77</td>
</tr>
<tr>
<td>SHRUB</td>
<td>43</td>
<td>40</td>
<td>50</td>
<td>5.77</td>
</tr>
<tr>
<td>GRASS</td>
<td>5</td>
<td>3</td>
<td>10</td>
<td>4.04</td>
</tr>
<tr>
<td>FORB</td>
<td>47</td>
<td>20</td>
<td>70</td>
<td>25.17</td>
</tr>
<tr>
<td>FERN</td>
<td>21</td>
<td>3</td>
<td>40</td>
<td>18.52</td>
</tr>
<tr>
<td>MOSS LICHEN</td>
<td>41</td>
<td>3</td>
<td>60</td>
<td>32.91</td>
</tr>
</tbody>
</table>

11C. OVERSTORY TREE DATA

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIVE BASAL AREA (square feet/acre)</td>
<td>113</td>
<td>80</td>
<td>140</td>
<td>30.55</td>
</tr>
<tr>
<td>LIVE DBH (inches)</td>
<td>10.3</td>
<td>9</td>
<td>12</td>
<td>1.53</td>
</tr>
<tr>
<td>LIVE HEIGHT (feet)</td>
<td>63</td>
<td>50</td>
<td>80</td>
<td>15.28</td>
</tr>
<tr>
<td>LIVE AGE</td>
<td>68</td>
<td>49</td>
<td>80</td>
<td>16.64</td>
</tr>
<tr>
<td>DEAD BASAL AREA (square feet/acre)</td>
<td>1.67</td>
<td>0</td>
<td>5</td>
<td>2.89</td>
</tr>
</tbody>
</table>
## 11D. Ground Cover Data

<table>
<thead>
<tr>
<th>Material</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>0.67</td>
<td>0</td>
<td>1</td>
<td>0.58</td>
</tr>
<tr>
<td>Gravel</td>
<td>0.33</td>
<td>0</td>
<td>1</td>
<td>0.58</td>
</tr>
<tr>
<td>Rock</td>
<td>0.33</td>
<td>0</td>
<td>1</td>
<td>0.58</td>
</tr>
<tr>
<td>Litter</td>
<td>43.3</td>
<td>20</td>
<td>80</td>
<td>32.15</td>
</tr>
<tr>
<td>Wood</td>
<td>4.7</td>
<td>1</td>
<td>10</td>
<td>4.73</td>
</tr>
<tr>
<td>Moss, Lichen</td>
<td>43.3</td>
<td>10</td>
<td>60</td>
<td>28.87</td>
</tr>
<tr>
<td>Basal Veg</td>
<td>5.3</td>
<td>3</td>
<td>10</td>
<td>4.04</td>
</tr>
<tr>
<td>Water</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

## 11E. Plant Species with an Indicator Score of 10 or Greater

<table>
<thead>
<tr>
<th>Plant Association</th>
<th>Transitional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Species</td>
</tr>
<tr>
<td><strong>Trees</strong></td>
<td><em>Pseudotsuga menziesii</em></td>
</tr>
<tr>
<td></td>
<td><em>Thuja plicata</em></td>
</tr>
<tr>
<td><strong>Shrubs</strong></td>
<td><em>Alnus incana</em></td>
</tr>
<tr>
<td></td>
<td><em>Alnus sinuata</em></td>
</tr>
<tr>
<td></td>
<td><em>Linnaea borealis</em></td>
</tr>
<tr>
<td></td>
<td><em>Lonicera ciliosa</em></td>
</tr>
<tr>
<td></td>
<td><em>Pachistima myrsinites</em></td>
</tr>
<tr>
<td></td>
<td><em>Prunus virginiana</em></td>
</tr>
<tr>
<td></td>
<td><em>Rhamnus alnifolia</em></td>
</tr>
<tr>
<td></td>
<td><em>Ribes spp.</em></td>
</tr>
<tr>
<td></td>
<td><em>Rosa woodsii</em></td>
</tr>
<tr>
<td></td>
<td><em>Sambucus spp.</em></td>
</tr>
<tr>
<td></td>
<td><em>Symphoricarpos albus</em></td>
</tr>
<tr>
<td><strong>Forbs</strong></td>
<td><em>Actaea rubra</em></td>
</tr>
<tr>
<td></td>
<td><em>Adenocaulon bicolor</em></td>
</tr>
<tr>
<td></td>
<td><em>Aralia nudicaulis</em></td>
</tr>
<tr>
<td></td>
<td><em>Arnica cordifolia</em></td>
</tr>
<tr>
<td></td>
<td><em>Cerastium spp.</em></td>
</tr>
<tr>
<td></td>
<td><em>Circaea alpina</em></td>
</tr>
<tr>
<td></td>
<td><em>Clintonia uniflora</em></td>
</tr>
<tr>
<td></td>
<td><em>Fragaria vesca</em></td>
</tr>
<tr>
<td></td>
<td><em>Galium trifidum</em></td>
</tr>
<tr>
<td></td>
<td><em>Galium triflorum</em></td>
</tr>
<tr>
<td></td>
<td><em>Habenaria saccata</em></td>
</tr>
<tr>
<td></td>
<td><em>Listera caurina</em></td>
</tr>
<tr>
<td></td>
<td><em>Listera cordata</em></td>
</tr>
<tr>
<td>Species</td>
<td>% Constancy</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>Botrychium ascendens</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Botrychium crenulatum</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Botrychium lanceolatum</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Botrychium lunaria</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>Botrychium minganense</strong></td>
<td>67</td>
</tr>
<tr>
<td><strong>Botrychium montanum</strong></td>
<td>67</td>
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</table>

**11F. BOTRYCHIUM CONSTANCY IN THE THUJA PLICATA/CIRCAEA**

**ALPINA/CINNA LATIFOLIA - CAREX DISPERMA TRANSITIONAL PA**
12. **CORNUS STOLONIFERA - SYMPHORICARPOS ALBUS - RHAMNUS**

**ALNIFOLIA PLANT ASSOCIATION (SHRUB WETLAND PA)**

12A. ENVIRONMENTAL SITE CHARACTERISTICS

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE (percent)</td>
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<td>0</td>
<td>11</td>
<td>4.58</td>
</tr>
<tr>
<td>ASPECT (degrees)</td>
<td>72</td>
<td>0</td>
<td>337</td>
<td>114.83</td>
</tr>
<tr>
<td>ELEVATION (feet)</td>
<td>3611</td>
<td>2639</td>
<td>4400</td>
<td>496.69</td>
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<tr>
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<td>2.3</td>
<td>0</td>
<td>6</td>
<td>2.02</td>
</tr>
<tr>
<td>FUEL DEPTH (feet)</td>
<td>3.2</td>
<td>0.1</td>
<td>5.8</td>
<td>1.67</td>
</tr>
<tr>
<td>FUEL MODEL</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HABITAT TYPE</td>
<td>PICE/COST</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>LANDTYPE</td>
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</table>

12B. VEGETATION PERCENT COVERAGE BY LIFE FORM

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREE</td>
<td>16</td>
<td>0</td>
<td>70</td>
<td>20.61</td>
</tr>
<tr>
<td>SHRUB</td>
<td>63</td>
<td>20</td>
<td>90</td>
<td>27.01</td>
</tr>
<tr>
<td>GRASS</td>
<td>7</td>
<td>1</td>
<td>30</td>
<td>8.92</td>
</tr>
<tr>
<td>FORB</td>
<td>41</td>
<td>10</td>
<td>80</td>
<td>22.75</td>
</tr>
<tr>
<td>FERN</td>
<td>17</td>
<td>0</td>
<td>50</td>
<td>18.37</td>
</tr>
<tr>
<td>MOSS LICHEN</td>
<td>34</td>
<td>1</td>
<td>80</td>
<td>28.95</td>
</tr>
</tbody>
</table>

12C. OVERSTORY TREE DATA

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIVE BASAL AREA</td>
<td>51</td>
<td>0</td>
<td>140</td>
<td>47.76</td>
</tr>
<tr>
<td>(square feet/acre)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIVE DBH (inches)</td>
<td>12.0</td>
<td>0</td>
<td>35</td>
<td>11.15</td>
</tr>
<tr>
<td>LIVE HEIGHT (feet)</td>
<td>60</td>
<td>0</td>
<td>110</td>
<td>40.73</td>
</tr>
<tr>
<td>LIVE AGE</td>
<td>73.42</td>
<td>0</td>
<td>180</td>
<td>56.79</td>
</tr>
<tr>
<td>DEAD BASAL AREA</td>
<td>13.3</td>
<td>0</td>
<td>120</td>
<td>34.53</td>
</tr>
<tr>
<td>(square feet/acre)</td>
<td></td>
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<td></td>
<td></td>
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</table>
### 12D. GROUND COVER DATA

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOIL</td>
<td>1.3</td>
<td>0</td>
<td>10</td>
<td>2.77</td>
</tr>
<tr>
<td>GRAVEL</td>
<td>5.1</td>
<td>0</td>
<td>60</td>
<td>17.3</td>
</tr>
<tr>
<td>ROCK</td>
<td>0.35</td>
<td>0</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>LITTER</td>
<td>43.5</td>
<td>1</td>
<td>90</td>
<td>33.43</td>
</tr>
<tr>
<td>WOOD</td>
<td>4.5</td>
<td>1</td>
<td>20</td>
<td>5.55</td>
</tr>
<tr>
<td>MOSS, LICHEN</td>
<td>34.2</td>
<td>1</td>
<td>80</td>
<td>28.95</td>
</tr>
<tr>
<td>BASAL VEG</td>
<td>4.6</td>
<td>1</td>
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<td>WATER</td>
<td>6.1</td>
<td>0</td>
<td>30</td>
<td>9.54</td>
</tr>
</tbody>
</table>

### 12E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

<table>
<thead>
<tr>
<th>PLANT ASSOCIATION</th>
<th>SHRUB WETLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>12</td>
</tr>
<tr>
<td>SPECIES</td>
<td>INDICATOR VALUE AVG COVER CONSTANCY</td>
</tr>
<tr>
<td>TREES</td>
<td></td>
</tr>
<tr>
<td>Betula papyrifera</td>
<td>15 25 17</td>
</tr>
<tr>
<td>Picea spp.</td>
<td>11 7 83</td>
</tr>
<tr>
<td>Populus trichocarpa</td>
<td>21 8 33</td>
</tr>
<tr>
<td>Pseudotsuga menziesii</td>
<td>12 3 42</td>
</tr>
<tr>
<td>SHRUBS</td>
<td></td>
</tr>
<tr>
<td>Acer glabra</td>
<td>28 10 50</td>
</tr>
<tr>
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<tr>
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<td>Geum macrophyllum</td>
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<td>Habenaria dilatata</td>
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12F. *BOTRYCHIUM CONSTANCY IN THE CORNUS STOLONIFERA - SYMPHORICARPOS ALBUS - RHAMNUS ALNIFOLIA SHRUB WETLAND PLANT ASSOCIATION*
13. *Picea spp./Ribes lacustre/ Senecio pseudaureus* Plant Association (Lower Subalpine Forest PA)

### 13A. ENVIRONMENTAL SITE CHARACTERISTICS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
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<td>4960</td>
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### 13B. VEGETATION PERCENT COVERAGE BY LIFE FORM

<table>
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<th>Minimum</th>
<th>Maximum</th>
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<tr>
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<td>10</td>
<td>50</td>
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<td>60</td>
<td>17.08</td>
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<tr>
<td>FORB</td>
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<td>20</td>
<td>60</td>
<td>17.08</td>
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<td>FERN</td>
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<td>1</td>
<td>20</td>
<td>9.5</td>
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<td>MOSS LICHEN</td>
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<td>1</td>
<td>30</td>
<td>12.53</td>
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### 13C. OVERSTORY TREE DATA

<table>
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</thead>
<tbody>
<tr>
<td>LIVE BASAL AREA (sq feet/acre)</td>
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<td>5.6</td>
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<tr>
<td>LIVE HEIGHT (feet)</td>
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<td>30</td>
<td>83</td>
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<td>LIVE AGE</td>
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<td>96</td>
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<td>DEAD BASAL AREA (sq feet/acre)</td>
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### 13D. GROUND COVER DATA

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<td>GRAVEL</td>
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<td>ROCK</td>
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<td>LITTER</td>
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<td>70</td>
<td>90</td>
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<td>WOOD</td>
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<td>3</td>
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<td>30</td>
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<tr>
<td>BASAL VEG</td>
<td>3</td>
<td>3</td>
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<tr>
<td>WATER</td>
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### 13E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

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<th>PLANT ASSOCIATION</th>
<th>LOWER SUBALPINE FOREST</th>
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<td>Sample size</td>
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<td>SPECIES</td>
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</tr>
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<td>Picea spp.</td>
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<td>Populus tremuloides</td>
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<tr>
<td>Cornus canadensis</td>
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</tr>
<tr>
<td>Ledum glandulosum</td>
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<tr>
<td>Lonicera involucrata</td>
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<tr>
<td>Menziesia ferruginea</td>
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<tr>
<td>Ribes lacustre</td>
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<td>Rubus parviflorus</td>
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<tr>
<td>Salix scouleriana</td>
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<td>Sambucus spp.</td>
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<tr>
<td>Fragaria virginiana</td>
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<td>Galium triflorum</td>
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<td>Gentianella amarella</td>
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<td>Geum macrophyllum</td>
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<td>Habenaria spp.</td>
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<td>Ligusticum canbyi</td>
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### FERNS

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<th>Species</th>
<th>% Constancy</th>
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<td>50</td>
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<tr>
<td>Botrychium virginianum</td>
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<tr>
<td>Equisetum hyemale</td>
<td>22</td>
<td>20</td>
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#### 13F. *BOTRYCHIUM* CONSTANCY IN THE *PICEA SPP./RIBES LACUTRE/SENECIO PSEUDAUREUS* LOWER SUBALPINE FOREST PLANT ASSOCIATION

#### 14. *ABIES LASIOCARPA/LUZULA HITCHCOCKII/ANGELICA DAWSONII* - *PARNASSIA FIMBRIATA* PLANT ASSOCIATION (UPPER SUBALPINE FOREST PA)

#### 14A. ENVIRONMENTAL SITE CHARACTERISTICS

<table>
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<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
<th>STD. DEV.</th>
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<tbody>
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<td>SLOPE (percent)</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>3.54</td>
</tr>
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<td>208</td>
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14B. VEGETATION PERCENT COVERAGE BY LIFE FORM

<table>
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<th>MAXIMUM</th>
<th>STD. DEV.</th>
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<td>10</td>
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<td>1</td>
<td>1</td>
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14C. OVERSTORY TREE DATA

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<th>LIVE HEIGHT (feet)</th>
<th>LIVE AGE</th>
<th>DEAD BASAL AREA</th>
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<tr>
<td></td>
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<td>75</td>
<td>4.95</td>
<td>70</td>
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<td>18</td>
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<td>74</td>
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14D. GROUND COVER DATA

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<th>MAXIMUM</th>
<th>STD. DEV.</th>
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</tr>
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### 14E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

<table>
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<tr>
<th>PLANT ASSOCIATION</th>
<th>UPPER SUBALPINE FOREST</th>
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<tr>
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<tr>
<td>Menziesia ferruginea</td>
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<td>Cerastium vulgatum</td>
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<td>Epilobium alpinum</td>
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<td>Gentiana spp.</td>
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<tr>
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<td>Mitella spp.</td>
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<td>Parnassia fimbriata</td>
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<td>Pedicularis bracteosa</td>
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<tr>
<td>Ranunculus spp.</td>
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<td>Ranunculus uncinatus</td>
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<td>Thalictrum occidentale</td>
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<td>Valeriana sitchensis</td>
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<td>Veronica spp.</td>
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<td>Veratrum viride</td>
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<td>Agrostis thurberiana</td>
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<td>Carex spp.</td>
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<tr>
<td>Deschampsia atropurpurea</td>
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</tbody>
</table>
Elymus glaucus | 13 10 50
Luzula hitchcockii | 90 12 100
Luzula piperi | 43 3 50
FERNS
Botrychium minganense | 17 1 100

**14F. BOTRYCHIUM CONSTANCY IN THE ABIES LASIOCARPA/LUZULA HITCHCOCKII/ANGELICA DAWSONII - PARNASSIA FIMBRIATA**

**UPPER SUBALPINE FOREST PLANT ASSOCIATION**

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>% CONSTANCY</th>
<th>SPECIES</th>
<th>% CONSTANCY</th>
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<td>B. CRENULATUM</td>
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<td>B. PARADOXUM</td>
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<td>B. LANCEOLATUM</td>
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<td>B. PEDUNCULOSUM</td>
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<tr>
<td>B. LUNARIA</td>
<td>0</td>
<td>B. PINNATUM</td>
<td>0</td>
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<tr>
<td>B. MINGANENSE</td>
<td>100</td>
<td>B. VIRGINIANUM</td>
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<td>B. MONTANUM</td>
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**15. TRIFOLIUM REPENS - PLANTAGO MAJOR - PRUNELLA VULGARIS**

**PLANT ASSOCIATION (ROADSIDE PA)**

**15A. ENVIRONMENTAL SITE CHARACTERISTICS**

<table>
<thead>
<tr>
<th>AVERAGE</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE (percent)</td>
<td>7</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>ASPECT (degrees)</td>
<td>168</td>
<td>33</td>
<td>330</td>
</tr>
<tr>
<td>ELEVATION (feet)</td>
<td>4170</td>
<td>3795</td>
<td>5100</td>
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<tr>
<td>DUFF DEPTH (inches)</td>
<td>0.22</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>FUEL DEPTH (feet)</td>
<td>1.88</td>
<td>0.5</td>
<td>11.5</td>
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<tr>
<td>FUEL MODEL</td>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>HABITAT TYPE</td>
<td>ABLA/CLUN</td>
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<td>LANDTYPE</td>
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</table>
### 15B. VEGETATION PERCENT COVERAGE BY LIFE FORM

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<tr>
<th>LIFE FORM</th>
<th>AVERAGE</th>
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<th>MAXIMUM</th>
<th>STD. DEV.</th>
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<tbody>
<tr>
<td>TREE</td>
<td>7</td>
<td>1</td>
<td>40</td>
<td>11.95</td>
</tr>
<tr>
<td>SHRUB</td>
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<td>1</td>
<td>20</td>
<td>6.04</td>
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<td>GRASS</td>
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<td>60</td>
<td>17.0</td>
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<td>FORB</td>
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<td>80</td>
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<td>FERN</td>
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<td>20</td>
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### 15C. OVERSTORY TREE DATA

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<tr>
<td>LIVE BASAL AREA</td>
<td>48</td>
<td>5</td>
<td>160</td>
<td>44.34</td>
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<tr>
<td>(square feet/acre)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>LIVE DBH (inches)</td>
<td>14.2</td>
<td>5</td>
<td>22</td>
<td>5.06</td>
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<tr>
<td>LIVE HEIGHT (feet)</td>
<td>76</td>
<td>30</td>
<td>100</td>
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<tr>
<td>LIVE AGE</td>
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<td>250</td>
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<td>DEAD BASAL AREA</td>
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<td>2.11</td>
</tr>
<tr>
<td>(square feet/acre)</td>
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### 15D. GROUND COVER DATA

<table>
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<th>STD. DEV.</th>
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<td>3</td>
<td>1.03</td>
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<td>LITTER</td>
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<td>90</td>
<td>18.41</td>
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<td>WOOD</td>
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<td>10</td>
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<td>10</td>
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### 15E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

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<tr>
<td>Populus angustifolia</td>
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<td>SHRUBS</td>
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<tr>
<td>--------------------------------------------</td>
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<tr>
<td><em>Arctostaphylos uva-ursi</em></td>
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<td><em>Berberis repens</em></td>
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<td><em>Juniperus communis</em></td>
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<tr>
<td><em>Potentilla fruticosa</em></td>
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<tr>
<td><em>Ribes viscosissimum</em></td>
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<td><em>Rosa woodsii</em></td>
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<td><em>Spiraea betulifolia</em></td>
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<td><em>Vaccinium caespitosum</em></td>
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<table>
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<td>Height</td>
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</tr>
<tr>
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<td>----------</td>
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15F. *Botrychium* constancy in the *Trifolium repens* - *Plantago major* - *Prunella vulgaris* roadside plant association

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<th>% CONSTANCY</th>
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16. *Ranunculus eschscholtzii* - *Potentilla diversifolia* - *Phleum alpinum* - *Poa alpina* plant association (Subalpine Meadow Pa)

16A. Environmental site characteristics

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<tr>
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<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>STD. DEV.</th>
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<td>2</td>
<td>7</td>
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<tr>
<td>ASPECT (degrees)</td>
<td>94</td>
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<td>ELEVATION (feet)</td>
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<td>FUEL DEPTH (feet)</td>
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16B. Vegetation percent coverage by life form

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### 16D. GROUND COVER DATA

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### 16E. PLANT SPECIES WITH AN INDICATOR SCORE OF 10 OR GREATER

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16F. *BOTRYCHIUM* CONSTANCY IN THE *RANUNCULUS ESCHSCHOLTZII* - *POTENTILLA DIVERSIFOLIA* - *PHLEUM ALPINUM* - *POA ALPINUM*

SUBALPINE MEADOW PA

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<th>% CONSTANCY</th>
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