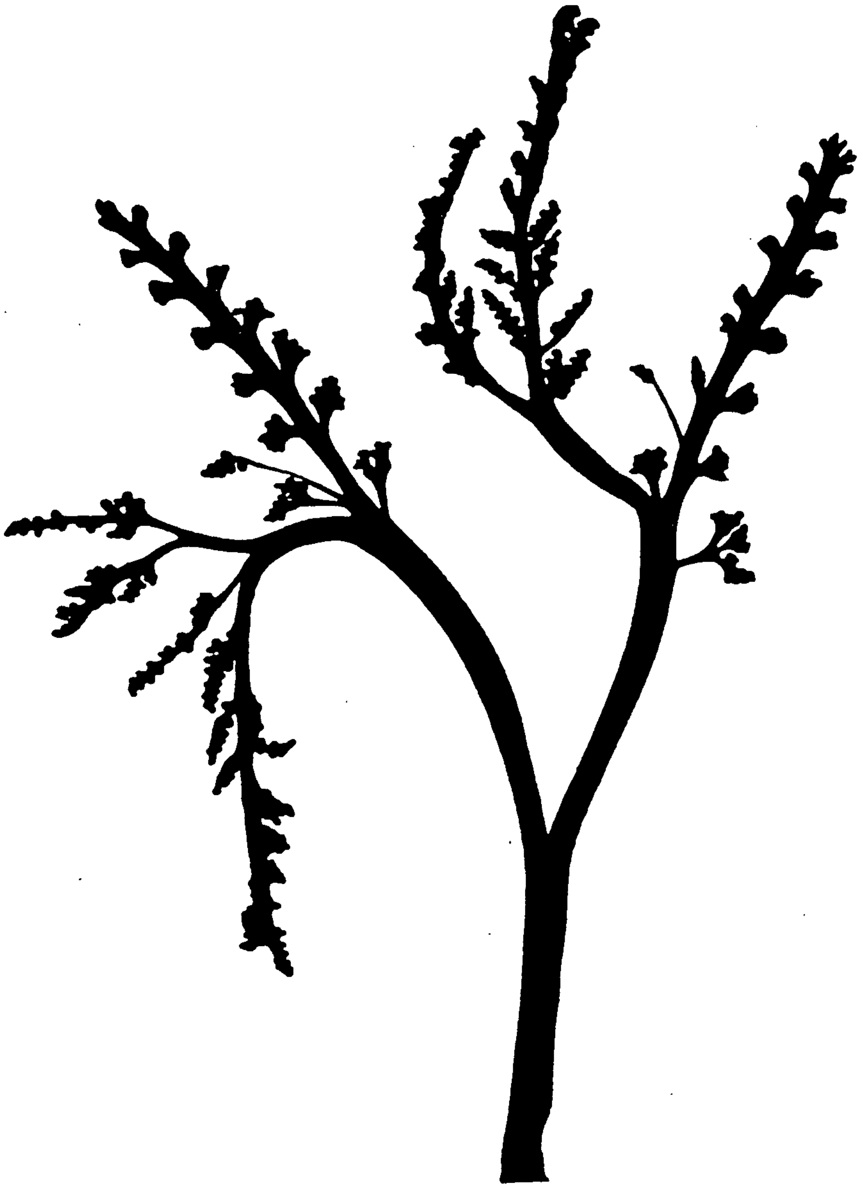
Grapeferns and Moonworts (*Botrychium*, Ophioglossaceae) in the Columbia Basin.



A report submitted to the Eastside Ecosystem Managment Project, US Forest Service, Walla Walla, Washington.

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Introduction

This report summarizes what is known about the range, habitat and ecology of a group of small pteridophytes known as grapeferns and moonworts, (family Ophioglossaceae; genus *Botrychium*). All recognized species that occur within the study area of. the Eastside Ecosystem Management Project (EEMP) were evaluated.

The goal of the EEMP is to produce an environmental impact statement for the study area. Biological and ecological data provided here should assist Forest Service efforts to develop long-term plans and 'models.

The study area (Figure 1) is defined as the Columbia River Basin south of Canada, east of the crest of the Cascade Mountains. It includes small portions of the Great Basin in southern Oregon and northeastern Nevada, and of the Klamath River Basin in southern Oregon. The EEMP area includes lands in seven states: Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming. Figure 2 shows the boundaries of the 102 counties that have lands within the project area. Some of the peripheral counties are only partially contained within the EEMP area. The color base map (1:2,000,000) produced by HEMP GIS staff should be consulted for more precise boundaries of the project.

Biogeography

In this section we present the species present in the study area, and discuss their taxonomy.

Species covered.

Seventeen species 'of *Botrychium* occur within the study area. Their common names, latin names, and nomenclatural authorities are given in Table 1. The occurrence of these taxa was determined after a review of major regional herbaria (see acknowledgements and Table 2) and the taxonomic literature (see bibliography). Technical taxonomic and nomenclatural questions were considered by regional floristicians such as Ken Chambers and expert pteridologists including W. Herb Wagner, Ed Alverson, Florence Wagner, and David Wagner. Many herbarium names and names long familiar in the literature have been' modernized in Table 1. A detailed synonymy (Table 3) was prepared to facilitate interpretation of all names in regional treatments such as Rydberg (1917), St. John (1937), Abrams (1940), Davis (1952), Peck (1961), Holmgren & Reveal (1966), Ireland (1968), Hitchcock et al. (1969), Hitchcock and Cronquist (1973), Cronquist et al. (1972), Shetler & Skog (1978), Mason (1980), Welsh et al. (1987), Bingham (1987), Lackschewitz (1991), Dom (1984, 1992), Hickman (1993), and Kartesz (1994a,b).

A complete list of all North American *Botrychium* is given in Table 4, based on Wagner &

Wagner (1993, 1994).

Some species reported *sensu lato* in older manuals are now more narrowly defined, and are not now considered to be part of the Columbia Basin flora. These and other excluded species are in Table 5.

Additional species are presumed to exist in the Columbia Basin. It is expected that further inventory will discover some disjuncts not in Table 1. Given the history of the group, undescribed species are also likely to be presented in the scientific literature in upcoming years (pers. comm. from E. Alverson, W. H. Wagner, F. Wagner, D.' Wagner). Undescribed species were not considered in this report, for there was no sensible way to gather unpublished biological and ecological data, and the taxa have no formal scientific or conservation status yet.

Taxonomic literature

The genus *Botrychium* encompasses ca. 55 species world-wide (Wagner and Wagner 1993). The species are known as grapefems (subgenus *Sceptridium*), rattlesnake ferns (subgenus *Osmundopteris*), and moonworts (subgenus *Botrychium*). *Botrychium* is in the adder's-tongue family (Ophioglossaceae). There are five genera in the family, which together cover the globe. The genera are *Botrychium, Cheiroglossa* (1 sp.), *Helminthostachys* (1 sp.), *Ophioglossum* (25-30 spp.) and *Rhizoglossum* (1 sp.).

We are fortunate that the first taxonomic volume of the Flora of North America project (Morin 1993) treats almost all of the ferns in this report. This treatment provides a broad picture of the distribution of *Botrychium* across North America and Greenland. For each species, the Flora of North America provides taxonomic descriptions, distribution maps, chromosome levels, notes on hybridization as well as data on nomenclatural history and ecology (Wagner and Wagner; in Morin 1993). The identification keys provide an important summary of the taxonomic complexes.

There were errors on two range maps in the Flora of North America that the authors discussed with W. Herb Wagner. One fern endemic to Oregon, *Botrychium pumicola*, was mistakenly mapped in Greenland. A second mapping mistake placed *Botrychium lanceolatum* ssp. *angustisegmentum* on the crest of the Rocky Mountains in western North America. Herb Wagner (pers. comm.) stated that this map was an editing error, and that the taxon does not occur west of Minnesota. Aside from those two problems, the maps and data in Wagner and Wagner (1993) were accurate and comprehensive up to the date of publication. In 1994 Wagner and Wagner published a description of a new species of *Botrychium* from the study area (*B. lineare*).

All published summaries of *Botrychium* have been rapidly outdated. The classification of *Botrychium* ferns has undergone a revolution over the last two decades, with the description of a number of new taxa endemic to North America (e.g., Wagner and Wagner 1981, 1983c, 1986, 1990a, 1990b, 1994; Farrar and Johnson-Groh 1991).

David Wagner (1991, 1992) wrote a guide for the Forest Service to the identification of the moonworts which. covered 14 of the 17 taxa discussed in this report. The reader is referred to his keys and illustrations, and those in. Wagner and Wagner (1993). For the uninitiated, the easiest way to study the species is to visit populations in the field, where one can carefully compare leaf outlines with silhouette photocopies; The graphics in the numerous publications by Wagner and Wagner (see bibliography) are essential for accurate identification. The problem complexes are presented in Table 6. Naming moonworts is subtle, as in butterflies, requiring largesamples and considerable care, especially in the case of *Botrychium crenulatum*.

There are 17 published species from the study area (Table 1), including one endemic (*B. pumicola*). Four more species (Table 7) have a type locality in the Columbia Basin, (*B. ascendens, B. lineare, B. paradoxum, B. pedunculosum*). -One (or more) undescribed species may be named soon from Oregon material (E. Alverson pers. comm; D. Wagner, 1992, pers. comm.). This report is concerned only with described taxa. The papers describing each species are cited in Table 7.

Taxonomic problems. The following list illustrates why *Botrychium* species are difficult to find and identify (Cody and Britton 1989, Wagner & Wagner 1990b):

1) Herbarium materials, the traditional route for study and comparison, are frequently misidentified, poorly prepared and lack an adequate sample size
2) Each population has numerous young or depauperate forms with underdeveloped fronds, fertile but nonetheless not easily named
3) Even "large" mature plants are small and simple, thus there are few characters available for defining and recognizingthespecies
4) They tend to grow in mixed species colonies, like orchids, as reported by Wagner & Wagner (1983a), confusing field workers and leading to mixed collections on herbarium sheets
5) Most of the species are disjunct and rare in isolated islands of habitat
6) Variations in leaf shapes of each taxon are still imperfectly understood, within and between populations, between sunny and shady microsites, and between years (Graham and Wagner 1991)
7) Most species are dwarfs, and difficult to find and study
8) Transplanting is usually fatal (Cody and Britton 1989)
9) Technology for growing sporophytes from spores is in its infancy (Whittier 1991)
10) Small morphological differences can be perpetuated in populations by the self-fertilizing nature of the gametophytes (McCauley et al 1985, Soltis & Soltis 1986, Watano & Sahashi

1992).

11) Occasional odd growth forms present more than the usual trouble in identification (e.g., see Graham & Wagner 1991; W. H. Wagner 1991; Wagner & Wagner 1988; Wagner et al. 1984, 1985; *Botrychium minganense* on cover)

12) Some species' are in human disturbed areas like roadsides,,ditches, pastures, railroad sidings, and fallow fields, where most botanists do not seek ferns

13) Some species are 'cryptic and resemble developing shoots of common forbs

14) Some plants are erratic and do not appear above ground each year

At present pteridologists agree that the taxa covered here are distinct (Alverson 1993). Most recent treatments (Lellinger 1985, Morin 1993, Hickman 1993, Kartesz 1994a, 1994b) accept all the species, supporting the prodigious work of Warren and Florence Wagner. Arthur Cronquist (deceased) disagreed with the'taxonomic concepts of the Wagners. Cronquist (pers. comm.) had little field experience with the rare western taxa, and apparently based his taxonomic judgements on shared characters (Gleason & Cronquist 1991, Cronquist et al. 1972, Hitchcock & Cronquist 1973). He lumped a number of *Botrychium* species.. This was in sharp contrast to the research 'and descriptions of the Wagners of Michigan, who emphasized differences rather than similarities in closely related taxa. In general the writer has found the concepts of Herb and Florence Wagner sustainable after study in the field with living plants (Zika 1994b).

A summary of taxonomic problems in *Botrychium* is given in Table 6. The test of time will be needed to see how- many of these taxa will persist as full species, and if some will be relegated to synonymy or varietal status by lumpers. -At present,, the taxonomic pendulum has swung towards the fern splitters.

Hybrids

Hybrid *Botrychium* are apparently rare in nature (Wagner and Wagner 1988, 1993), but there are records of nearly a dozen sterile hybrid combinations in the'literature (F. Wagner 1993; W. Wagner 1980, 1991, Wagneret al. 1984, 1985). A hybrid (*B. ascendens X crenulatum*) was collected at the type locality for *B. ascendens* in Wallowa Co., OR (Wagner and Wagner 1986). A cross (*B. pedunculosum X pinnatum*) was produced at the type locality of *Botrychium pedunculosum*, Wallowa Co., OR (Wagner and Wagner 1986). Speciation in *Botrychium* via poly-pldidy of hybrids was suggested by Meyer (1981), but refuted by F. Wagner (1993), since hybrids are so rare and because available morphological and chromosome evidence does not support allopolyploids of interspecific hybrids (nothospecies).

Range, maps

Distribution data for all *Botrychium*, based on herbarium specimens, was mapped at the county level in Figure 3. Our methodology for producing maps was the same as in Brainerd et al. (1995) and is reiterated here.

We recorded county and state locality data from labels of collections housed at more than 30 herbaria (see acknowledgements) to assemble distribution data for all *Botrychium* in the study area. All distribution data was ultimately computerized and mapped (Figure 3). The distribution maps show herbarium specimens with a dot (solid circle). Open (hollow) circles on the maps indicate literature reports for the counties where we did not find a herbarium voucher.

The USFS EEMP personnel in Walla Walla were provided with our database on a disk.

Data collection

We visited large regional herbaria to gather distributional data, including ID, MONTU, ORE, OSC, RM, WILLU, WS, and WTU (see Table 2 for acronym translation). Smaller herbaria such as MRC, SOSC and Crater Lake National Park were also inventoried. Some museums, such as CLNP, BOIS and RM provided us with additional digital geographic data. Specimens on loan from other herbaria were also viewed during our visits.

In addition, distribution data were collected from literature sources including regional floras, state natural heritage programs, plant checklists of national parks and national forests, monographs, taxonomic literature, and species lists (see bibliography). Many local species lists were received from agency botanists and were mapped as literature reports.

At herbaria we recorded state and county locality data from herbarium specimen labels. More specific locality data was not consistently available on the labels. When a county was not specified on the label, we attempted to determine the county from using any other locational information provided. For cases in which only a portion of a county is within the EEMP boundary (e.g., Deer Lodge Co., MT) we attempted to ascertain if the specimen was collected within the study area. If not, or if exact location could not be determined, locality data for the specimen was not recorded.

Herbarium identifications were not comprehensively verified, and species identifications were accepted as labelled and annotated. While most records could be accurately accepted at face value, obvious misidentifications were rejected. Some specimens were examined more closely and annotated when appropriate. However, it was not possible to verify all specimens.

The distributional data were databased and each observation of each species-county combination was coded for its source: herbarium specimen or literature citation. Herbarium specimens cited in the taxonomic literature (i.e., Wagner & Wagner articles) were coded as herbarium records. All other literature records were coded as such.

Mapping

County dot maps were generated from the county distribution dataset. The maps are presented for each species in Figure 3. Herbarium records were mapped as a filled circle (dot) and literature records as an open circle (the letter "0"). Herbarium records were given priority over literature records: if a county had both herbarium and literature records for a species, only the herbarium record (filled circle) was mapped. Inexpensive, albeit awkward, commercial techniques for this now exist (e.g., Angelo 1994).

We discussed the use of hand-drawn mylar maps with Lisa Croft (USFS) and agreed that distribution data in dbase format would be a superior alternative. All our distribution data was provided on disk to the USFS.

The maps in Figure 3 present a substantial data summary, but with some limitations.

Caveats.

1) We were not able to resolve the distribution data any finer than on a county level. County data were available in much of the literature. County data are the most precise on many herbarium labels, especially the older records. In many cases, county data are the only location data available. More detailed placement (e.g., UTM, lat.. long., TRS) was not practicable given the constraints of funds and time for the EEMP project. The study area is divided into 102 counties (Figure 2) on the range maps. County dot maps are an approximation of the true distribution of the species, especially in 'large counties with widely varying habitats. For example, a large county like Hamey County, Oregon has *Botrychium* habitat in less than five per cent of the surface area.

2) We did not have the time or funds to visit all of the regional herbaria, much less the major holdings in eastern or Canadian herbaria. (A few loans from these museums were seen.) It would have been particularly instructive to catalogue the holdings of agencies and those at MICH, where the world's leading *Botrychium* experts,. W, H. and F. Wagner, have centralized vast collections (and many loans). Not all recent-sighting reports of rare taxa were entered in Heritage Program databases. As a result, some county occurrences may have been missed.

3) A few records from complex groups were difficult to map, due to poorly documented populations. Examples were single immature and/or poorly pressed fronds of difficult complexes like *Botrychium lunaria, B. crenulatum, B. ascendens* and *B. minganense.*

4) The majority of the Oregon collection records were annotated or collected by the first author of this report, in collaboration with E. Alverson and D. Wagner. Thus the distributions and discussions of Oregon ferns are the strongest in this report.

6) It was not possible to field check disjuncts and rare taxa, nor to collect in poorly explored counties. The Forest Service will have to use their staff to continue this research. It is likely that most mountain ranges have extant but undocumented *Botrychium* taxa (Wagner and Wagner 1993).

7) Literature reports could not be verified due to limited time and funds.

8) Only a few disjunct herbatium collections from outside of Oregon were validated, by Herb Wagner, David Wagner (Washington specimens), Ed Alverson, or Peter Zika. The status of other apparent disjuncts may be correct as mapped.

9) Recent annotations on herbarium collections were accepted without question, especially the corrections or affirmations of W. H. Wagner, F. Wagner, D. Wagner, and E. Alverson.

10) Where resources and convenience allowed, several dubious records were re-examined and, if misidentified, excluded from the species list in Table 1. (See "excluded species" in Table 5.)

The distribution of *Botrychium* in general is correlated with the distribution of mountain ranges in the study area. *Botrychium* is primarily a boreal and montane genus, preferring mesic or wet sites. Relatively few records are found in the arid lowlands of the study area (e.g., see St. John 1937, who did not fmd any *Botrychium* in southeastern Washington and only *B. multifidum* in adjacent Idaho). This moisture and elevation preference by the genus is shown graphically in Figure 4, which totals the-number of *Botrychium* species found in each county.

Biodiversity

We looked at biodiversity in several ways. Our main approach was to map species richness, the number of different species in each county (Figure 4). We also examined the number of rare species in each county (Figure 5). Finally, we addressed endemism in the region (Table 8). Compiling all of this data, we assembled a summary (Table 9) of the lands we considered the most important centers of diversity for the genus *Botrychium* in the study area.

Species richness

We took all the range maps in Figure 3 and created a computer overlay.,,. The result was a map (Figure 4) showing how many different taxa were found in each county of the study area. The counties with the greatest species richness, were shaded the darkest. The 10 most species rich counties were automatically placed in Table 10, which displays the centers of diversity.

Rare species

At present all but one of the *Botrychium* species are considered rare in some part of the Columbia Basin (Table 11). Only *Botrychium multifidum* is considered common throughout the study area, in appropriate habitats. Table 11 summarizes the status of all rare *Botrychium*, based on the publications and computerized data available from the heritage programs.

Endemism

Endemism can be defined very broadly, to include taxa found only in North America. Or it can be defined quite narrowly, for plants restricted to a few square miles in one state (*Botrychium gallicomontanum*, Minnesota; *B. soccoroensis* Mexico). The discussion below shows how endemism in the broad sense suggests that *Botrychium* endemics are concentrated in Mexico, northwestern North America mountain ranges, and in the Great Lakes area (Tables 4,8). Exceedingly narrow endemics are uncommon in *Botrychium* presumable due to the ease of long distance spore dispersal.

There is only one member of the genus endemic to the EEMP area. This is *Botrychium pumicola*. It is found on the crest and east side of the southern Cascades of Oregon. ‘Populations are known on the Deschutes NF, the Winema NF, the Fremont NF, Prineville BLM, Crater Lake National Park, and in Newberry Crater National Monument. Populations are extant on each of these federal administrative land holdings. The Oregon Natural Heritage Program database has 112 records for the species (as of this writing, the 112 records were last updated in August 1994, and included sighting reports through 1993). Only one population was on private land. Clearly federal land management completely controls the fate of this narrow endemic, which is restricted to three counties.

A larger view of the distribution patterns in the genus (Table 4) reveals that 23 of the 32 North American *Botrychium* taxa are endemic to North America (Wagner & Wagner 1993, 1994). Of these, 14 of the taxa are endemic to western North America (Table 8), with a distribution restricted between the Great Lakes and the Pacific Ocean. Five species are endemic to the western cordillera of North America (Table 8). Three species are restricted to the Great Lakes. W. Herb Wagner (pers. comm.) pointed out that 7 of the 8 Mexican *Botrychium* taxa are endemic to Mexico, and none of the Mexican species are found in the United States. W. Wagner also noted that only 4 *Botrychium* have been recorded in Central America south of Mexico (*B. jenmanii, B. virginianum, B. underwoodianum, B. decompositum*), and only one of these is endemic.

From the 23 endemics in North America, 11 are found in the study area (Table 4, *B. ascendens, B. campestre, B. crenulatum, B. hesperium, B. lineare, B. minganense, B. montanum, B. paradoxum, B. pedunculosum, B. pinnatum,* and *B. spathulatum*).

Of the 14 *Botrychium* endemic to western North America, 9 are found in the study area (Table 8, *B. ascendens, B. campestre, B. crenulatum, B. hesperium, B. montanum, B. paradoxum, B. pedunculosum, B. pinnatum, B. pumicola*).

Speciation has apparently taken place on either side of the continental divide. The Rockies have created strong environmental gradients to the east and west, resulting in radically different vegetation:. These general floristic patterns and their consequences are discussed in Barbour and Christensen (1993). It has left east/west pairs of closely related species (e.g., *Botrychium mormo/montanum*). A more common pattern is the speciation of a close. species pair at the periphery of.the range of a widespread species (e.g., *B. lanceolatum* vars., *B. simplex/pumicola, B. lunaria/crenulatum, B. pinnatum/boreale*). All of these pairs have at least one representative within the EEMP, although not restricted to it.

Five *Botrychium* are endemic to the western cordillem per se, and four of these are found in the study area (*B. crenulatum, B. montanum, B. pinnatum, B. pumicola*). Other clear northwestern endemics spread away from the main mountain ranges in southwestern Canada (e.g., *B. paradoxum, B. pedunculosum*). The only place where all of these endemics overlap is in Oregon.

This suggests the mountain ranges in Oregon have been critical in the post-glacial migration of the genus, and perhaps have been a refugia or speciation center, despite the recent upheaval of 'vegetation zones in the wake of the-last retreat of glacial ice, and the subsequent hypsithermal period (Habeck 1988).

The widespread nature of *Botrychium* habitat, in mountain ranges, and the rarity of the genus as a whole, strongly implies that any regional planning should consider the contributions and importance of land outside the EEMP area when modeling for climate change. Present day diversity centers for *Botrychium* within the EEMP area, such as Wallowa County, Oregon (Figures 4,5,6), may be important as cool climate refugia in the face of a warming climate (Houghton et al. 1990; Grabherr et al. 1994).

Whether "endemic" is defined narrowly (sensu Ratti et al. 1991) or broadly, it is clear that

Federal lands within the EEMP area, especially Forest Service lands, are critical habitats for members of the genus *Botrychium*. The Forest Service is the largest owner of cool climate, high elevation lands in the region, areas that will likely be important refugia for members of this mostly montane group of plants should the climate continue to warm. *Botrychium* habitats within the EEMP area will be important not only for the taxa currently documented to exist there, but also for those that occur in neighboring regions to the south.

Centers of diversity

We analyzed our distribution data for centers of diversity several ways.

1) Species richness of each county was tallied (Figure 4), using the data in Figure 3. Wallowa County, Oregon is the single most important *Botrychium* region in the EEMP, in terms of species richness.

2) Counties with the highest species richness in each state (Figure 3) were examined more closely, for public or Indian land holdings (the larger the better). These are noted in Table 9. In general it was not possible to identify key private land ownerships.

3) Records of rare, threatened and endangered *Botrychium* species, tracked by natural heritage programs, were examined for mention of public ownership. These are mentioned in Table 9 if they were found to have a number of rare *Botrychium* records. (Note: this analysis was not done for Washington; that heritage program did not provide access to ownership information. Nevada and Utah did not have any databased rare *Botrychium* records in the study area.) It was not possible to identify key private land ownerships. All 5 federal candidates (C2) were all included in public lands identified this way in Table 9. The remaining Federal candidate (Cl, *B. pumicola*) of Table 11 was missed by concentrating on species rich counties.

   Wallowa County, OR, has five federal candidate (C2) *Botrychium*. Ferry and Stevens Cos., WA, each have four federal candidate (C2) *Botrychium* (Figure 6).

4) The only endemic, *Botrychium pumicola*, is or several National Forests, a National Monument and a National Park in Oregon, out in an area (the southern Cascade Mts.) that does not support a high diversity of *Botrychium*. Because it is a Cl federal candidate and the only EEMP endemic, it was added to the summary of critical federal lands (Table 9).

5) All species in Table 11, considered rare (and tracked) in one or more EEMP states, were checked for overlapping ranges. Their combined ranges from Figure 3 were mapped in Figure 5. Wide-ranging species of *Botrychium* are tracked only when they are locally rare. In some cases these species are common in adjacent states in the EEMP. So Figure 5 does **not** show concentrations of range **limits. It shows concentrations**

of species that become rare in some part of the EEMP. Thesi species are clustered in the Cascade Mountains of Washington and Oregon;- desert mountains in Hamey Co., OR; the Ochoco and Blue Mountains of Oregon; northeastern Washington, northern and north 'central Idaho; and the Rockies in northwestern Montana, and the Rockies -along the Idaho-Wyoming border.

Arguments to preserve genetic diversity across the entire range of 'a species are' applicable here. -In the face of climate change predictions (Houghton'et al. 1990; Grabherr et al. 1994) it would be wise to avoid eliminating diversity. What research has been'done on plant physiology shows varied adaptations and tolerances to the stresses of climate change even within one population (Crawford et al. 1993, Crawford and Abbott 1994).

Major species

We placed all the *Botrychium* into species groups;' as requested by the Forest Service. Our groups were defined by shared habitat preferences. A list of 3 'habitats is given in Table 12, along with the species in each habitat group. The habitat groups are defined below, and pertinent ecological data is summarized for them in panel forms in Table 13.

Criteria for individual treatment

All Federal Candid&es (C 1 or C2) in Table 11 were given individual treatment. Panel forms for these species, in Table 14, provide ecological and management data summaries.

Species groupings by habitat

We chose to group the *Botrychium* taxa by habitat. Three general habitat types were sufficient to cover all the species in our area These are explained below.

Criteria and definitions.

The habitat groupings used here were deliberately broad and general. Habitats were based on moisture regime and shade. Habitats chosen were meadow, marsh and forest.

Assignment of each- species to a habitat category was based on extensive literature review (see bibliography) and the personal experience of the authors. Some *Botrychium* are found in more than one habitat grouping.

Meadow All *Botrychium* characteristically found in sunny open sites, mesic to xeric, were included here. The-species included are listed in Table 12. Sighting reports from natural heritage programs, forest service personnel, contractors, and the experience of the authors suggests that there is little to unify the ecology of *Botrychium* meadows besides the presence of *Botrychium*. The amount of associated herbaceous vegetation, and the composition of the associates varies tremendously, within and between mountain ranges. One species, *Botrychium multifidum*, goes from sea level to alpine meadows. The openings include subalpine thickets and the edges of montane meadows,as well as trailsides and roadsides.

Ecologically these meadows can be considered early successional. 'Their long-term' creation or maintenance (over the course of centuries) is by widely spaced events such as changing precipitation patterns, rockslides, landslides, thin soils over till, thick pumice deposits, and perhaps earthquakes. Short term (over the course of decades) maintenance is from a variety of natural disturbances, such as forest pests and diseases, wildfire, windthrows, catastrophic flooding, snow avalanches, debris fans, alluvial fans, ice-scouring, frost pockets, seasonal drought cycles, and population cycles of native herbivores. Human disturbances niimic some natural disturbances, and provide ephemeral habits for a number of meadow species. -Recent research on *Ophioglossum* (McMaster 1994) and *Botrychium* (Muller 1991, 1992, 1993). supports contentions by previous authors that many members of the family Ophioglossaceae are ephemeral and must colonize' newly available habitats to stay ahead of successional changes. Many of these species have small leaf surfaces, apparently a convergent evolutionary trend useful in dry environments.

Marsh Those *Botrychium* found primarily in moist ground, with little or no shade, were included here. A list of the species is in Table 12. Ecologically this habitat type is similar to the meadow type defined above, but saturated soil is less seasonal in this habitat. These are essentially hydric openings, with open marshy edges, thickets, or even open canopy light forest such as that found at the edge of a peatland. The sunniness of these systems is generally created or maintained by the high water table and natural disturbances. In addition to the natural disturbances listed under meadows, we can add beaver dams; with their subsequent flooding, abandonment, siltation, and gradual transformation into wet meadows. or marshes. Human disturbances tend to degrade rather than create marsh habitats. Our largest and leafiest species (*B. multifidum* and especially *B. virginianum*) are found most commonly in this habitat, where water stress is minimal. In-the eastern deciduous forest, where summer rainfall is much more plentiful, *Botrychium virginianum* and *B. multifidum* are frequently encountered in mesic woods or meadows and are not so commonly associated with high water tables.

Forest There are *Botrychium* found in a number of different shaded habitats, which are grouped together here. In Idaho and Oregon old growth *Thuja plicata* provides a deeply shaded environment where the ferns grow in alluvium in the virtual absence of other vascular plants, as though they were mushrooms. In Washington and Oregon some of the same species can be found under pole-sized trees of many species on a variety of moisture regimes. The major unifying feature simply seems to be shade, which does exclude a number of the meadow species. The species in this group are provided in Table 12.

In Table 13 are "panel" forms for the three habitat groups, which include more information on:

- Key ecological functions
- Key environmental correlates
- Habitat processes
- Ecological role
- Sensitivity to disturbance
- Population trends.
- Dispersal modes and requirements
- Research needs
- Assumptions
- Trends of the habitats

Supplementary data on all these subjects is also presented in the panel forms for federal candidate species, in the literature review, and in the sections on Analysis Issues and Research Needs.

Cover types

We do not have and were unable to find data that would allow us to determine the presence or absence of individual species or species groups in the wide variety of forest and range cover types used by the EEMP. (For example, most of the sites for *Botrychium lineare* have ecological data no more detailed than "along a woodland trail" 'Wagner and Wagner 1994.) This is an area that requires more research. Habitat processes and requirements for the species groups are discussed in the panel forms.

We did assign the major species and the species groups to forest and rangeland structural stages where possible (see Tables' 15, 16).

Major species and the species groups were also assigned to appropriate sections of Bailey's ecoregion map (see Table 17,18).

Geographic distribution; of course, is covered in the maps of Figure 3.

. Criteria for bioindicators

Several *Botrychium* have value in indicating the presence or absence of a wetland plant community in jurisdictional wetlands. These are provided in Table 19, and are based on Reed (1988). The writers note in passing that this list could use revision to bring it up to date with recently published species and nomenclature in *Botrychium.*

Wagner and Wagner (1983a) introduced the idea of a genus community, which is of. taxonomic value in comparing closely related species growing side by side. The concept arose from repeated observations of aggregates of mixed species. Large populations and large numbers of *Botrychium* taxa may indicate a particularly vigorous fungal flora. The same may be true of large populations and/or species mixes. of orchids (Zika 1993).

There is no substitute for a thorough inventory to determine the true biodiversity of an area. Botanists often use the presence of a rare plant to indicate an area worthy of conservation. But an aggregate of locally rare species (almost always from more than 1 genus) are a better indicator of significant and intact disjunct or relictual plant communities. *Botrychium* is one of the few genera we know of where it is "common" to find large mixes of locally rare species in a single site.

We propose that any site with five or more *Botrychium* taxa indicates unusual diversity. All such sites should be considered highly significant and worthy of special management and conservation by federal agencies. We note that fewer than five *Botrychium* species have been documented in 75 % (76/102) of the counties in the EEMP (Figure 3).

Encountering a rich diversity of *Botrychium* along a transect may indicate a change in bedrock. Calcareous basins in the Wallowa Mountains and in Montana apparently are among the richest sites for, *Botrychium* diversity. This includes the Lostine River and Hurricane Creek limestone basins in Wallowa Co., OR (N. Wagner 1958; Zika 1992a, 1994b), which harbor far more *Botrychium* species than adjacent -igneous or volcanic canyons. Nothing has been published on this that we are aware of. However, in other parts of the country calcareous soils are well correlated with floral diversity (e.g., comparisons of southwestern Vermont and southcentral Vermont, at similar elevations but with soils derived from igneous vs. sedimentary limy rock; J. C. Jenkins pers. comm.). We note that *Botrychium lineare, B. pedunculosum* and *B. ascendens* are entirely restricted to limestone basins in the Wallowa Mountains.

Land use history has an important influence on biodiversity. For example, asphalt paving, overgrazing, strip mines, clearcuts followed by broadcast bums, and nuclear explosions are all documented to decrease biodiversity over the short term. Land use history may overwhelm the influence of soil fertility, and thus large clusters of *Botrychium* may not infallibly indicate calcareous substrates. Similarly, robust fungal colonies may be present without any *Botrychium*, as any dedicated field mycologist will attest.

There are numerous observations of *Botrychium* in early successional habitats (Wagner & Wagner 1993). In some cases large populations were found in human disturbed sites such as roadsides and livestock pastures (Vanderhorst 1993). We advise against using these data to indicate that *Botrychium paradoxum* and other taxa have an obligatory relationship with cattle, horses or roads. The obvious argument is that the species have not been monitored long enough to demonstrate if the populations thrive, endure or decline given human disturbances. Equally obvious is the millennia that the species have existed in the absence of human disturbances.

We are reluctant to propose other indicator status to *Botrychium* at this time, as we are lacking data.

Structural stages

We prepared a summary of the major species (Cl and C2 candidates) and the species groups by structural stages (Tables 15,16). We found that our wetland group (marsh species) did not fit the existing framework of rangeland and -forest structural stages. There clearly is a need for more research in this area of vegetation classification and modeling.

Bailey's Ecoregions

Table 17 presents the major species and the habitat groups in a matrix with the Bailey's Ecoregions. This was prepared by looking at the county distribution maps for each species, and comparing them with the FS base map. Our table noted intersections of counties and ecoregions.

Key environmental correlates

This part of the contract is covered by the entries in the "panel" forms for major species; and for the habitat groupings. See Tables 13,14.

Ecological key functions

This part of the contract is covered by entries in the "panel" forms (Table 13,14). Refer also to the discussion of ecological literature and life cycle. It is presumed that *Botrychium* do not have a direct role in forest litter decomposition, but that their fungal associates do.

Special Habitats

Calcareous meadows are rare in the study area. Those present in the Wallowa Mountains of Oregon are the richest *Botrychium* sites in the EEMP. They should be protected from commercial grazing and heavy recreation use because of their high diversity and because they support a number of other locally rare species (e.g., *Listera borealis, Platanthera obtusata, Carex concinna, C. norvegica, C. dioica*; Zika & Alverson 1992, Zika 1993). Recent work in peatlands in Idaho and Montana have shown a number of rare species in calcareous fens, but those workers did not find unusual *Botrychium* in their surveys (Lesica 1992, Moseley et al. 1994).

Botrychium crenulatum is known from calcareous wetlands in the Wallowa Mountains. This is a habitat that is perhaps even rarer than calcareous montane meadows in the EEMP (it is much rare in Oregon). *B. crenulatum* is a C2 federal candidate, and its habitats in calcareous sites are in need of protection from firewood cutting, recreational use, and commercial grazing and trampling by professional "packers" using the backcountry wilderness areas in the Wallowa-Whitman National Forest.

The calcareous habitats do not appear extraordinary to the non-botanist;. Perhaps this is one reason that they have received so little special management attention devoted to their botanical resources:

In the past some of these sites have been heavily grazed by sheep, although the extent of the degradation is not well documented.

Suggested conservation measures

Plant conservation is based on protection of populations. What is a population? The minute size of a fern propagule (the spore) changes the population definition. Populations of *Botrychium* are fundamentally different from those of the average wildflower, since even widely separated individuals can be connected genetically by wind dispersal of spores. Classic studies (e.g., Ingold 1971) have shown that all propagules, regardless of size, are mostly found near the parent in a leptokurtic distribution. But long distance dispersal is much more frequent with ferns than it is with wildflowers. Plants like *Botrychium lunaria* and *Dryopteris filix-mas* (Zika 1994a) are circumpolar colonists, with widely disjunct populations on islands and scattered across the northern continents. Yet even closely spaced gametophytes may never cross-fertilize. Definition of a population is difficult, but is probably most accurately defined with a long-term view: by a watershed rather. than by the size of a meadow or woodland. Patches of ferns in different meadows or forested zones within a drainage or sub-drainage are probably very closely related and part of one population. This of course can be tested with any number of modem techniques in the lab (e.g., McMaster 1994). Chloroplast DNA testing, enzyme comparison with electrophoresis, or even old-fashioned chromatography might resolve population boundaries. A practical interim approach is to use watershed lines in defining functional populations, and managing to protect the maximum amount of habitat available within the watershed. This should be applied to the major species (Cl, C2) of *Botrychium* in this report. This should insure the continued viability'of the highest priority and rarest species over the coming centuries.- For' other, more widespread species with vast continental or multi-continental distributions, such an approach is not warranted (i.e., *Botrychium lanceolatum, B. lunaria, B. minganense, B. multifidum, B. pinnatum, B. simplex,* and *B. virginianum*). For such abundant and well-. dispersed species, protection of the largest and most vigorous sites on each National Forest should be pursued, in the traditional manner, rather than attempting to manipulate entire watersheds for 'their sake.

Two species are especially rare and endangered in the basin, *Botrychium pedunculosum* and *B. lineare*. The latter is known from fewer than 100 plants across the continent, despite its range from Quebec to California (Wagner & Wagner 1994). The former is found in disturbed early successional sites in Canada more frequently than in the US (W. H. Wagner pers. comm.). Both should be considered for federal listing. Conserving them in the US should consider:

> Immediate C2 status for *Botrychium lineare*.
>
> A key *B. lineare* population in the Columbia Basin is the Lapover Ranch in the Lostine River canyon, which is a tiny private inholding in the Wallowa-Whitman National Forest, Eagle Cap Ranger District. This is the type locality and the largest extant population west of Colorado (Wagner & Wagner 1994, W. H. Wagner pers. comm.).
>
> Additional inventory for *B. pedunculosum* in northeastern Washington, and in calcareous meadows in Montana and in Oregon.
>
> If additional; unthreatened popuiations of the plants can not be found rapidly, they should both be recommended for Cl federal status.
>
> Canadian inventories should be conducted, to determine how rare *B. pedunculosum* is in that country, and what threats there are to its known populations (see Wagner & Wagner 1983b).

Analysis issues

Montane meadows are important habitats for *Botrychium* species. Long-term threats to meadow habitats should be considered by Forest Service planners.

As the cost of petroleum rises, the use of meadows and ridgelines for wind-generators will become increasingly desirable over the next 100 years. Typical development requires miles of roads, wide treeless swaths around the generators, and considerable ground disturbance at the sites of the towers. This could affect known'populations for rare *Botrychium*, and potential habitat corridors as well. Some *Botrychium* species are known from alpine ridges in Deschutes, Klamath, Hamey and Wallowa Counties in Oregon, for example. Conflicts with windmill power generation are inevitable in the Columbia Basin, and are already controversial in mountain passes in California and on Appalachian ridges in New England (Allen 1995).

Resource extraction presents many conflicts. Salvage logging of standing 'or recently fallen deadwood threatens a number of *Botrychium* sites, especially of the endemic *Botrychium pumicola*. The species may be best protected by winter logging when snow cover prevents. ground disturbance. Some removal of larger woody cover may be essential as succession proceeds (Muller 199 1, Wagner and Wagner 1993). Commercial livestock grazing has too many disadvantages (e.g., weed introduction, trampling; compaction, competition with native grazers) to recommend-it for woody plant suppression in key *Botrychium* populations or communities. Fire management or maintenance of open habitats may be acceptable or preferable in some situations.

The negative impact of feral horses, asses, etc. should be considered in Basin and Range territory. At present these invasive animals have ready access to RNAs and other supposedly ungrazed areas. Impacts on native plant communities, long-term research, baseline monitoring, rare plants, and *Botrychium* communities should be considered. This is a cogent issue from the perspective of *Botrychium gallicomontanum*. A narrow endemic to northern Minnesota prairies, it is apparently found only in ungrazed grasslands and is absent from adjacent commercially grazed land (Farrar and Johnson-Groh 1991). It is reasonable to ask how many narrow endemics may have been eliminated by grazing excesses in past 150 years. And equally reasonable to ask that research areas remain undisturbed by exotic grazers prior to inventory and scientific examination.

Management (especially resource extraction) in wetlands (along waterways, in forests, while road building, and in rangelands) should meet Clean Water Act standards applied to the civilian world, and be subject to the same rigorous review and permitting by local and federal agencies, on a per site basis. *Botrychium* species are often found in jurisdictional wetlands such as wet meadows and forest springs.

Dam building, water diversions for agriculture, fossil ground water extraction that lowers the water table, logging and grazing in riparian strips are all important factors determining the diversity of *Botrychium* in wetlands and especially riparian zones.

Additional emphasis should be placed on permanently protecting certain classes of areas from resource extraction and management activities on public land. These include:

Botrychium populations at the type localities (Table 7).

Undisturbed populations of both rare and common species, serving as baseline monitoring and study areas for comparing with management activities. The present RNA system is inadequate in representing meadow communities with diverse *Botrychium* assemblages. The existing wilderness areas are often grazed by commercial interests (stockmen, sheep ranchers, and recreational pack strings).

Headwater wetlands at all elevations.

Recreational planning needs improvement in some forests. It should balance encouraging human use against the carrying capacity and projected needs, costs and biological impacts on rare or common species. Planning is needed to alleviate problems between commercial pa&strings and prime *Botrychium* sites in the Eagle Cap Wilderness and Lostine Canyon in the Wallowa-Whitman National Forest.

More resources should be allotted to monitoring, by acquiring more staff or by contracting private or NGO researchers.

Biodiversity inventory (mandated under NEPA) needs to become a higher priority. This study was continually hampered by the lack of basic data.

The majority of interesting *Botrychium* records in the area are high elevation high latitude species, that exist on "islands" of moist mountain habitat surrounded by barren "seas" of inhospitably dry low elevation habitat. These montane habitats are the ones most threatened by current projections of a warming drying climate in the next century. Grazing and other intensive disturbances in meadows should be appropriately reduced at middle and high elevations, to reduce stress on these plant communities and their still rich assemblage of *Botrychium* species.

Analysis should consider the implications of artificial maximum limits on the length of sensitive species lists (as in Region 4). Political concepts should not supplant scientific criteria in choosing the conservation priorities across Regions. Ideally, regional sensitive species lists would be updated annually, after consultation with all forests in the Region, as well as adjacent countries and regions. Failure to do so means failure to meet stated goals of maintaining one aspect of biodiversity.

Laws and regulations protect wetlands, and the rarest and most endangered species, but little legal framework exists to protect the most common species, especially in upland areas. Most *Botrychium* occur in meadows that are not wetlands and that do not appear to be extraordinary to non-biologists. Analysis should consider the implications of reeducating managers and the public about the need for (and techniques to) protect a higher percentage of the biodiversity from commercial management and development activities. We note that Ratti et al. (1991) did not consider the fate of common species and common habitats in the event of climate change.

Research needs

Fire management research programs for natural community restoration and maintenance should be enlarged and expanded.

Grazing issues need research. In all cases extensive studies will first be needed in natural systems without commercial grazing, to establish baseline data. Some of the questions to be answered for *Botrychium* include:

> How does native grazing (by meadow voles, rabbits, or elk) differ from commercial livestock grazing? Do different native grazers affect spore production and dispersal differently? Do native grazer population cycles exert an influence on *Botrychium* reproduction?
>
> Have *Botrychium* persisted, endured or thrived when grazed heavily by native animals? How do populations vary in grazed and ungrazed sites?
>
> Large native ungulates are being managed at artificially high levels for hunting in some areas. How is this affecting the *Botrychium* microsites?
>
> How is the nature of relations between fungal and vascular associates influenced by native and introduced fauna?
>
> *Botrychium* needs some level of disturbance for recruitment (Muller 1991, 1993, Wagner & Wagner 1993). Is commercial grazing in meadows "too much" disturbance?

Research into the taxonomic status of many *Botrychium* would be welcome. Do all the local forms require binomials? If funded by the agencies, taxonomic research should include frequent updates on the best identification techniques. Most agency botanists are overlooking the value of published silhouette illustrations, for example. More effort should be made to improve documentation and collecting methods for this genus (D. Wagner 1992).

Botanical collecting of *Botrychium* may have long-term deleterious effects on the individual plant, as in many species of orchids. This needs immediate research, in the face of advice to collect large numbers of fronds for taxonomic research. D. Wagner (pers. comm.) is studying this for *B. simplex*, but many more species need to be investigated.

Additional taxonomic research is needed to address the species concept in *Botrychium*. We do not know if the species are similar due to convergent evolution, or due to their recent evolutionary separation from common ancestors. The controversial splitting of species groups centered around *Botrychium minganense* and *Botrychium matricariifolium* morphologies has many trendy Pteridologists excited and many other botanists dismayed. Only with additional research into the genetics, enzymes, and other.modem lines of systematic inquiry will stronger arguments arise. Lacking the publication of any electrophoretic work, for example, we can only assume that the Wagnerian species concept, based on difficult morphological separations, is acceptable.

In the interim, an important research need is to continue to inventory for new populations, to enlarge our picture of where these plants are, and to monitor the populations, 'to begin to understand the subtle differences between the life histories of the different species. Only with these basic needs fulfilled can we intelligently set accurate conservation priorities and manage sites wisely.

It is not clear why the Wallowa Mountains and northeastern Washington are such rich *Botrychium* sites. Other parts of the country were equally well botanized by Pteridologists and are lacking our diversity of species. A substantial biogeographic inquiry into distribution and endemism across the northern hemisphere is needed.

There is no good explanation for why *Botrychium* are common in one site and apparently absent from the next 20-50 seemingly similar sites. Long-distance spore dispersal suggests how they can move around between disjunct sites, but it does not explain what it is that characterizes a good site.

We were unable to find representative species that would indicate a rich *Botrychium* diversity. This needs research. It may not be possible except on a very local basis, given the great diversity of species, geology, land use history, and habitats. Often the presence of rare species is used as a proxy, but generally several rare species (of different genera) are present in biologically diverse areas.

We did not have detailed data available to assign *Botrychium* to cover classes. This is an area that needs research.

Muller (1992) suggested that drought did not influence the seasonal abundance of *Botrychium matricariifolium* in France. Some populations showed the effects of drought whether or not they appeared in large numbers that year. Is this true in all populations? In all species? Is the timing of the drought critical? American authors have long contended (but without much data) that the population numbers vary year to year BECAUSE of available precipitation.

Assumptions

We made several assumptions in collating the data in this report.
At the level of data collection and processing, we assumed that all or most of Wagnerian species will stand the test of time, despite any present controversy.

We assumed that each *Botrychium* species is unique, as is our experience with other taxonomic groups. Thus it is difficult to accurately lump together the ecology and management concerns, for disparate species, even when they share the same habitats.

In discussions of habitat, we assumed that the geomorphology of a site is at least as important as the immediate successional stage or management regime. Widely spaced geological events (e.g., rockslides) may create new meadow habitats, while fire may restore meadow habitats, and droughts may maintain meadow habitats in natural systems. Similarly, calcareous groundwater, an undisturbed braided stream channel and the glacial carving of a broad valley floor may be as critical as centuries of beaver activity in the maintenance of certain wet meadows types for *Botrychium*.

We assumed that management of habitats by watershed will be as necessary as managing for individual populations.

We assumed that in ten years the distribution and population accounts of all the species will be much better, if inventory receives increased priority. We further assumed that contemporary knowledge will improve as state natural heritage programs recover from backlogs in data entry.

We lacked highly detailed data for many taxa from areas outside of Oregon. We assumed that our familiarity with the species in Oregon could be roughly extrapolated across the entire EEMP.

We assumed that long-term goals, like the perpetuation of rare gene pools, would be best served by a conservative approach to habitat management. We assumed that 100 years from now, many more people will live in the Columbia Basin, the natural processes and preserves will be increasingly fragmented, and the pressures for resource and recreational use will, be. immensely intensified.

Inventory

Everyone who works on this genus acknowledges that more inventory is needed (Wagner & Wagner 1993). Two approaches to federal lands inventory are needed. One is to continue to conduct individual site examinations well in advance of ground disturbance (years ahead preferably, keeping in mind that small populations are not present above ground every year

(Muller 1992, 1993, Montgomery 1990). A second approach is to continue to fund or contract inventories to search likely habitats (e.g., Vanderhorst 1993; or NSF funding for Wagner: & Wagner).

The work of Whittier (1984, 199 1, Whittier & Thomas 1993) and others has established the importance of fungal associates in the life cycle of *Botrychium*. Fungal inventories (and taxonomy) are at least five decades behind the work of vascular plant: students, and need increased attention and funding.

Inventory is needed to relocate type localities (Table 7) and to determine the location of diverse genus communities (sensu Wagner and Wagner 1983a). Baseline-demographic and population biology research should be started at undisturbed genetic reserves at type localities and exceptionally diverse genus communities.

At present a strong argument could be made for federal listing of species like *Botrychium lineare* and *B. pedunculosum*. More inventory is needed for these exceedingly scarce plants, before advancing the federal listing packages; At present their known populations are quite small and they face a number of threats. Will the picture change with two or three more years of additional inventory?

Monitoring

Recent monitoring work on the genus is sparse. What work has been done has presented some fascinating possibilities for further work. The results suggest that it is unwise to use the data from one species to predict what a different species will do. For example, studies of different species in the juvenile stage yielded a different length of time for the'sporophyte'to reach maturity and produce fertile leaves (Muller 1993, Whittier 1976, Campbell 1922, Bruchman 1906). Muller (1993) suggested that the adult (reproductive) phase of *Botrychium matricariifolium* sporophytes may average only two years, while the juvenile phase may average ten years. Clearly demographic monitoring will have to take this into account, and must be done for individual species, not species groups.

Long term studies of a *Botrychium* colony have been done by Montgomery (1990). He examined the evergreen species *B. dissectum* (a close relative to *B. multifidum*) for the'. effects of deer browsing, and annual fluctuations in the population. He found that the adult plants could persist for a number of years underground between emergences, and that they were resilient in the face of l-2 years of defoliation by deer. In contrast, Muller (1993) felt that deciduous *B. matricariifolium* (a close relative of *B. hesperium*) had an extremely short adult (spore-producing) life span, perhaps averaging two years. These plants would not be expected to tolerate botanical collecting or grazing animals prior to release of their spores.

Excellent monitoring projects have started (e.g., Lesica & Ahlenslager 1994, Montgomery 1990, Muller 1992, 1993; D. Wagner with *B. simplex*; many *B. pumicola* monitoring sites). All C2 species need long-term monitoring. Most of the known populations are on federal land (Table 9), and monitoring is one place where the federal contribution to science can be significant.

Early questions by taxonomic skeptics included: did the plants change morphology from year to year. (In other words, was it one "species" one year and another so-called "species'-' the next year.) To date all the species have maintained their identity from year to year. Now questions about the longevity of individual plants, their replacement rates, and their. interactions with herbivores need to be addressed.

The demography of all the western members of the species is unknown. More observations on population cycles must be made before any explanations can be proposed and management applied.

Monitors should follow the life history of rare and common species for at least ten years in undisturbed "control" situations, to provide baseline data for management decisions.

Important species should be monitored in a variety of successional habitats over time, to discover when they thrive and when they decline. It will be important for land managers to monitor populations (and recruitment) in natural disturbances (fire, landslide, snow avalanche, flood, frost heaving, areas of heavy elk/deer grazing, etc.). Then adequate comparisons can be drawn with monitored populations (and recruitment) in unnatural disturbances (mowed roadsides, grazed pastures, campgrounds, livestock staging areas, etc.).

Diskette data

An electronic copy of the report was provided to the contracting officer in Walla Walla. Text was in Word Perfect. Distribution information was databased for use by EEMP GIS staff, as requested.

Literature review

In addition to the discussion below, the reader is referred to the section on taxonomy, where standard taxonomic works were reviewed. The best approach to studying *Botrychium* taxonomy is to read the papers by Wagner and Wagner (1981,' 1982, 1983c, 1986, 1990a, 1990b, 1994). Their best summary is the treatment in Flora of North America (Wagner and Wagner 1993).

Uses

The fern family Ophioglossaceae is well studied for insights into plant systematics and evolution. The odd tracheary elements in the family suggest affinities to ancestors of the gymnosperms (Pant et al. 1993). The genus *Ophioglossum* has the highest chromosome count of any plant: 1260 chromosomes in 0. *reticulatum* of the tropics (Bold et al. 1980). High chromosome levels may be adaptive for tiny colonies in isolation, a common feature of members of this family. McMaster (1994) showed extremely low levels of genetic variability in presumably selfing small colonies of *Ophioglossum vulgatum*. This may have counter-intuitive benefits, by removing deleterious recessive genes (Frankel & Soule 1981, Lesica & Allendorf 1992). This has implications in many genetic and breeding studies across biology. *Botrychium* and other fleshy-rooted "primitive" plants interact with soil fungus. This, and similar-rooted fossils, suggest that all land plants were evolved from fungal dependant ancestors in the Devonian (Pirozynski and Malloch 1975). The nature of the interactions between the plant and the vesicular-arbuscular mycorrhizae (VAM) have potential economic applications in agriculture and horticulture (Mosse 1959, Berch and Kendrick 1982). . The long evolutionary history of the family suggests that its potent chemical repellents, far from being "primitive," are quite advanced, and may have medicinal uses if investigated.

Most members of the family Ophioglossaceae are not known to palatable to humans. However, Mabberley (1993) reports that *Botrychium ternatum* of Japan is eaten as a vegetable.

Ecology

Little is known about the ecology of *Botrychium*.

Life cycle. Basic fern morphology and biology is different from that of flowering plants. Diagrams of the topography of a grape fern can be found in Lorain (1990). The life cycle is diagrammed in Taylor (1984) and reproduced in Zika (1994a). It provides a stylized illustration of the life cycle of a fern, showing the gametophyte (haploid) generation alternating with the sporophyte (diploid) generation. Gametophytes are rarely seen, since they are tiny and grow underground. The. sporophyte phase is the familiar green "fern" seen afield.

Sporophytes. The stem is entirely underground, erect, fleshy, and slow-growing. The leaf bud is rolled along its axis, and protected by the dried remains of the previous years leaves. For a number of years the juvenile sporophyte produces underground leaves, before finally developing an aerial adult green leaf. If the protection derived from dried leaf remains is important,, the picking of adult leaves by botanists, even trimmed at ground level, may have severe impacts on the shoot in harsh conditions such as late spring frosts. David Wagner (pers. comm.) has started to investigate this in *Botrychium simplex*, but his monitoring project requires more time to reach conclusions. Other species should be investigated as well.

There is considerable variability between species in the amount of time it takes to mature and produce sporangia. Bruchman (1906) recorded [illegible] rudimentary underground leaves (and presumably years) before an emergent leaf was produced in *Botrychium lunaria*. Campbell (1922) found it took 5 years for *B. simplex* to produce its first emergent leaf. Muller (1993) reported it took ca. 10 years for *Botrychium matricariifolium* to develop adult sporophytes. However, Whittier (1976) found that cultured juvenile *B. dissectum* plants fed sucrose supplements could be matured in one year. It is doubtful this ever takes place in nature. (Farrar & Johnson-Groh 1990).

A single adult emergent leaf and a single root is produced each year, according to Bold et al. (1980). One root is associated with each old adult leaf base. The one leaf per year formula. may allow a way to age mature plants, if they can be sacrificed: uprooting plants carefully and counting the number of roots or root/leaf scars should yield the post-reproductive age of the individual, if scars from juvenile subterranean leaves can be distinguished from. scars of adult leaves. Some species can produce more than a single juvenile leaf in a year (Whittier and Thomas 1993).

Food storage (starches) is in the thick root cortex. In the related *Ophioglossum* root tips are thick, lack root hairs, and the older portions of the root are suberized (Peterson & Brisson 1977) and support endophytic fungus.

Vegetative reproduction is known from three tetraploid species, *Botrychium echo, B. minganense, B. gallicomontanum* and the diploid *B. campestre*. Some plants of these species produce globular underground gemmae, 0.5-1.0 mm in diameter, in clusters on the roots. Pteridophyte gemmae are exceedingly rare, known only from *Psilotum, Equisetum*, and the fossil record (Farrar and Johnson-Groh 1990). The gemmae balls can germinate if associated with endogenous fungal hyphae, and probably require 5-8 years to produce a plant with above ground leaves (Farrar & Johnson-Groh 1990). Juvenile plants produce 4-5 roots, then form the first leaf, which does not reach the soil surface. Thereafter a solitary leaf is produced with a single root, on an annual schedule, as in sexually-derived sporophytes. Gemmae may have evolved as a method of coping with summer drought in the prairie and welldrained dune habitats of *Botrychium campestre*. They are larger and hence may be a more reliable means of reproducing than gametophytes, in moisture-limited environments (Farrar & Johnson-Groh 1990).

A *Botrychium* "leaf" or frond forks near the junction of the petiole and the blade. The fertile axis (sporophore) bears sporangia; the blade (trophophore) photosynthesizes. *Botrychium virginianum* is unique in our flora, in regularly producing juvenile leaves without sporangia. All the moonworts (subgenus *Botrychium*) characteristically produce at least one sporangia on even the smallest above-ground individuals, if undamaged by compaction, frost, browsing, etc. Evergreen *B. multifidum* produces a new leaf in the spring; which over-winters and withers the following spring as a new leaf emerges. Some *B. multifidum* leaves last well into a second summer.. All our other species wilt in summer or autumn, and are dormant over the winter.

W. H. Wagner (pers. wmm.) notes there is a definite phenological sequence to the taxa, which is sometimes useful in separating the taxa in the field. *Botrychium campestre* is phenologically timed to emerge and produce spores much earlier than the other species (April to June in Iowa). Presumably this is an adaptation to the droughty summer conditions prevalent across most of the range of the species, in the midwestem prairie. The plant is physiologically active when there still is soil moisture available early in the growing season (Farrar & Johnson-Groh 1986).

Spores are produced in sporangia. There are'generally 1500-2000 spores per sporangium in *Botrychium* (Bold et al. 1980). The spores are released explosively from the-sporangium. In central 'Iowa Farrar (1976) found most *Botrychium* spores were released in a two week period and matured simultaneously. In contrast, fern spores with maturation spread over a longer time period (e.g., *Adiantum, Polypodium*) were shed over a long period between late summer and autumn (Farrar 1976).

Dissemination.- Short distance dispersal of spores'may take place using an animal vector.. Mature spores cling tenaciously to the sporangia, perhaps electrostatically (W. H. Wagner pers. wmm.). There are numerous observations of 1) clusters of plants, presumably arising from a cluster of gametophytes established from a cluster of spores; 2) sporangia bitten off by unknown animals, but generally assumed to be mammals like rodents, rabbits, hares, or. deer/elk. There is the possibility that plants with mature spores are attractive to animals and the sporangia afford enough protection to the spores that they can pass safely through an animal gut. 'Animal leavings would then' deposit a cluster of spores (and some fertilizer) in the next appropriate feeding area where the animal lingers (Wagner et al. 1985). An eastern species closely related to *B. montanum* is *B. mormo*. Wagner and. Wagner (1993) suggest that the sporangia of *B. mormo*, which -never dehisce, may require animal ingestion to release and disperse the spores. The phenomenon of mammalian dispersal of ferns needs study; although such studies would be complicated, time consuming and expensive (Zika 1994b).

Most spore dispersal surely takes place by passive means.. The lightweight spores are easily moved by. breezes, or splashed by rainwater. Most spore dispersal is characterized by a leptokurtic distribution (Ingold 1971). The vast majority of spores land within the same meadow as the parent plant. Peck et al. (1990) found 92% of the spores of *Botrychium virginianum* stayed within 5 meters of the parent plant under a closed canopy. : Some, of course, are distributed much farther. Even a medium sized fern like a temperate *Thelypteris* can produce a staggering amount of spores, calculated at up to 50 million in a single growing season (Bold et al. 1980). Page (1979) reported spore production *per frond* of between 7.5 $X 10^5$ to 7.5×10^9. Many spores are available for an occasional "sweepstakes" long-distance dispersal (W. H. Wagner 1972). Studies in island biogeography have examined this phenomenon (Carlquist 1967; Smith 1972; Tryon 1970, 1972, 1986). It easily explains the transglobal, bipolar distribution of ***Botrychium lunaria*** in remote Greenland, Iceland, Australia and New Zealand as well as on the large continents (Wagner & Wagner 1993; Kaynak & Tuyuji 1991). Most spores are washed from the airstream when they first encounter a rainstorm (Page 1979).

Spores can sift several centimeters down into porous soil (Wagner et al. 1985). They can remain dormant (Goswami 1987) or, germinate immediately.

Gametouhvtes. The gametophyte phase of a fern is illustrated in Figure 2 of Zika (1994b), which is reproduced from Foster & Gifford (1974) and Whittier (1991). Gametophytes are, rarely seen,. since they are tiny and grow underground. ***Botrychium*** gametophytes are fleshy, lack green, pigment for photosynthesis (since they are subterranean), and are always infected with endophytic fungal hyphae.

Gametophyte biology is little known, because studying them in nature requires the nearly impossible task of finding them. Whittier (1972, 1976, 1981, 1984; Whittier & Peterson 1984) is one of the few students of ***Botrychium***, and has come the closest to understanding their requirements in cultivation in a laboratory. Several factors appear to be important in this phase of the life cycle for the genus. Spore germination requires darkness, moisture, and unless grown in an enriched culture medium, the spore needs a carbohydrate source from a mycorrhizal fungus (Whittier 1991). Gametophyte growth rates vary, and the prothalli can overwinter (Page 1979). A nitrogen fertilizer has been used in the cultivation of a gametophyte (Whittier and Thomas 1993).

The gametophytes are closely associated' with (or perhaps partially parasitic on) mycorrhiza, and are found underground. Wagner et al. (1985) suggested this is an adaptation to habitats such as fields, grassy meadows and other seasonally dry habitats. The gametophytes can self-fertilize themselves, perpetuating local ecotypes and facilitating long distance colonization by a single spore.

Hybrid ***Botrychium*** plants are the result of gamete movement between the underground gametophytes of -two, species, requiring an aqueous link and motile sperm (Wagner et al. 1985). Genetic variation'is minimal in small populations of sporophytes of ***Ophioglossum***, suggesting outcrossing between gametophytes of the same species is rare (McMaster 1994). This may explain why hybrid ***Botrychium*** are rarely seen in nature (Wagner and Wagner 1988, 1993), even though different species can commonly be found within a few centimeters of each other (Zika pers. obs.).

Fire ecology.

A number of *Botrychium* grow in plant associations that historically were maintained by frequent fire intervals. Included are all species in lodgepole pine woods and meadows (e.g., *B. pumicola, B. pedunculosum*) and those found in prairies (i.e., *B. campestre*). These ferns must be able to either withstand some degree of burning (if soil temperatures are not excessive), or, more likely, to recolonize rapidly from adjacent unburned areas. Fire suppression and the lack of fire management in the last century are creating problems for these ferns and their habitats, including woody plant succession and increasingly explosive fuel loads. Little is known about the details of the fire ecology of *Botrychium*, and it needs to be studied to provide sound management options (Farrar & Johnson-Groh 1986).

Muller (1991) and McMaster (1994) recommend mechanical mowing or pruning to maintain open habitats for Ophioglossaceae, rather than grazing or tie.

Resumes

A resume for all the authors is attached as an appendix to this report, as required by the contract (Table 20).

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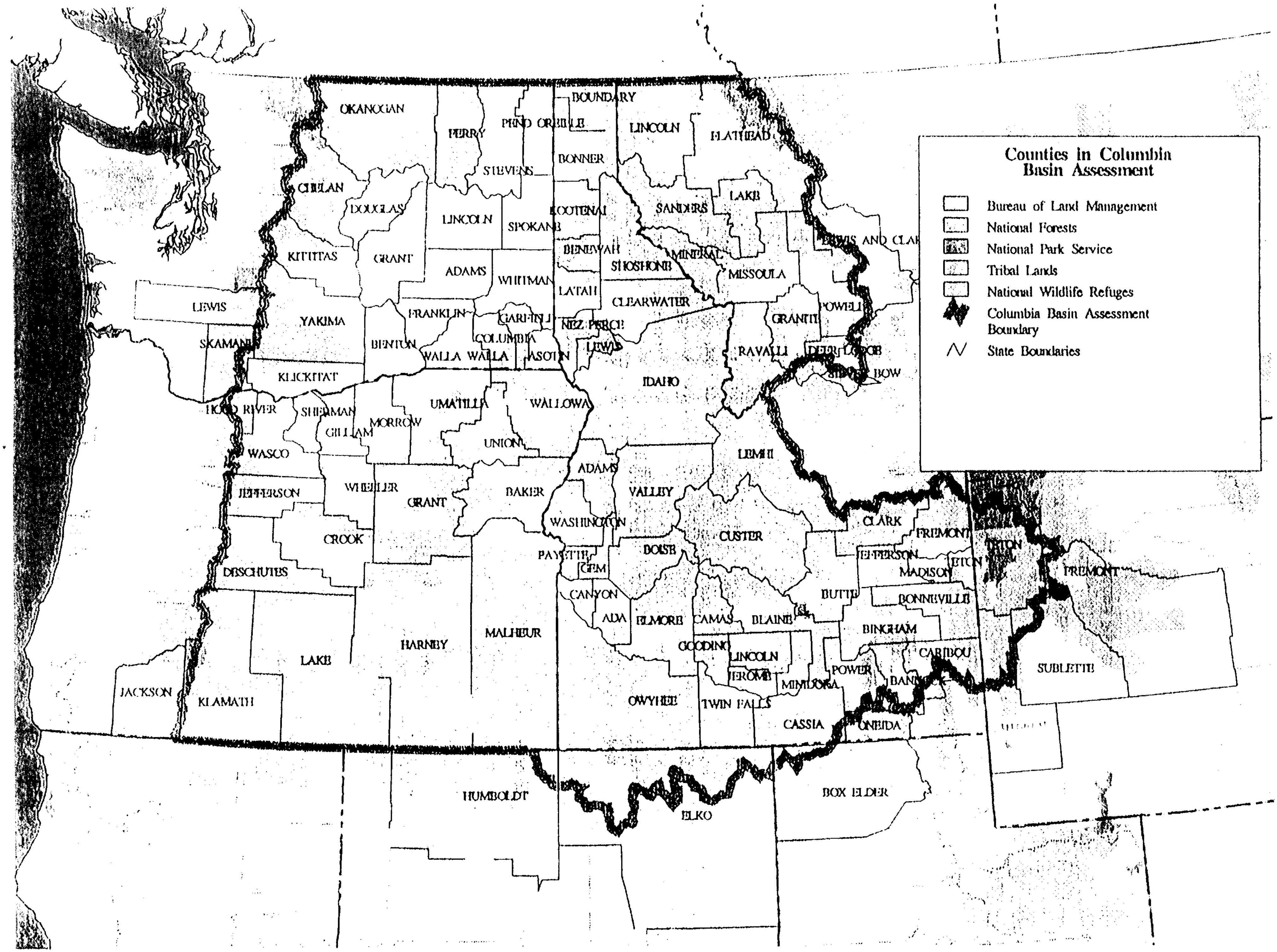
FIGURES

Figure 1. Color map of project area.


Counties in Columbia Basin Assessment
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National Forests
National Park Service
Tribal Lands
National Wildlife Refuges
Columbia Basin Assessment Boundary
State Boundaries
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FERRY
PEND OREILLE
BOUNDARY
LINCOLN
FLATHEAD
BONNER
STEVENS
CHELAN
DOUGLAS
LINCOLN
SPOKANE
KOOTENAI
SANDERS
LAKE
BENEWAH
MINERAL
KITTITAS
GRANT
ADAMS
WHITMAN
SHOSHONE
MISSOULA
LEWIS AND CLARK
LEWIS
YAKIMA
LATAH
CLEARWATER
FRANKLIN
GARFIELD
NEZ PERCE
GRANITE
POWELL
SKAMANIA
BENTON
COLUMBIA
WALLA WALLA
ASOTIN
LEWIS
RAVALLI
DEER LODGE
SILVER BOW
KLICKITAT
IDAHO
HOOD RIVER
SHERMAN
UMATILLA
WALLOWA
GILLIAM
MORROW
UNION
WASCO
LEMHI
ADAMS
JEFFERSON
WHEELER
GRANT
BAKER
VALLEY
WASHINGTON
CLARK
CROOK
CUSTER
FREMONT
PAYETTE
BOISE
JEFFERSON
TETON
DESCHUTES
GEM
MADISON
FREMONT
CANYON
BUTTE
BONNEVILLE
ADA
ELMORE
CAMAS
BLAINE
MALHEUR
BINGHAM
HARNEY
GOODING
LAKE
LINCOLN
CARIBOU
POWER
JEROME
SUBLETTE
BANNOCK
JACKSON
KLAMATH
OWYHEE
MINIDOKA
TWIN FALLS
CASSIA
ONEIDA
HUMBOLDT
BOX ELDER
ELKO

Figure 2. Key to counties in the study area.

A more detailed map of the county lines and the project boundaries can be found in the government files. The EEMP project has an excellent GIS department which has produced a multicolored 1:2,000,000 base map used in preparation of this report. Only portions of some of the counties on the periphery are within the study drainage.

Key to County Numbers

	State	County
1	Idaho	Ada
2	Idaho	Adams
3	Idaho	Bannock
4	Idaho	Benewah
5	Idaho	Bingham
6	Idaho	Blaine
7	Idaho	Boise
8	Idaho	Bonner
9	Idaho	Bonneville
10	Idaho	Boundary
11	Idaho	Butte
12	Idaho	Camas
13	Idaho	Canyon
14	Idaho	Caribou
15	Idaho	Cassia
16	Idaho	Clark
17	Idaho	Clearwater
18	Idaho	Custer
19	Idaho	Elmore
20	Idaho	Franklin
21	Idaho	Fremont
22	Idaho	Gem
23	Idaho.	Gooding
24	Idaho	Idaho
25	Idaho	Jefferson
26	Idaho	Jerome
27	Idaho	Kootenai
28	Idaho	Latah
29	Idaho	Lemhi
30	Idaho	Lewis
31	Idaho	Lincoln
32	Idaho	Madison
33	Idaho	Minidoka
34	Idaho	Nez Perce
35	Idaho	Oneida
36	Idaho	Owyhee
37	Idaho	Payette
38	Idaho	Power
39	Idaho	Shoshone
40	Idaho	Teton
41	Idaho	Twin Falls
42	Idaho	Valley
43	Idaho	Washington
44	Montana	Deer Lodge
45	Montana	Flathead
46	Montana	Granite
47	Montana	Lake
48	Montana	Lewis & Clark
49	Montana	Lincoln
50	Montana	Mineral
51	Montana	Missoula
52	Montana	Powell
53	Montana	Ravalli
54	Montana	Sanders
55	Montana	Silver Bow
56	Nevada	Elko
57	Nevada	Humboldt
58	Oregon	Baker
59	Oregon	Crook
60	Oregon	Deschutes
61	Oregon	Gilliam
62	Oregon	Grant
63	Oregon	Hamey
64	Oregon	Hood River
65	Oregon	Jackson
66	Oregon	Jefferson
67	Oregon	Klamath

68 Oregon Lake
69 Oregon Malheur
70 Oregon Morrow
71 Oregon Sherman
72 Oregon Umatilla
73 Oregon Union
74 Oregon Wallowa
75 Oregon Wasco
76 Oregon Wheeler
77 Utah Box Elder
78 Washington Adams
79 Washington Asotin
80 Washington Benton
81 Washington Chelan
82 Washington Columbia
83 Washington Douglas
84 Washington Ferry
85 Washington Franklin
86 Washington Garfield
87 Washington Grant
88 Washington Kittitas
89 Washington Klickitat
90 Washington Lincoln
91 Washington Okanogan
92 Washington Pend Oreille
93 Washington Skamania
94 Washington Spokane
95 Washington Stevens
96 Washington Walla Walla
97 Washington Whitman
98 Washington Yakima
99 Wyoming Fremont
100 Wyoming Lincoln
101 Wyoming Sublette
102 Wyoming Teton

Counties in the EEMP Area

Numbers correspond to county names in the key to county codes on the preceding page

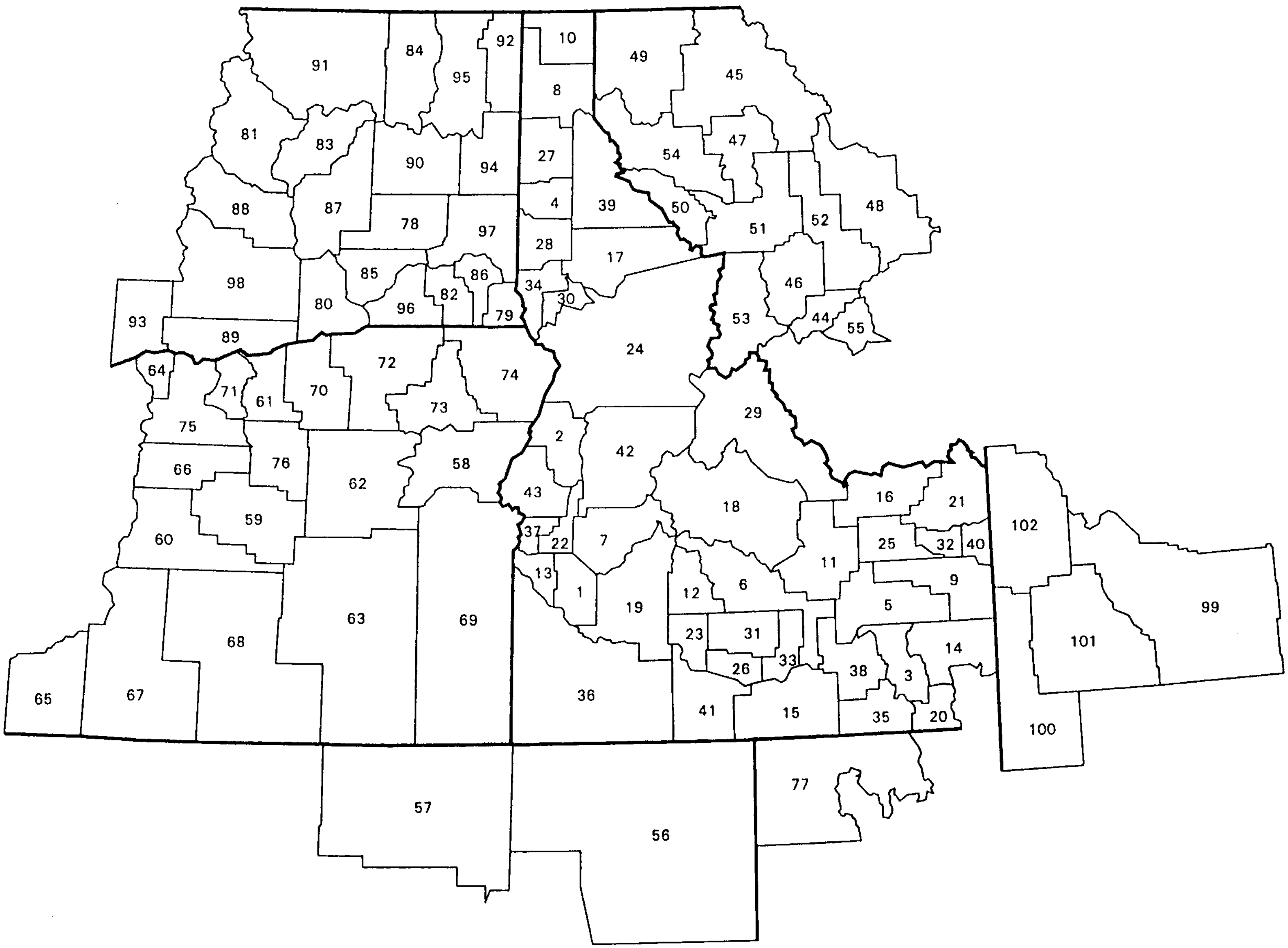
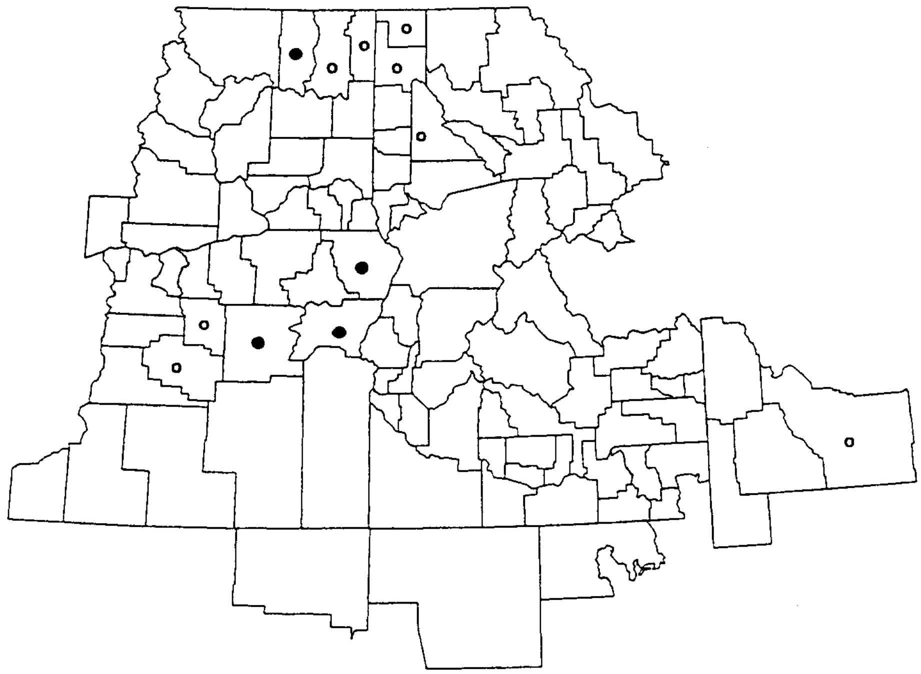


Figure 3. County distribution maps.



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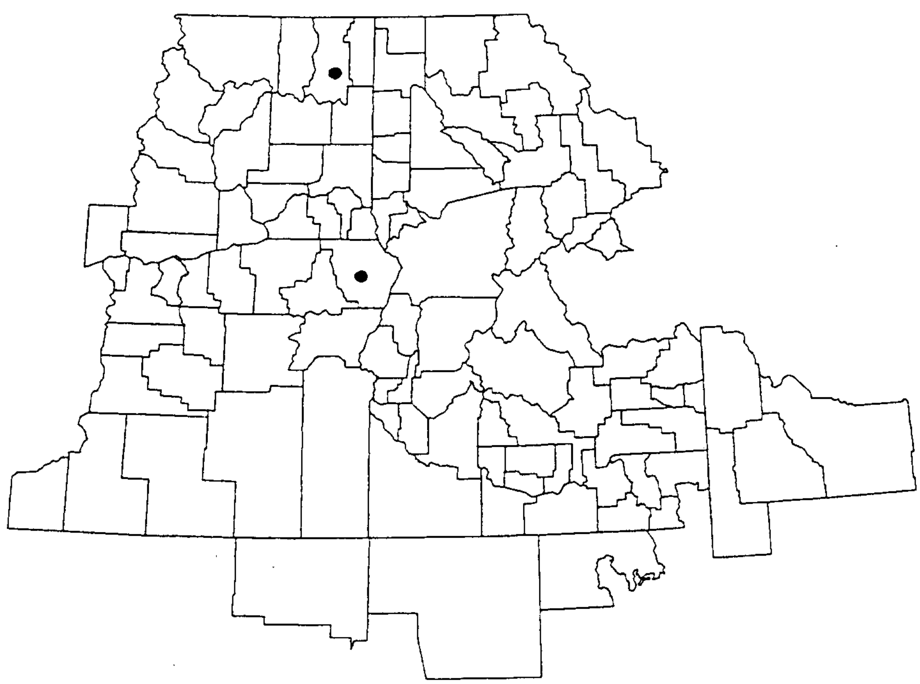

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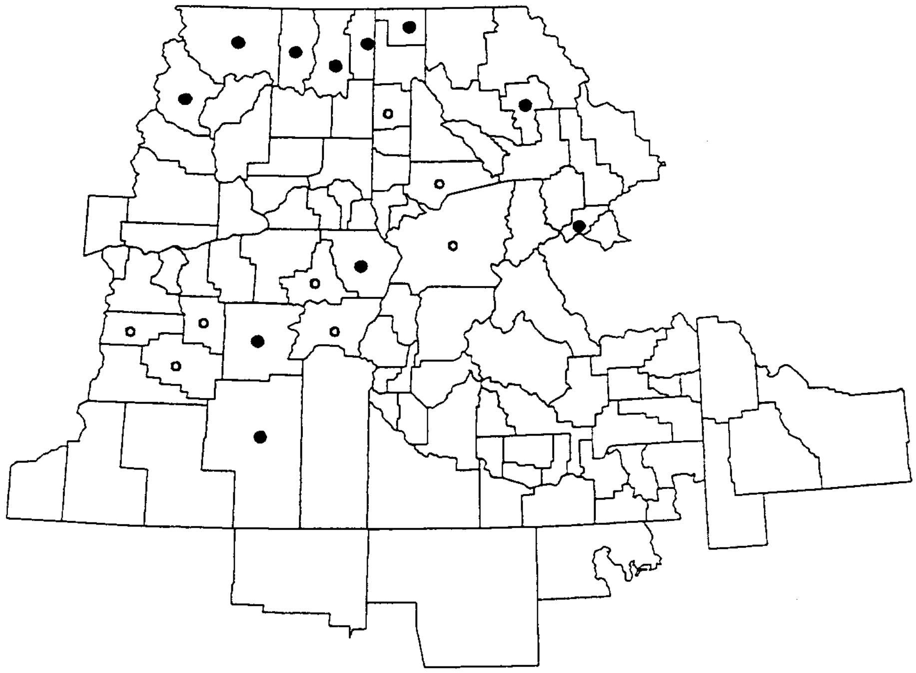
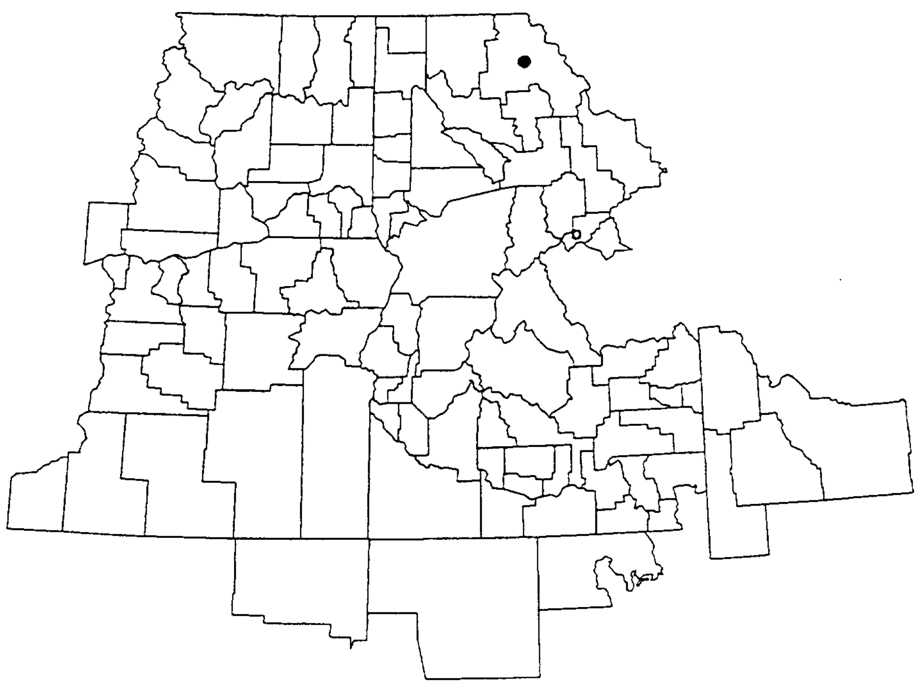
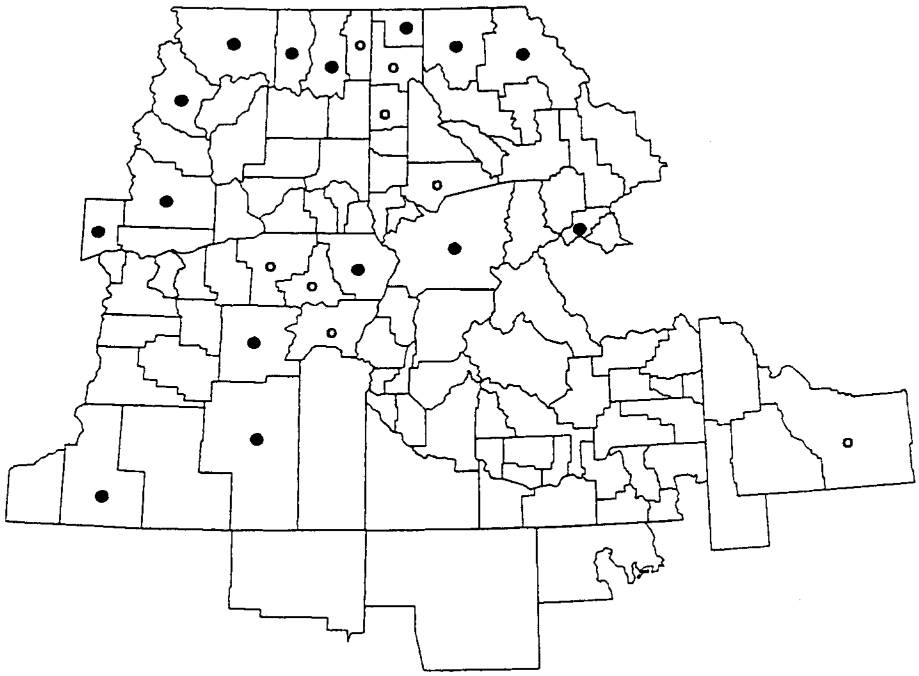


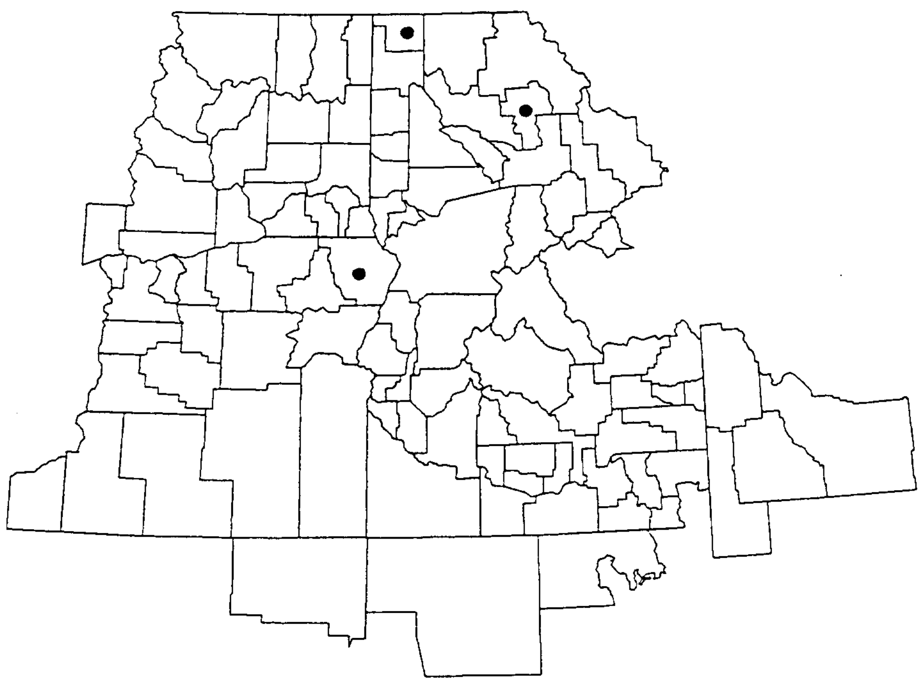
Botrychium crenulatum



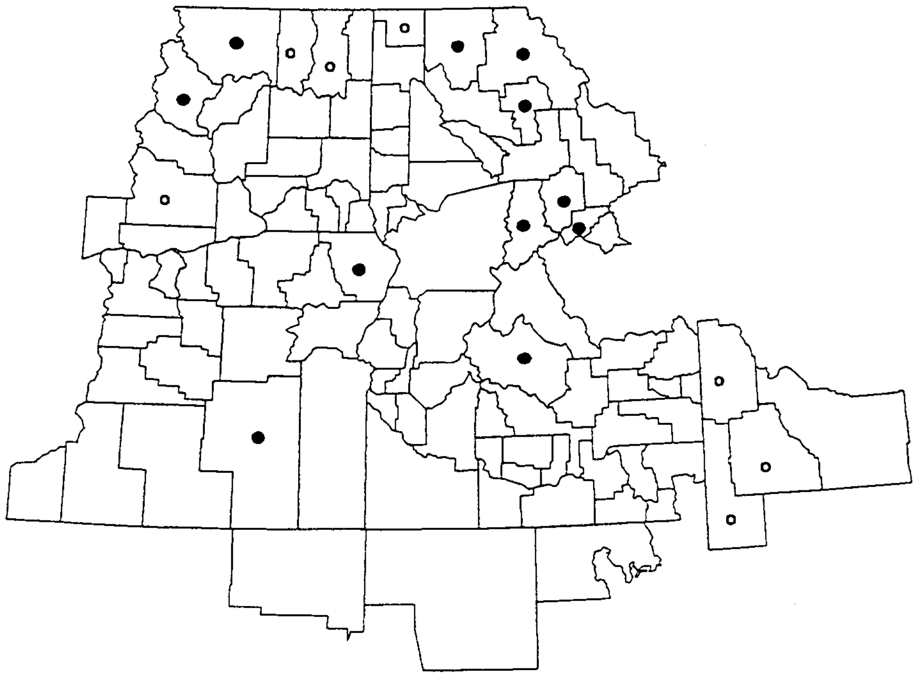
Botrychium hesperium



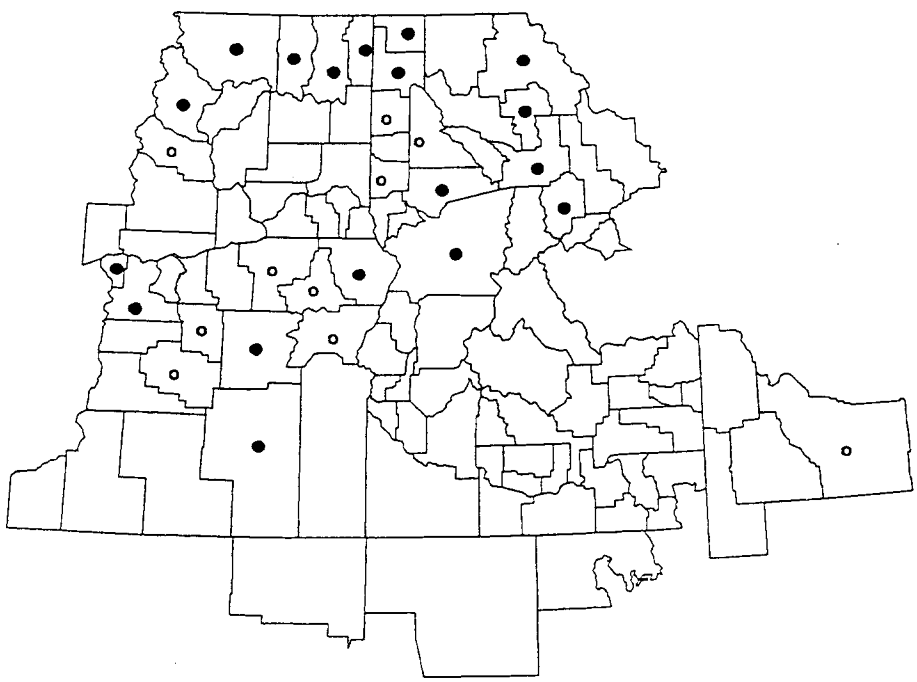
Botrychium lanceolatum ssp. lanceolatum



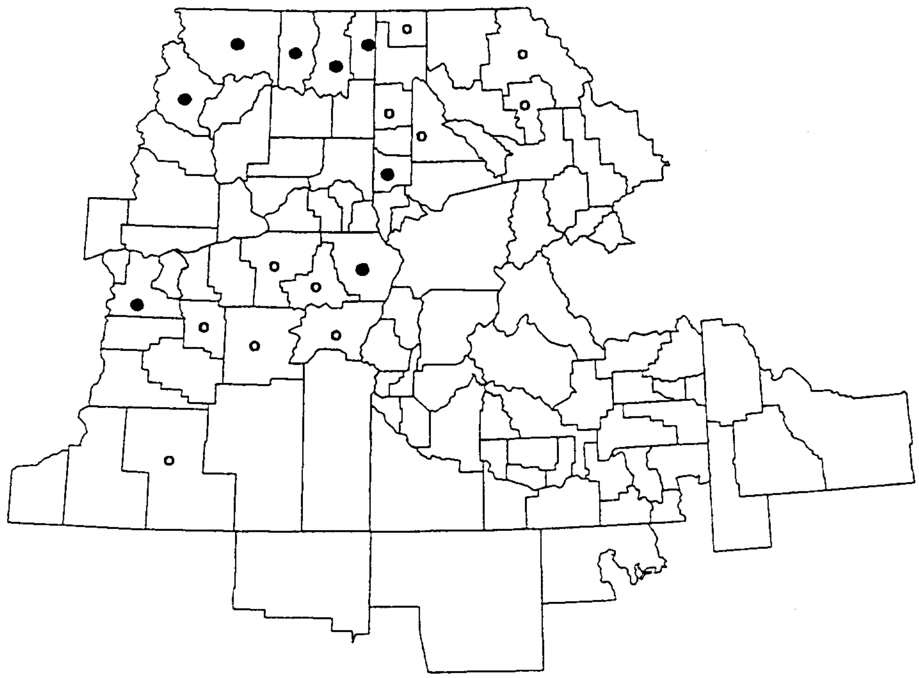
Botrychium lineare



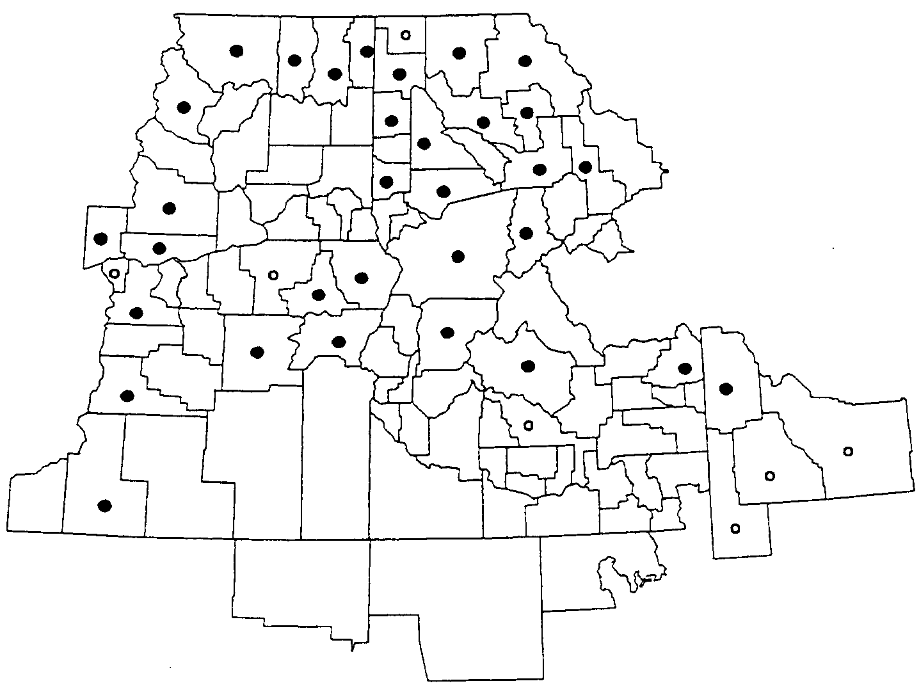
Botrychium lunaria



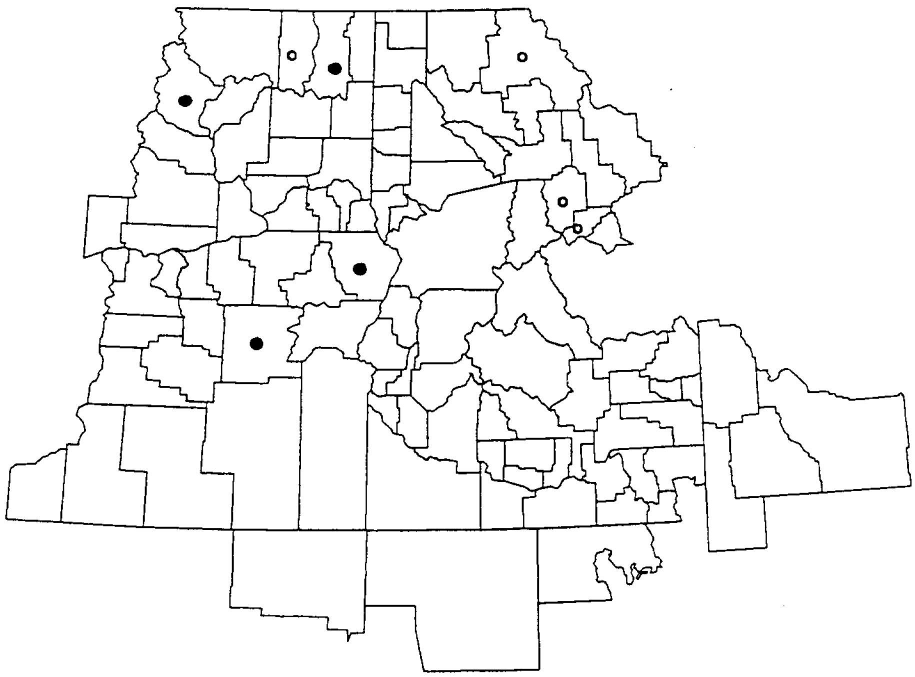
Botrychium minganense



Botrychium montanum



Botrychium multifidum



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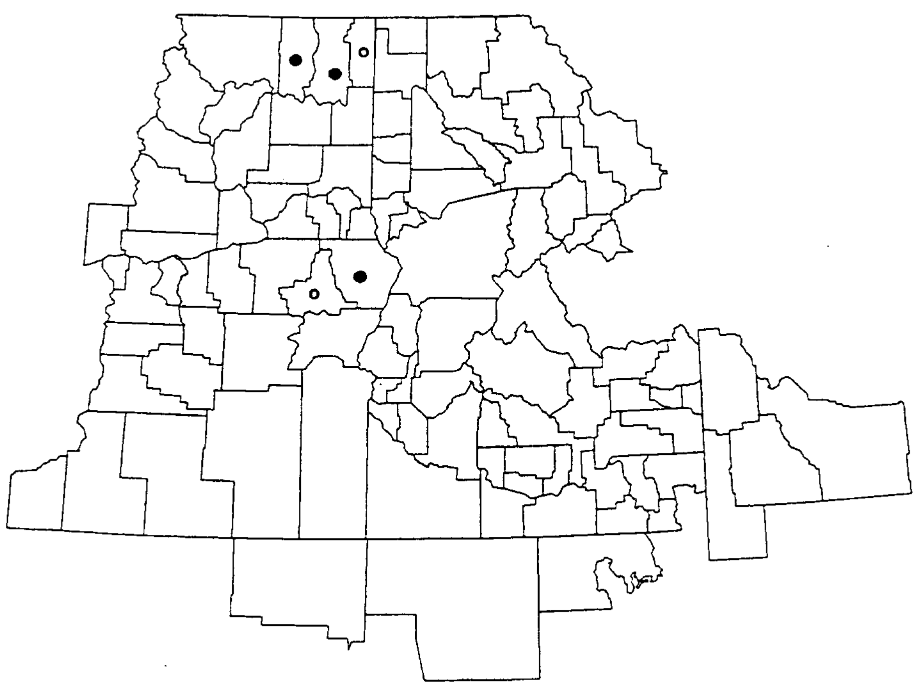
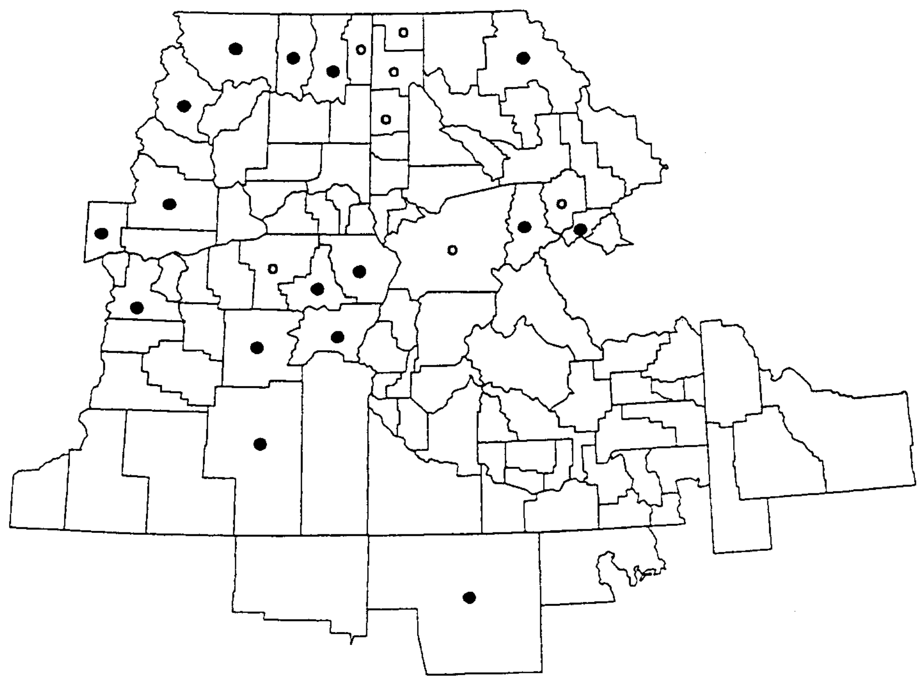
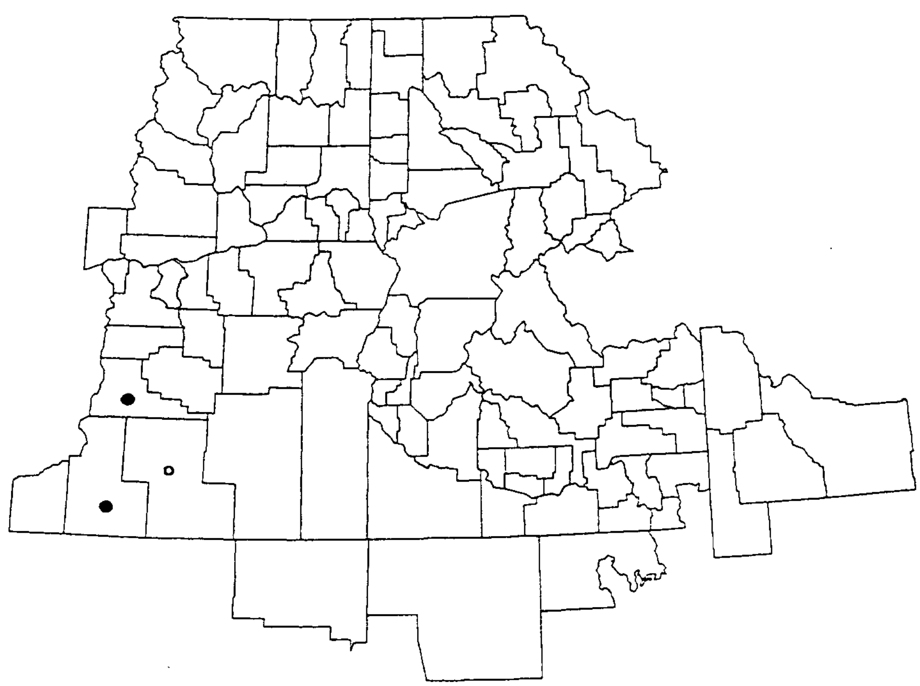


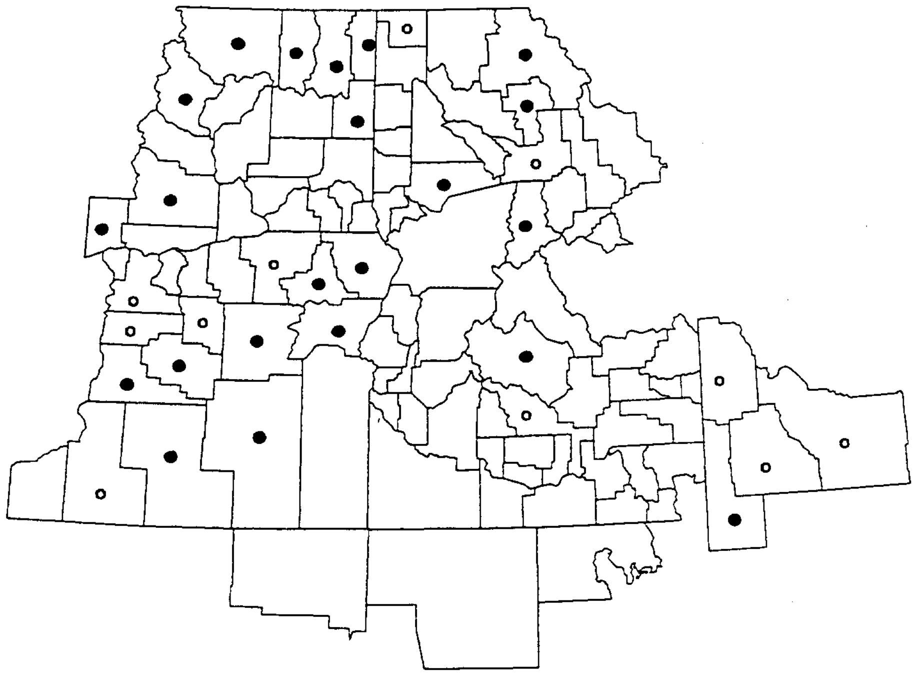
Botrychium pedunculosum



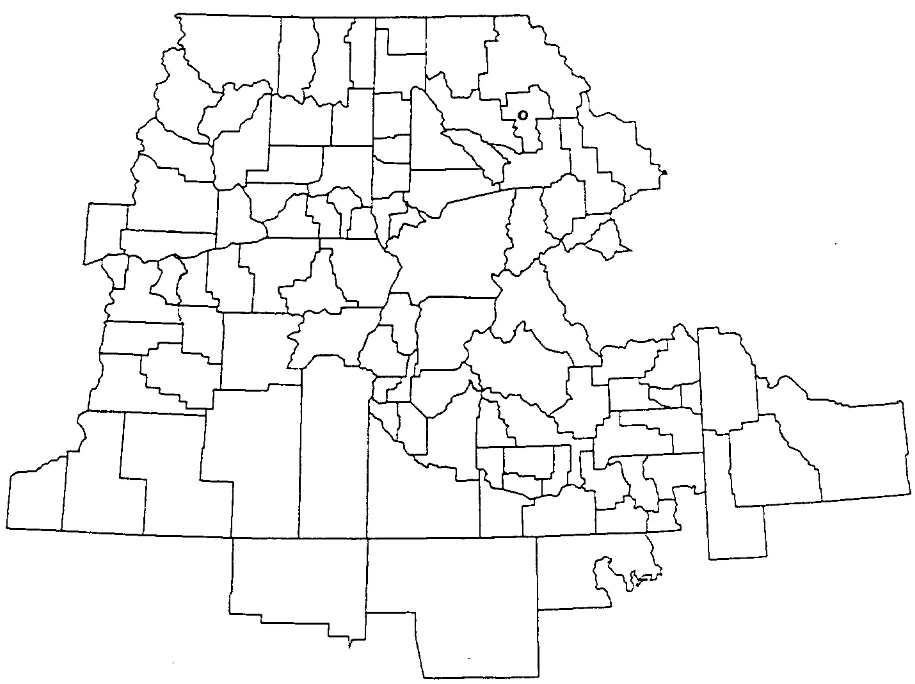
Botrychium pinnatum



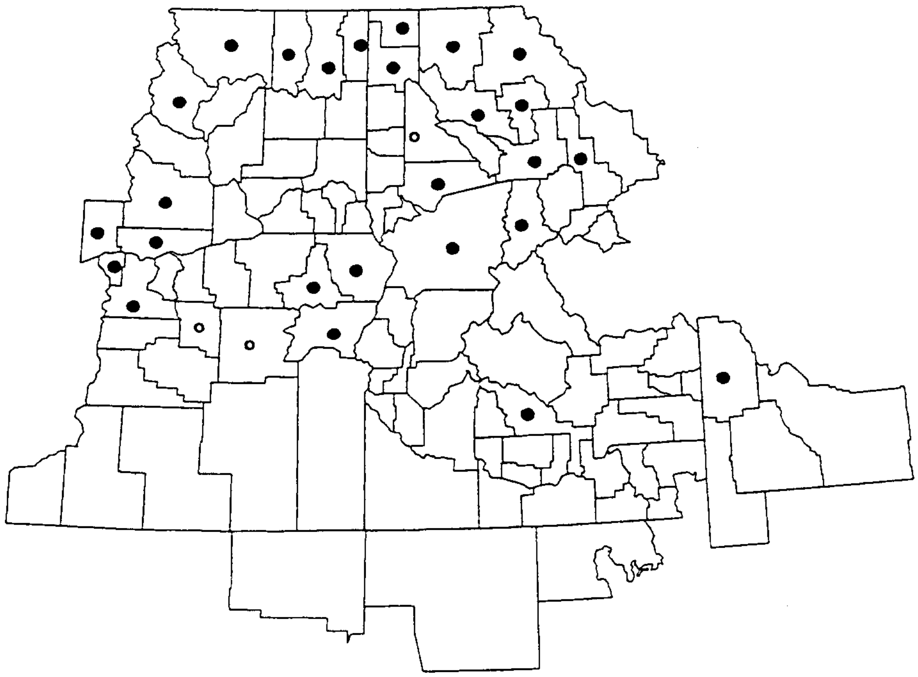
Botrychium pumicola



Botrychium simplex



Botrychium spathulatum



Botrychium virginianum

Figure 4. Total *Botrychium* taxa in each county.

Total Botrychium Taxa by County

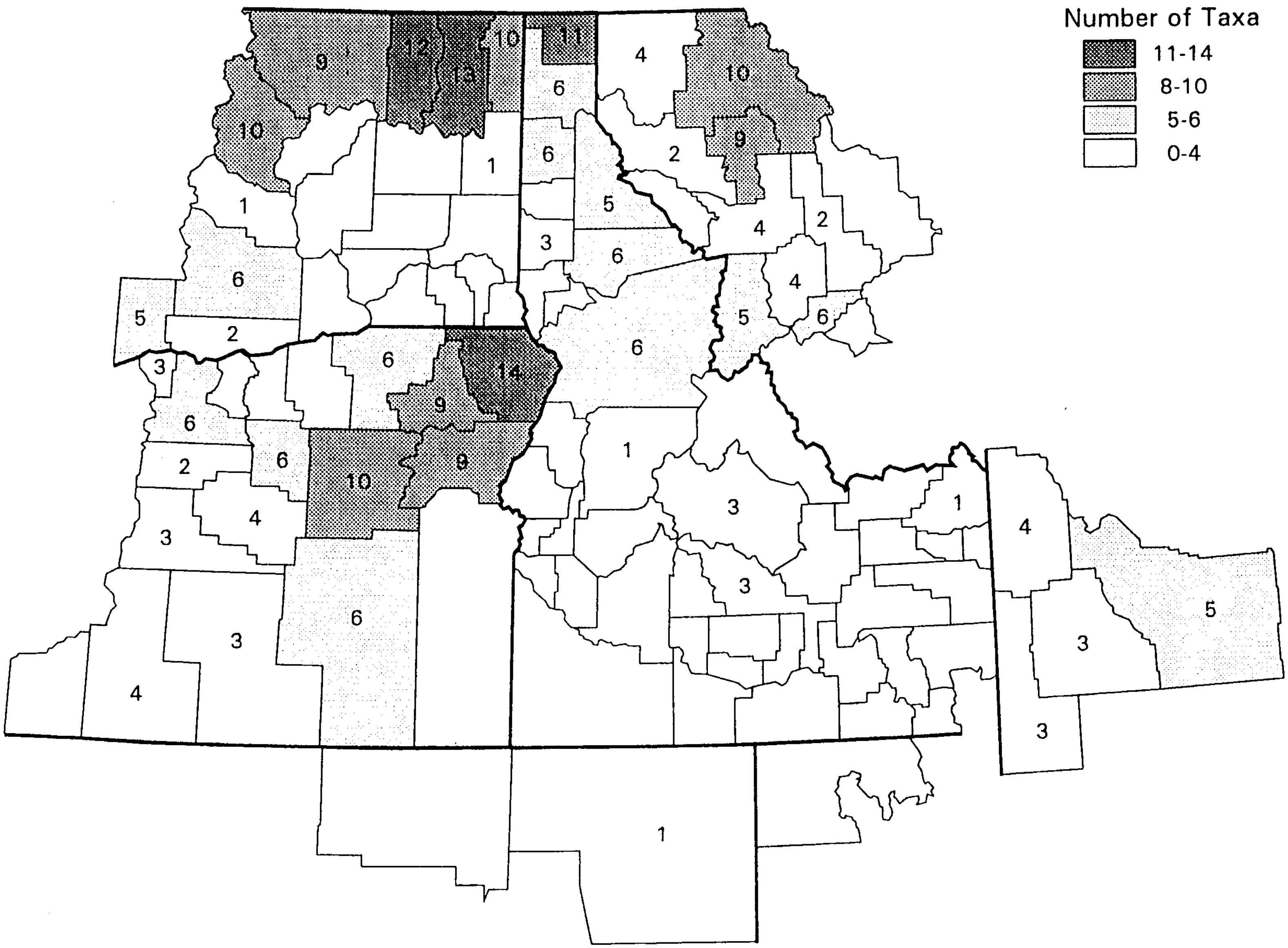


Figure 5. Rare *Botrychium* in each county.

Rare Botrychium Taxa by County

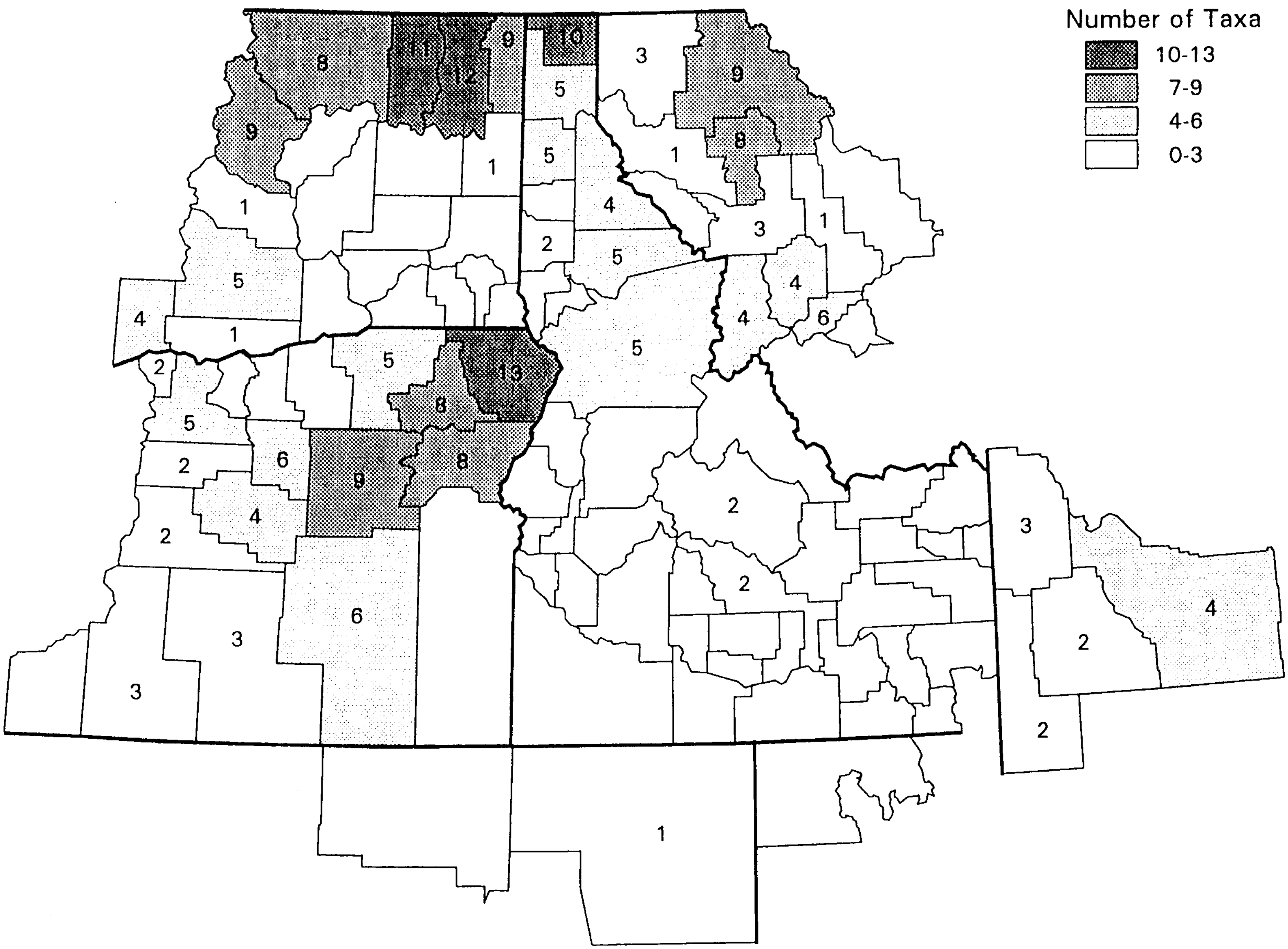
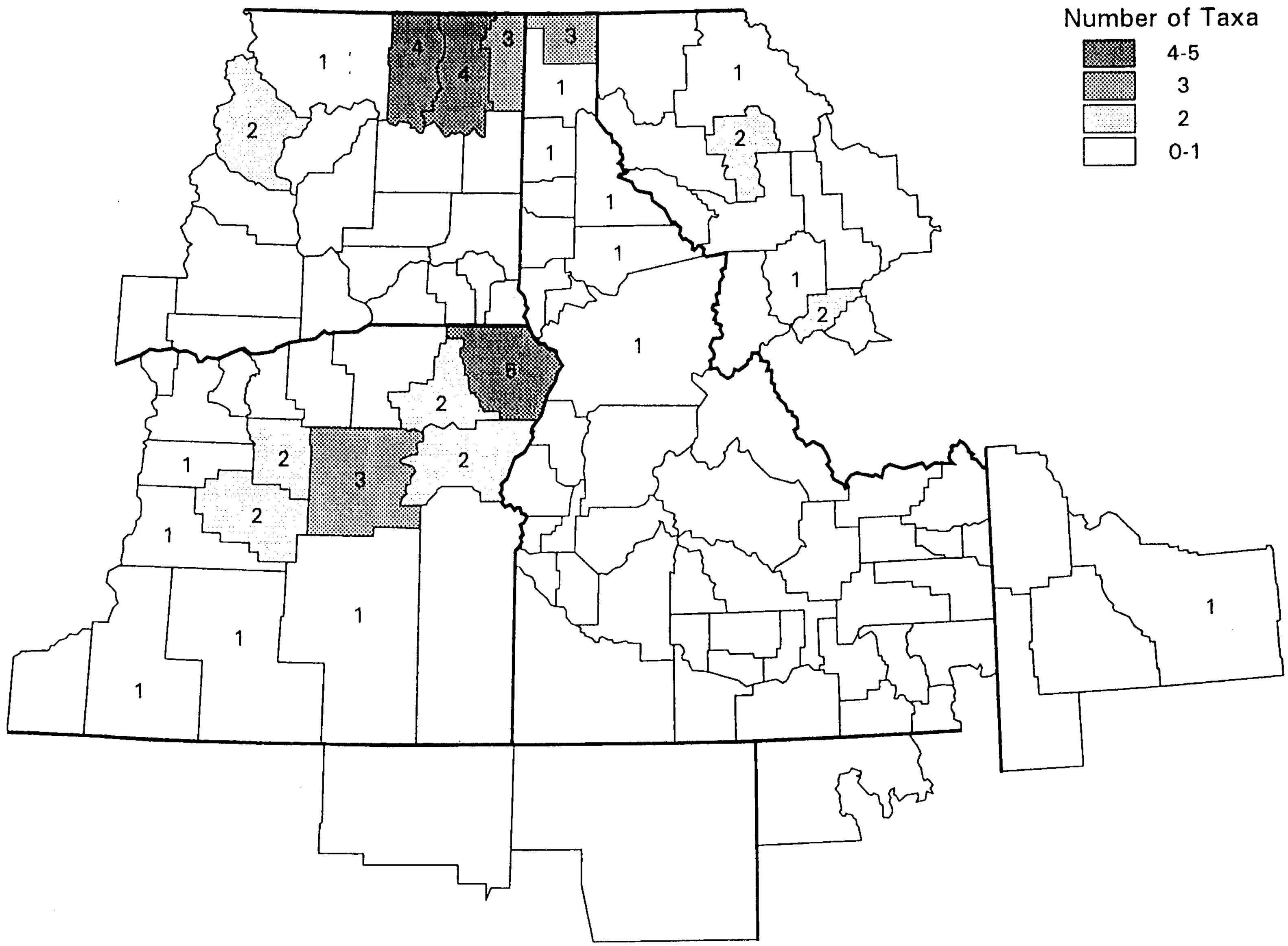


Figure 6. Federal candidates in each county.

Federal Candidate Botrychium Taxa by County



TABLES

Table 1. Recognized *Botrychium* taxa in the EEMP project area.

Nomenclature and vernacular names from Wagner and Wagner (1993) in Flora of N. America.

Botrychium (17 taxa)

*	*B. ascendens* W. H. Wagner	upswept moonwort
*	*B. campestre* W. H. Wagner & Farrar	prairie moonwort
*	*B. crenulatum* W. H. Wagner	dainty moonwort
*	*B. hesperium* (Maxon & Clausen) W. H. Wagner & Lellinger	western moonwort
*	*B. lanceolatum* (S. G. Gmelin) Angstrom ssp. *lanceolatum*	triangle moonwort
*	*B. lineare* W. H. Wagner	skinny moonwort
*	*B. lunaria* (L.) Swartz	common moonwort
*	*B. minganense* Victorin	Mingan moonwort
*	*B. montanum* W. H. Wagner	western goblin
	B. multifidum (S. G. Gmelin) Ruprecht	leather grapefem
*	*B. paradoxum* W. H. Wagner	paradox moonwort
*	*B. pedunculosum* W. H. Wagner	stalked moonwort
*	*B. pinnatum* H. St. John	northwestern moonwort
*	*B. pumicola* Coville in L. Underwood	pumice moonwort
*	*B. simplex* E. Hitchcock	least moonwort
*	*B. spathulatum* W. H. Wagner	spatulate moonwort
*	*B. virginianum* (L.) Swartz	rattlesnake fern

* = r/t/e in at least one EEMP state

Table 2. Herbarium acronyms.

This table translates the standard acronyms (Holmgren et al. 1981) used by botanists to designate herbaria. It is a composite of the museums visited in this study and those cited in literature used to assemble the distribution maps (Figure 3).

Acronym	Institution and Location
ASC	Northern Arizona University, Flagstaff, Arizona
BC	Institut Botanic de Barcelona, Catalonia, Spain
BH	Cornell University, Ithica, New York
BOIS	Forest Service, Boise, Idaho
BRY	Brigham Young University, Provo, Utah
CAN	National Museum of Natural Sciences, Ottawa, Ontario
CAS	California Academy of Sciences, San Francisco, California
CIC	College of Idaho, Caldwell, Idaho
CU	Cornell University, Ithaca, New York
DAO	Biosystematics Research Inst., Ontario, Canada
DS	Stanford University, San Francisco, California
FNLO	Forest Service, Lakeview, Oregon
GH	Harvard University, Cambridge, Massachusetts
HSC	Humboldt State University, Arcata, California
ID	University of Idaho, Moscow, Idaho
JEPS	University of California, Berkeley, California
K	Royal Botanic Gardens, Kew, England
KANU	University of Kansas, Lawrence, Kansas
LA	University of California, Los Angeles, California
LCU	Catholic University of America, Washington, D.C.
MICH	University of Michigan, Ann Arbor, Michigan
MO	Missouri Botanical Garden, St. Louis, Missouri

Acronym	Institution and Location
MONTU	University of Montana, Missoula, Montana
MRC	Forest Service, Missoula, Montana
MT	Universite de Montreal, Montreal, Quebec
NY	New York Botanical Garden, Bronx, New York
ORE, OSC, WILLU	Oregon State University, Corvallis, Oregon
POM	Rancho Santa Ana Botanic Garden, Claremont, California
QFA	Universite Laval, Sainte-Foy, Quebec
RM	University of Wyoming, Laramie, Wyoming
SOC SOSC	Southern Oregon State College, Ashland, Oregon
UBC	University of British Columbia, Vancouver, British Columbia
UC	University of California, Berkeley, California
US	Smithsonian Institution, Washington, D.C.
USFS	University of Wyoming, Laramie, Wyoming
WELC	Wellesley College, Wellesley, Massachusetts
WS	Washington State University, Pullman, Washington
WTU	University of Washington, Seattle, Washington

Table 3. ***Botrychium*** **synonymy in the EEMP project area.**

NOTE: format of synonymy is:
(synonym = accepted name for this report)

Botrychium

ascendens
boreale
boreale ssp. obtusilobum = pinnatum
boreale var. obtusilobum = pinnatum
califomicum = multifidum
campestre
coulteri = multifidum
crassinervium var. obtusilobum = pinnatum
crenulatum
hesperium
kannenbergii f. compositum = simplex
lanceolatum ssp. lanceolatum
lineare
lunaria
lunaria ssp. minganense = minganense
lunaria var. minganense = minganense
lunaria var. onondagense of authors = minganense
matricariae = multifidum
matricariifolium
matricariaefolium var. lanceolatum = lanceolatum
. matricariifolium ssp. hesperium = hesperium
matricariifobum var. hesperium = hesperium
minganense
montanum
multifidum
multifidum ssp. silaifolium = multifidum
multifidum ssp. califomicum = multifidum
multifidum ssp. coulteri = multifidum
multifidum var. califomicum = multifidum
multifidum var. compositum = multifidum
'multifidum var. coulteri = multifidum
neglecturn = matricariifolium
occidentale = multifidum
onondagense = lunaria shade form
palmatum = multifidum
paradoxum
pedunculosum
pinnatum
pumicola
ramosum = matricariifolium
rutaceum = multifidum
rutaefolium = multifidum
silaifolium = multifidum
silaifolium var. **coulteri** = multifidum
simplex
simplex var. compositum = simplex
simplex var. tenebrosum = simplex
spathulatum
tenebrosum = simplex
tematum = multifidum
tematum var. coulteri = multifidum
virginianum
virginianum var. europaeum = virginianum
virginianum var. occidentale = virginianum

Table 4. *Botrychium* in North America north of Mexico.

Based on Wagner & Wagner (1993, 1994).

Botrychium:

acuminatum *
ascendens *
bitematum *
boreale
campestre *
crenulatum *
dissectum
echo *
gallicomontanum *
hesperium *
jenmanii
lanceolatum ssp. angustisegmentum *
lanceolatum ssp. lanceolatum
lineare *
lunaria
lunarioides *
matricariifolium
minganense *
montanum *
mormo *
multifidum
oneidense *
pallidum *
paradoxum *
pedunculosum *
pinnatum *
pseudopinnatum *
pumicola *
rugulosum *
simplex
spathulatum *
virginianum

* = endemic to.North America

Table 5. Excluded species.

There are reports from several taxonomists that some undescribed species exist in the EEMP study area, but there is no reasonable way to collect data and treat these unnamed plants, until they are formally described in the scientific literature. All unpublished species are excluded.

Botrychium taxa	Citation	Native range	Mistaken for
B. boreale	Hitchcock et al. 1969; Welsh et al. 1987; WNHP 1981; Shetler & Skog 1978; Holmgren & Reveal 1966	n. Europe, Greenland	*B. pinnatum* in New World
B. dusenii	Sidall et al. 1979; ONHP 1991; Wagner & Wagner 1981	South America	*B. crenulatum*
B. echo	reports from Umatilla NF 1994	Arizona, Colorado & Utah	An undescribed species (W. H. Wagner pers. comm.)
B. lanceolatum var. *angustisegmentum*	Morin 1993	eastern US, w. as far as Minnesota	*B. lanceolatum* ssp. *lanceolatum* by [an unnamed map editor in] Flora of North America
B. matricariifolium	Hitchcock et al. 1969; WNHP 1981; Davis 1952; Shetler & Skog 1978; Piper & Beattie 1915; Rydberg 1932; Dorn 1984; Lorain 1990	Europe and eastern US, w. as far as Minnesota	*B. pinnatum* and *B. lanceolatum* [judging from misidentifications in herbaria]; possibly an undescribed sp. is the source of some reports

Table 6. Taxonomic problems in *Botrychium.*

Authorities of the species can be referenced in Table 1, Wagner & Wagner (1993), or in Kartesz (1994a,b). Parenthetical chromosome counts are from F. Wagner (1993). Additional taxonomic problems exist with as yet unresolved and unpublished species (E. Alverson pers. comm., D. Wagner pers. comm., F. Wagner pers. comm., W. H. Wagner pers. comm.).

B. ascendens -- (n=90) A split from the *B. minganense* complex. -Narrow forms complicate the boundaries with *B. lineare.* Quite similar to *B. campestre* of the prairies.

B. campestre -- (n=45) A split from the *B. minganense* complex. Gleason & Cronquist (1991) did not accept this as more than a hexaploid form of *B. minganense. B. gallicomontanum* (n=?) is a grazing sensitive isolate in Minnesota, presumably derived from hybridization between *B. campestre* and *B. simplex* (Farrar & Johnson-Groh 1991).

B. crenulatum -- (n=45) A split in the middle of morphological gradient between *B. lunaria* and *B. minganense*. Frequently misidentified with both.

B. hesperiwn -- (n=90) Similar to and considered a subspecies of widespread *B. matricariifolium* (n=90) by earlier authors (e.g., Clausen 1938, Harrington 1954). Differing in chromosome level and other minor features from *B. pseudopinnanun* (n= 135, F. Wagner 1993). Could be confused with any member of the *B. matricariifolium* complex, which aside from *B. lanceolatum, B. pinnatum* and *B. pedunculosum* are not otherwise in the study area. Gleason and Cronquist (1991) lumped *B. hesperium in B. lanceolatum var. lanceolatum.*

B. lanceolatum ssp. *lanceolatum* -- (n=45) Confused with the eastern subspecies *angustisegmentum* (n=45), see note in Table 5. This taxon raises the issue of why there are so many full species in the genus, and not more subspecies. Small forms are sometimes confused with *B. pinnatum.*

B. lineare -- (n=?) An odd plant, an extreme morphological split from the *B. minganense* complex. It would be most likely confused with *B. ascendens* or *B. campestre.* Other species are known to have skeletonized forms (Wagner and Wagner 1994).

B. lunaria -- (n=45) As currently defined, a fairly uniform plant morphologically, with a global distribution (Wagner & Wagner 1993). Frequently *confused* with *B. minganense* and *B. crenulatum* in our area. Juvenile western North American forms of *B. simplex are the source* of many of the *B. Zunaria* records that are inexplicably difficult to eradicate from the ONHP database.

B. minganense -- (n=90) A controversial split from *B. lunaria.* Wagner & Lord (1956) set the foundation of the current splitter's philosophy with this taxon *(B. minganense),* based on small differences. Cronquist steadfastly refused to accept it as different from *B. lunaria,* based on overall similarities (Cronquist et al. 1972, Hitchcock & Cronquist 1973, Hitchcock et al. 1969). Still not accepted by Gleason and Cronquist in 1991, when it was given only a parenthetical comment, noting it was much like shade forms of *B. lunaria* (called *B. lunaria* var. *onondagense* but with no valid claim to taxonomic status as a shade form).

An increasingly narrow definition on *B. minganense* has lead to the taxonomic splits of *B. crenulatum, B. pallidum, B. spathulatum, B. campestre, B. mormo, B. montanum.* and *B. ascendens.* Any of these species can be confused with each other, and with juvenile forms of *B. simplex.* Skeletonized forms of *B. minganense,* like the cover illustration, are easily passed *off as B. paradoxum* or *B. lineare.* This narrowing view of *B. minganense* promises , more **taxa** will be split in *the* future *(e.g., B. lineare* Wagner & Wagner 1994).

B. monranum -- (n=ca. 45) Close to the more eastern *B. mormo,* and even Wagner and Wagner (1993) suggest, that the two may differ only at the subspecific level.

B. multifidum -- (n=45) Unique in the EEMP area, but the subgenus *Sceptridium* is-quite complicated in the eastern US and in Asia. Difficult to tell from forms of *B. robustum, B. rugulosum, B.* oneidense and *B. dissectum.*

B. paradoxum -- (n=90) An odd fern morphology, split from *the B. minganense* complex. It can only be c&fused with monstrosities and shade forms of other species, such *as B. minganense, B. montanum* and skeletonized *B. pedunculosum* (Zika pers. obs.). The hybrid fern *B. x watertonense* (n =90) is a cross between *B. paradoxum* and *B. hesperium* and can be confused with *B. paradoxum* (Wagner et al. 1983).

B. pedunculosum -- (n=90) A split **from** *the B. matricariifolium* complex, and most likely to be confused with *B. pinnatum* or *B. hesperium.* The marginal sporangia on the lower **pinnae,** used as a diagnostic in keys, can lead to confusion with nearly any other species, for supernumerary sporangia are sometimes present in most members of the subgenus. The red stem coloration is also misinterpreted as **unique, and** leads to confusion with *B. virginianum* (!), *B. pinnatum* and *B. pinnatum.*

B. pinnatum -- (n=90) Confused with and perhaps conspecific **with** *B. boreale* (an Old World **taxon**). See note in Table 5, **excluded** species. Narrowly differentiated from *B. pseudopinnatum, B. echo, B. hesperium* and *B. matricariifolium.* Aberrant forms from the **study area (e.g.,** *Zika* 11342 OSC, **Wallowa** Co., OR) with acuminate tips blur the morphological boundaries between *B. pinnatum, B. matricariifolium* and *B. acuminatum* (F. Wagner 1993).

B. pumicola -- (n=45) Strikingly similar to *B. simplex* in western North America, **and** surely derived from that globally distributed species. Only known record in California (Munz 1968 p. 3) based on a misidentification (Skinner & Pavlik 1994 p. 84). **Depauperate** plants could be confused with *B. lunaria* but large plants are clearly differentiated.

B. simplex -- (n=45) Well-formed plants are mistaken only for *B. pumicola* in the western US. The abundance of immature plants inevitably leads to confusion with *B. minganense* and *B. lunaria,* as on the Mt. Hood National Forest (Zika 1992b) and Steens Mt, Hamey Co., OR.

B. *spathulatum* -- (n=90) A split from *the B. minganense* complex, **q.v.** Repeatedly reported, in error, from far west of the Rocky Mountains.

Table 7. Type localities.

Species	Type Description	Locality
Bonychium ascendens	Wagner & Wagner (1986)	Hurricane Cr., Wallowa Co., OR; ECWA, WWNF
Botrychium campesrre	Wagner & Wagner (1986)	Plymouth Co., Iowa
Botrychium crenulatum	Wagner &Wagner (1981)	Los Angeles Co., CA
Botrychium hesperium	Wagner-& Wagner (1983c)	Boulder Co., CO
Botrychium lanceolatum	Angström (1854)	Europe
Botrychiwn lineare	Wagner & Wagner (1994)	Lostine River, Wallowa Co., OR; WWNF
Botrychium lunaria	Swartz (1800)	Europe
Bonychium minganense	Victorin (1927)	Quebec, Canada
Botrychium montanum	Wagner & Wagner (1981)	Swan Valley, Lake Co., MT
Bonychium multifidum	Ruprecht (1859)	Russia
Botrychium paradoxum	Wagner & Wagner (1981)	Storm Lake, Deerlodge Co., MT; DNF
Bonychium pedunculosum	Wagner & Wagner (1986)	Lostine River, Wallowa Co., OR; WWNF
Bonychium pinnarwn	St. John (1929)	Mt. Adams, Yakima Co., WA; GPNF
Botrychium pumicola	Underwood (1900)	Llao Rock, Crater Lake, Klamath Co., OR; CLNP
Botrychium simplex	Hitchcock (1823)	Franklin Co., MA
Bonychium spathulatum	Wagner & Wagner (1990a)	Ontario, Canada
Bonychium virginianum	Swartz (1800)	Virginia

Explanation of codes:

CLNP = Crater Lake National Park
ECWA = Eagle Cap Wilderness Area
GPNF = Gifford Pinchot National Forest
WWNF = Wallowa-Whitman National Forest

Table 8. Western North America endemics.

Approximate center of range is based on maps in Wagner and Wagner (1993) and data collated for this report.

Botrychium species	West to East range limits	Approximate center of range
B. acuminatum	Ontario	Upper Great Lakes
B. ascendens	Alaska to Ontario	western Montana
B. campestre	Oregon to New York	South Dakota
B. crenulatum *	California to Wyoming	northern Nevada
B. echo *	Arizona to Colorado	Utah
B. gallicomontanum	Minnesota	Minnesota
B. hesperium	British Columbia to Ontario	western Wyoming
B. montanum *	British Columbia to Montana	Oregon
B. mormo	Minnesota to Michigan	Wisconsin
B. paradoxum	British Columbia to Saskatchewan	western Montana
B. pedunculosum	British Columbia to Saskatchewan	southern Alberta
B. pinnatum *	Alaska to Colorado	southern British Columbia
B. pseudopinnatum	Ontario	southern Ontario
B. pumicola *	Oregon	Oregon

* = western cordilleran endemics

Table 9. Public and Indian lands in counties with significant *Botrychium* populations.

Note that *Botrychium* habitat and populations, like Indian Nation and public lands, do not follow county lines perfectly.

BLM = Bureau of Land Management DOD = Department of Defense
NF = National Forest NM = National Monument NP = National Park
NRA = National Recreation Area NWR = National Wildlife Refuge
RA = Resource Area RD = Ranger District RNA = Research Natural Area
WA = Wilderness Area

State	County	Public Lands
ID	Boundary	1) Idaho Panhandle NF (Kaniksu NF, Bonners Ferry RD, Priest Lake RD) 2) Kootenai NF 3) Kootenai NWR 4) Kootenai Indian Reservation 5) State lands
ID	Bonner	1) Idaho Panhandle NF (Kaniksu NF, e.g., Priest Lake RD, Priest R. Exper. Forest, Canyon Creek RNA, Bonners Ferry RD, Sandpoint RD; Couer d'Alene NF) 2) Kootenai NF 3) Coeur D'Alene District BLM (Emerald Empire RA) 4) State lands
ID	Clearwater	1) Clearwater NF (Palouse RD, North Fork RD) 2) Idaho Panhandle NF (St. Joe NF, St. Maries RD) 3) Nez Perce Indian Reservation 4) State lands
ID	Idaho	1) Nez Perce NF (e.g., Selway RD) 2) Clearwater NF (e.g., North Fork RD, Powell RD, Selway-Bitterroot WA) 3) Bitterroot NF 4) Nez Perce Indian Reservation 5) Hells Canyon NRA 6) BLM 7) Payette NF 8) State lands

State	County	Public Lands
ID	Kootenai	1) Idaho Panhandle NF (Kaniksu NF, Fernan RD, Sand Point RD) 2) BLM 3) Coeur D'Alene Indian Reservation 4) State lands
MT	Flathead	1) Glacier NP 2) Flathead NF (Swan Lake RD, Glacier View RD, Hungry Horse RD) 3) Kootenai NF 4) Lolo NF 5) Flathead Indian Reservation 6) State lands
MT	Lake	1) Flathead NF (Swan Lake RD) 2) Lolo NF 3) National Bison Range (USFWS) 4) Flathead Indian Reservation 5) State lands (e.g., Swan River State Forest)
MT	Deer Lodge	1) Deer Lodge NF (Deer Lodge RD; Philipsburg RD Bopa in Granite Co.) 2) State lands
NV	Elko	1) Humboldt NF 2) BLM 3) Duck Valley Indian Reservation
OR	Deschutes	1) Newberry Crater NM (Deschutes NF) 2) Prineville BLM, Deschutes RA 3) Deschutes NF
OR	Harney	1) Ochoco NF 2) Malheur NF 3) Burns District BLM (e.g., Andrews RA, Steens Mt. Recreation Area, & Willow Cr. RNA) 4) Malheur NWR 5) Burns Paiute Indian Reservation 6) State lands
OR	Klamath	1) Winema NF (Chemult RD) 2) Fremont NF 3) Prineville BLM (Deschutes RA) 4) Crater Lake NP (e.g., proposed Llao Rock RNA; a type locality) 5) Deschutes NF (Crescent RD & Fort Rock RD) 6) State lands

State	County	Public Lands
OR	Lake	1) Fremont NF (Silver Lake RD) 2) Deschutes NF (Fort Rock RD) 3) State lands
OR	Wallowa	1) Umatilla NF 2) Wallowa-Whitman NF (e.g., Lostine R. scenic corridor, with 2 type localities; Eagle Cap RD, Eagle Cap WA with 1 type locality on Hurricane Cr.) 3) BLM 4) State lands 5) Hells Canyon NRA
OR	Grant	1) Malheur NF 2) Ochoco NF 3) Umatilla NF 4) BLM 5) John Day Fossil Beds National Monument 6) State lands
OR	Baker	1) Malheur NF 2) Wallowa-Whitman NF 3) BLM 4) State lands
OR	Union	1) Umatilla NF 2) Wallowa-Whitman NF 3) BLM 4) State lands
OR	Wheeler	1) Ochoco NF 2) Umatilla NF 3) BLM 4) John Day Fossil Beds NM 5) State lands
WA	Chelan	1) Wenatchee NF 2) Lake Chelan NRA 3) North Cascades NP
WA	Okanogon	1) Yakima Indian Reservation 2) Okanogon NF 3) Conboy Lake NWR 4) Colville Indian Reservation
WA	Stevens	1) Colville NF (e.g., Kettle Falls RD) 2) Little Pend Oreille NWR 3) Colville Indian Reservation
WA	Ferry	1) Colville NF

State	County	Public Lands
WA	Pend Oreille	1) Colville NF 2) Idaho Panhandle NF (Kaniksu NF) 3) Kalispell Indian Reservation
WY	Fremont	1) Bridger-Teton NF
WY	Teton	1) Bridger-Teton NF 2) Targhee NF 3) Yellowstone NP 4) Grand Teton NP 5) National Elk Refuge 6) State lands

Table 10. Species richness summaries.

Land ownership priorities (Table 9) were primarily based on the following concentrations of total and rare Botrychium species:

Key: T = total Botrychium species occurring in county (from Figure 4)
R = total rare species (federal and state lists) occurring in county (from Figure 5)
F = species with federal status occurring in county (from Figure 6)

Counties that have been struck out were considered but not included.

State	County	T	R	F
Idaho	Boundary	11	10	2
	Bonner	6	5	1
	Clearwater	6	5	1
	Idaho	6	5	1
	Kootenai	6	5	1
	~~Shoshone~~	~~5~~	~~4~~	~~1~~
Montana	Flathead	10	9	1
	Lake	9	8	1
	Deer Lodge	6	6	2
	~~Ravalli~~	~~5~~	~~4~~	~~0~~
Nevada	Elko	1	1	0
Oregon *	Wallowa	14	13	5
	Grant	10	9	3
	Baker	9	8	2
	Union	9	8	2
	Wheeler	6	6	2
	Harney	6	6	1
	~~Umatilla~~	~~6~~	~~5~~	~~0~~
	~~Wasco~~	~~6~~	~~5~~	~~0~~
Washington	Stevens	13	12	4
	Ferry	12	11	4
	Chelan	10	9	2
	Pend Oreille	10	9	3
	Okanogan	9	8	1
	~~Yakima~~	~~6~~	~~5~~	~~0~~
	~~Skamania~~	~~5~~	~~4~~	~~0~~
Wyoming	Fremont	5	4	1
	Teton	4	3	0

* Several counties in the southern Oregon Cascades were added to Table 9 to include lands with *Botrychium pumicola*, the only regional endemic.

Table 11. Status of rare *Botrychium* species in the Columbia River basin.

Criteria for inclusion in table: 1) species occurs in EEMP study area, and 2) species listed by one or more natural heritage programs in the states within the study area.

Explanation of codes follows table.

Botrychium Species	US ESA	Global TNC	USFS	BLM	State TNC	Comments
ascendens	C2	G3?	R1:S R2:S R4:S R6:SOR	OR:FC WA:FC WY:C2	ID:S1 MT:S1 NV:S1 OR:S2 WA:S2 WY:S1	ODA:C ONHP:1 WYNDD:D
campestre		G2	R2:S	OR:BAO WY:FS	OR:S1 WY:S1	ONHP:2 WYNDD:D
crenulatum	C2	G3	R1:S R4:S R6:SOR	OR:FC UT:C2 WA:FC	ID:SU MT:S1 NV:S1? OR:S2 UT:S1 WA:S2S3	ODA:C ONHP:1 WYNDD:U
hesperium		G3	R1:S		MT:S1 UT:S1	MT:S WYNDD:U
lanceolatum ssp. lanceolatum		G5 T4	R1:S R6:S	OR:BA WA:BA	ID:S2 OR:S3 UT:S1 WA:S3 WY:S1	INPS:2 ONHP:2 WYNDD:P
lineare	C2	G1	R2:S	UT:C2	ID:SH MT:S1 OR:S1 UT:S1	
lunaria		G5	R6:S	OR:BA WA:BA	OR:S1 UT:S1 WA:S3	ONHP:2

Botrychium Species	US ESA	Global TNC	USFS	BLM	State TNC	Comments
minganense		G4	R1:S R6:S	OR:BAO WA:BTW	ID:S1 MT:S1 OR:S3 UT:S1	INPS:2 MT:S ONHP:2 WYNDD:U
montanum		G3	R1:S R6:S	OR:BA WA:BA	ID:S1 MT:S2 OR:S2 WA:S3	INPS:M ONHP:2
paradoxum	C2	G1G3?	R1:S R4:S	OR:BSO UT:C2 WA:BSW	MT:S1 OR:S1 UT:S1 WA:S1	ONHP:1
pedunculosum	C2	G3?	R6:SOR	OR:FC WA:FC	OR:S1 WA:S1	ODA:C ONHP:1
pinnatum		G4?G5	R1:S R6:S	OR:BA WA:BA	ID:S1 OR:S2S3 UT:S1 WA:S3	INPS:2 ONHP:2 WYNDD:U
pumicola	C1	G3	R6:SOR	OR:FC	OR:S3	Regional endemic ONHP:1
simplex		G5	R1:S R4:E R6:SWA	WA:BAW	ID:S1 OR:S5 UT:S1 WA:S2	INPS:2 ONHP:C WYNDD:W
spathulatum		G2G3			MT:S1	
virginianum		G5			OR:S4 WY:S1	ONHP:C WYNDD:P

Explanation of codes

- **U.S. ESA** The U.S. Endangered Species Act (P.L. 93-205, 1973 and amendments).

The U.S. Fish & Wildlife Service occasionally summarizes changes in the legal federal status of taxa in the Federal Register (see F.R. 30 September 1993).

Category 1 = Sufficient data indicate taxon is appropriate for federal listing as threatened or endangered.

C1

Category 2 = Possibly appropriate for federal listing as threatened or endangered. Further research needed to assess status.

c2

Category 3 = No longer receiving federal consideration for listing as threatened or endangered.

3A = Persuasive evidence of extinction
3B = Indistinct taxon, considered a synonym of a common taxon
3C = More widespread or abundant than once believed, or not subject to identifiable threats

- **Global TNC** ratings.

Global and State TNC status is based on the most recently published state Natural Heritage Program publication. See Master (1991) for detailed explanation of TNC ranking system given under state and global columns.

G is a rangewide, or global ranking
S is a statewide ranking
T is a rangewide (global) trinomial ranking of an infraspecific taxon, (e.g., a var. or a ssp.)
U is unknown
Q indicates some question about the taxonomic status
? means the ranking is not completed

SH = formerly part of the state's native flora, implying that it may be rediscovered
GX or SX = Presumed extinct or extirpated, Globally, or Statewide
G1 or S1 = critically imperiled (usually 5 or fewer populations)
G2 or S2 = imperiled (usually 6-20 populations)
G3 or S3 = uncommon or rare but not imperiled (usually 21-100 populations)
G4 or S4 = Not rare, apparently secure, some cause for long-term concern (usually

more than 100 populations)
G5 or S5 = Globally secure, or statewide secure

ID status is from Conservation Data Center (1994).
MT status is from Heidel (1994).
OR status is from ONHP (1993), and EEMP project research.
UT status is from unpublished file data, Utah Natural Heritage Program (received 1994)
WA status is from WNHP (1994)
WY status is from Fertig (1994)

● USFS

A U.S. Forest Service "Sensitive" ranking (by Region), based on the most recent Region Sensitive Species List.

The regions are:

R1 = Region 1, Northern Region (The Regional Forester last updated the sensitive species list 10 June 1994)
R2 = Region 2, Rocky Mountain Region
R4 = Region 4, Intermountain Region (Updated 29 April 1994)
R6 = Region 6, Pacific Northwest Region (Updated March 1991, suggested March 1993 revisions not yet formalized)

S = Sensitive is defined in FS Manual 2670, as taxa for which viability is a concern, as evidenced by significant current or predicted downward trends in population numbers or density, or significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

R6:SOR = Sensitive in Oregon but not Washington in Region 6
R6:SWA = Sensitive in Washington but not Oregon in Region 6

PS = Proposed for sensitive status
W = Watch List, limited distribution but no current threats, or only suspected to be on USFS land in the Region
E = Edge [of range], important in biodiversity analysis, generally quite rare in Region (4)
FS-TNF = Forest Sensitive in Teton National Forest, Region 4 (Fertig 1994)

● BLM

The following states do not have a sensitive species list approved by the State Director: Nevada, Utah, Wyoming, and Montana. Idaho, Oregon and Washington have a sensitive species list approved by the State Director, under policies established in BLM Manual 6840. All states keep track of any Federal Candidates (C2, Cl) on their lands, as required by law and policy. Some states are also concerned with other categories of rare plants, as noted below.

ID: list updated lo-1992
- no *Botrychium* on official list
- track C2 spp.

MT: no official list
- track C2 spp. and MNHP species

NV: no official list
- track C2 spp.

OR: list updated 9-7-1994
- BA, BAO = Bureau assessment, a review for sensitive status (ONHP List 3,4)
- BS, BSO = Bureau sensitive (ONHP list 1, and/or State candidate)
- FC = Federal candidate (Cl, C2)

UT: no official list
- keeps track of federal candidate (C2) spp. known to occur in state

WA: list updated g-7-1994
- BA, BAW = Bureau assessment (a review for sensitive status; Washington Dept. of Natural Resources [WDNR] found, in WA, was vulnerable, declining, or could become threatened or endangered without active management)
- BS, BSW = Bureau sensitive (WDNR rated as threatened or endangered in WA)
- BT, BTW = Bureau tracking (WDNR monitors; potential concern but no current conservation status)
- FC = Federal candidate (Cl, C2)

WY: no official list
- keeps track of federal candidate (C2) spp. as well as
- FS = Forest Service Forest Sensitive species

● Comments

Endemism

Noted if a regional endemic.

Idaho

INPS (Idaho Native Plant Society) ratings, reported in CDC (1994).

INPS:1 = Priority 1. In danger of becoming extinct or extirpated in Idaho in the foreseeable future

INPS:2 = Priority 2. Likely to become Priority 1 in Idaho in the foreseeable future, if population declines 'or habitat loss continues

INPS:M = Monitor. Common within a limited range, or no identifiable threats in Idaho

INPS:R = Review. May be of conservation concern in Idaho; more research is needed to evaluate status

INPS:S = Sensitive. Populations and habitats may be jeopardized without active management or removal of threats in Idaho

INPs:x = Historical/Extirpated. Taxa which are known in Idaho only from historical (pre-1920) records or are considered extirpated from the state by the 'INPS

ID:N = No evidence of ID occurrence, misidentification (Whitkus thesis)

ID:C = Common to abundant, dropped from consideration in ID (CDC 1994, p.22)

Montana

Montana Natural Heritage Program ratings (Lesica and Shelly 1991).

MT:S = Sensitive. May become threatened or endangered within Montana, has limited populations or restricted habitats

Nevada

Northern Nevada Native Plant Society (NNNPS) status (Morefield and Knight 1992, Morefield 1994)

NV:A = Absent from Nevada. currently and historically (but previously reported)

NV:D = Deleted, presently secure or indistinct taxon in NV

There are no *Botrychium* protected under Nevada state law (NRS 527.260-.300) as of 1 Feb 1994.

Oregon

Oregon Dept. of Agriculture status (ONHP 1993) under the state endangered species act of 1987 (ORS 564.100-564.135).

ODA:C = Candidate for state listing as threatened or endangered

Oregon Natural Heritage Program (ONHP 1993) rankings

ONHP: 1 = Endangered or threatened throughout range
ONHP:2 = Endangered or threatened in Oregon but more common elsewhere
ONHP:3 = Review of status needed to determine if qualified for categories 1 or 2
ONHP:4 = Rare but secure, or declining but too common for listing as threatened or endangered in Oregon; watch list
ONHP:C = Common and/or secure, so dropped from consideration as a state rare, threatened or endangered species
ONHP:N = Never documented in Oregon, although reported in literature

Wyoming

Wyoming Natural Diversity Database rankings (Fertig 1994)
WYNDD:D = Disjunct in WY
WYNDD:P = Populations in WY peripheral to contiguous range
WYNDD:R = Regional endemic, taxon range is smaller than WY
WYNDD:U = Uncertain status, reported from WY
WYNDD:W = Watch list, dropped from higher WY status between 1993 and 1994

Table 12. Habitat groups.

Botrychium Species of Meadow/Open Habitats

ascendens
campestre
hesperium
lanceolatum ssp. lanceolatum
lineare
lunaria
minganense
multifidum
paradoxum
pedunculosum
pinnatum
pumicola
simplex
spathulatum

Botrychium Species of Marsh Habitats

crenulatum
multifidum
simplex
virginianurn

Botrychium Species of Forest Habitats

crenulatum reports
minganense
montanum
multifidum
pinnatum'
virginianum

Table 13. Panel forms for species groups.

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Paneiist Name: Zika
Species or Species Group: **BOTRYCHIUM -- MEADOW SPECIES GROUP**
Province and/or Section: All except desert Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Canopy cover
   Categorical ✓
   Suitable Categories:
   1. No cover
   2. Partial shade, meadow margins
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?
2. Soil moisture regime
   Categorical ✓
   Suitable Categories:
   1. Mesic
   2. Xeric (rarely)
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season
3. Summer precipitation
   Categorical ✓
   Suitable Categories:
   1. Present
   Continuous __
   Unit. of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? Growing season
4. Saline-free soils
   categorical ✓
   Suitable Categories:
   1. Present
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity
2. Mammal food (perhaps serving rodents that disperse the spores by eating sporangia)

Threats

(Indicate L - M - H)

Change in fire regime: M (fire suppression)
Grazing: M
Mining: H

Exotics: M
Development: H
Timber harvest: M
Roads (explain): roads through meadows: medium; subsequent improved access and development: high
Others: Recreation impacts: trampling, camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H, depending on size of site
Others: Succession = M

Key Assumptions

1) Found throughout EEMP elevation range and latitude range, in a stunning variety of mesic meadows & assoc. spp.
2) In 100-500 year time scale: requires long-term maintenance of meadows, or natural "catastrophic" creation of new meadows nearby.

Comments

Diverse Botrychium community probably indicates rich biodiversity of vascular and non-vascular plants.
Representative species (if group): *Botrychium lanceolatum* ssp. *lanceolatum*

Dispersal

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
Requirements for dispersal: minimal exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses have driven endemic taxa to extinction in past 150 years.
Explanation for widely scattered populations of genus (besides obvious long-distance spore dispersal).
Nature of relations with fungal & vascular associates, native & introduced fauna.
Systematics.
Long-term effects of botanical collecting.
Demography of any western spp. in genus.
Effects of grazing by native ungulates (which are being managed for'increased numbers).
Causes of population cycles.

Monitoring needs:
Follow life history of rare & common spp for 10+ years in undisturbed "control" situations, to provide baseline for management decisions.
Monitor one species in variety of successional habitats over time.
Monitor populations (and recruitment) in natural disturbances (fire, landslide, snow avalanche, flood,-frost heaving, areas of heavy elk/deer grazing, etc.)
Monitor populations (and recruitment) in unnatural disturbances (mowed roadsides; grazed pastures, campgrounds, livestock staging areas, etc.)

Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of plant
More inventory to locate new populations & habitats.
Establish undisturbed genetic reserves at type localities and exceptionally diverse genus communities, for baseline research.
Improve taxonomy. Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi ✓ medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing ✓ unknown _

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Panelist Name: Zika

Species or Species Group: **BOTRYCHIUM -- MARSH SPECIES GROUP**

Province and/or Section: All except desert Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Canopy cover
   Categorical ✓
   Suitable Categories:
   1. No cover
   2. Partial shade, marsh margins

   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?

2. Soil moisture regime
   Categorical ✓
   Suitable Categories:
   1. moist or saturated

   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season

3. Saline-free soils
   Categorical ✓
   Suitable Categories:
   1. Present

   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity
2. Mammal food (perhaps serving rodents that disperse the spores by eating sporangia)

Threats

(Indicate L - M - H)

Change in fire regime: L
Grazing: M
Mining: H
Exotics: M

Development: H
Timber harvest: M
Roads (explain): altering hydrology, introducing exotics: H
Others: Recreation impacts: trampling, compaction from associated backcountry livestock: M to H
Others: Succession = M

Key Assumptions

1) Found throughout EEMP elevation range and latitude range, in a stunning variety of moist or wet meadows & assoc. spp.
2) In 100-500 year time scale: requires long-term maintenance of wet meadows, or natural "catastrophic". creation of new wet meadows nearby.

Comments

Diverse Botrychium community probably indicates rich biodiversity of vascular and non-vascular plants.
Representative species (if group): *Botrychium crenulatum*

Dispersal

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
Requirements for dispersal: minimal exotic livestock. trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses have driven endemic taxa to extinction in past 150 years.
- Explanation for widely scattered populations of genus (besides obvious spore dispersal)
- Nature of relations with fungal & vascular associates, native & introduced fauna.
- Systematics.
- Long-term effects of botanical collecting.
- Demography of any western spp. in genus.
- Effects of grazing by native ungulates (which are being managed for increased numbers).
- Causes of population cycles.

Monitoring needs:
- Follow life history of rare & common spp for 10+ years in undisturbed "control" situations, to provide baseline for management decisions.
- Monitor one species in variety of successional habitats over time.
- Monitor populations (and recruitment) in natural disturbances (fire, landslide, ~~snow~~ avalanche, flood, frost heaving, areas of heavy elk/deer grazing, etc.)
- Monitor populations (and recruitment) in unnatural disturbances (mowed roadsides, grazed pastures, campgrounds, livestock staging areas, etc.)

Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of plant
- More inventory to locate new populations & habitats.
- Establish undisturbed genetic reserves at type localities and exceptionally diverse genus communities, for baseline research.
- Improve taxonomy. Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi ✓ medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing ✓ unknown _

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Panelist Name:, Zika

Species or Species Group: **BOTRYCHIUM -- FOREST SPECIES GROUP**

Province and/or Section: All except desert & alpine Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Canopy cover
   Categorical ✓
   Suitable Categories:
   1. Complete cover
   2. Partial shade
   'Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? Growing season

2. Summer precipitation
   Categorical ✓
   Suitable Categories:
   1. Present
   Continuous __
   Unit of Measure: Minimum: Maximum!
   Applies seasonally? Yes ✓ No __ Which seasons? Growing season

3. *Saline-free* soils
   categorical ✓
   Suitable Categories:
   1. Present
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity
2. Mammal. food (perhaps serving rodents that disperse the spores by eating sporangia)

Threats

(Indicate L - M - H)

Change in fire regime: H (fire suppression)
Grazing: M
Mining: H
Exotics: H

Development: H
Timber harvest: H
Roads (explain): 'subsequent improved access and development: high
Others: Recreation impacts: firewood cutting, trampling, camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H, depending on size of site
Others: Succession = M

Key Assumptions

Found essentially throughout EEMP elevation range and latitude range, in most seral stages, with many different associated woody plants.

Comments

Diverse Botrychium community probably indicates rich biodiversity of vascular and non-vascular plants.
Representative species (if group): *Botrychium montanum*

Dispersal

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
Requirements for dispersal: minimal exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses have driven endemic taxa to extinction in past 150 years.
- Explanation for widely scattered populations of genus.
- Nature of relations with fungal & vascular associates, native & introduced fauna.
- Systematics.
- Long-term effects of botanical collecting.
- Demography of any western spp. in genus.
- Effects of grazing by native ungulates (which are being managed for increased numbers).
- Causes of population cycles.

Monitoring needs:
- Follow life history of rare & common spp for 10+ years in undisturbed "control" situations, to provide baseline for management decisions.
- Monitor one species in variety of successional habitats over time.
- Monitor populations (and recruitment) in natural disturbances (fire, landslide, ~~snow~~ avalanche, flood, frost heaving, areas of heavy elk/deer grazing, etc.)
- Monitor populations (and recruitment) in unnatural disturbances (mowed roadsides, grazed pastures, campgrounds, livestock staging areas, etc.)

Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of plant
- More inventory to locate new populations & habitats.
- Establish undisturbed genetic reserves at type localities and exceptionally diverse genus communities, for baseline research.
- Improve taxonomy. Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi ✓ medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing ✓ unknown _

Table 14. Panel forms for C2 candidate species.

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Panelist Name: Zika

Species or Species Group: ***Botrychium ascendens***

Province and/or Section: boreal/montane Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Canopy cover
   - Categorical ✓
     - Suitable Categories:
       1. No cover
       2. Partial shade, meadow margins, streamsides
   - Continuous __
     - Unit of Measure: Minimum: Maximum:
   - Applies seasonally? Yes __ No ✓ Which seasons?

2. Soil moisture
   - Categorical ✓
     - Suitable Categories:
       1. Mesic
       2. Xeric (rarely)'
   - Continuous __
     - Unit of Measure: Minimum: Maximum:
   - Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season

3. Summer precipitation
   - Categorical ✓
     - Suitable Categories:
       1. Present
   - Continuous __
     - Unit of Measure: Minimum: Maximum:
   - Applies seasonally? Yes ✓ No __ Which seasons? Growing season

4. Elevation
   - Categorical ✓
     - Suitable Categories:
       1. Moderate to subalpine
   - Continuous __
   - Unit of Measure: Minimum: Maximum:
   - Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity
2. Mammal food (perhaps serving rodents that disperse the spores by eating sporangia)

Threats . .

(Indicate L - M - H)

Change in fire regime: M (fire suppression)
Grazing: H
Mining: H
Exotics: M
Development:- H
Timber harvest: M
Roads (explain): roads through meadows = M; subsequent improved access and development = H
Others: Recreation impacts: trarnpling, camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H; depending on size of site
Others: Succession = M

Key Assumptions

Narrative on form based primarily on familiarity with 'species at type locality and other sites in Oregon.
In 100-500 year time scale: requires long-term maintenance of meadows, or natural "catastrophic," creation of new meadows nearby as existing meadows revert to forest.

Comments

Diverse *Botrychium* community probably indicates rich biodiversity of vascular and non-vascular plants.

Dispersal

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
Requirements for dispersal: minimal exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses extirpated populations in past 150 years.
- Explanation for widely scattered populations of species (besides obvious wind-dispersal of spores)
- Nature of relations with fungal & vascular associates, native & introduced fauna.
- Systematics; long-term effects of botanical collecting.
- Demography

Monitoring needs:
- Follow life history for 10+ years in undisturbed "'control" situations, to provide baseline for management decisions.
- Monitor in variety of successional habitats over time.
- Monitor populations (and recruitment) in natural disturbances (fire, streamside, landslide, snow avalanche, flood)
- Monitor populations (and recruitment) in unnatural disturbances (roadsides, grazed pastures, campgrounds, livestock staging areas)

Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of pla
- More inventory to locate new populations & habitats.
- Establish undisturbed genetic reserve at type localities and large populations for baseline research.
- Improve taxonomy. Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi ✓ medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing ✓ unknown _

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Panelist Name: Zika

Species *or* Species Group: ***Botrychium lineare***

Province and/or Section: CRB004 subalpine herbaceous Life Form: 'LF4 (Cryptophytes)

Key Environmental Correlates..

1. Canopy cover
   Categorical ✓
   Suitable Categories:
   1. No cover
   2. Partial shade, meadow margins
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?

2, Soil moisture.
   Categorical ✓
   Suitable Categories:
   1. Mesic
   continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season

3. Summer precipitation
   Categorical ✓
   Suitable Categories:
   1. Present
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? Growing season

4. Elevation
   Categorical _
   Suitable Categories:
   1.
   Continuous_ X
   Unit of Measure: feet Minimum: 5000 Maximum: 6000
   Applies seasonally? Yes __ No ✓ Which seasons? .

Key Ecological Functions

1. Primary productivity
2. Mammal food (Perhaps serving rodents that disperse the spores by eating sporangia)

Threats

(Indicate L - M - H)

Change in fire regime: H (fire suppression)
Grazing: H Mining: H Exotics: M
Development: HIGH. Most plants on small private land inholding in Wallowa-Whitman NF, area is oriented towards maximizing recreation opportunities.
Timber harvest: M
Roads (explain): roads through meadows = M; subsequent improved access and development = H
Others: Recreation impacts: trampling,camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H; depending on size of site
Others: Succession = H

Key Assumptions

Narrative on form based primarily on familiarity with species at type locality and other sites in Oregon.
Current private owners of type locality rare plant friendly, but also continue to develop property, and are not managing to control succession or trampling around population-
In 100-500 year time scale: requires long-term maintenance of meadows, or natural "catastrophic" 'creation of new meadows nearby as 'existing meadows revert to forest.

Comments

Diverse Botrychium community probably indicates rich biodiversity of vascular and non-vascular plants.
Long-term protection and management needed for type locality.
Recently described species (Wagner & Wagner 1994). G1, fewer than 100 living plants known in world..

Dispersal.

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
. Requirements for dispersal: minimal exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses extirpated populations in past 150 years.
Explanation' for widely scattered populations of species (besides obvious wind-dispersal of spores): Gaspe to OR.
Nature of relations with fungal & vascular associates, native & introduced fauna.
Systematics; long-term effects of botanical collecting and trampling, frost or grazing damage to individuals at type locality over last 4 years.
Demography
Monitoring needs: Follow life history for 10+ years in undisturbed "control" situations, to provide baselin for management decisions.
Monitor in variety of successional habitats over time.
Monitor populations (and recruitment) in natural disturbances
Monitor populations (and recruitment) if found in unnatural disturbances
Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of pla
More inventory to locate new populations & habitats.
Establish undisturbed genetic reserve at type station for baseline research on systematics and management needs.
Improve taxonomy. Improve identification skills and documentation 'of field workers.

Degree of confidence in knowledge of species: high ✓ med-hi medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing ✓ unknown _

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 . Panelist Name: Zika

Species or Species Group: ***Botrychium paradoxum***

Province and/or Section: CRB004 subalpine herbaceous Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Exposure
   Categorical ✓
      Suitable, Categories:,
      1. No tree cover
      2. Partial shade, meadow margins
   Continuous
      Unit of Measure: . Minimum: Maximum:,
   Applies seasonally? Yes __ No ✓ Which seasons?

2. Soil moisture regime
   Categorical ✓
      Suitable Categories:
      1 . Mesic
   Continuous __
      Unit of Measure: Minimum: Maximum!
   Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season

3. Summer precipitation
   categorical ✓
      Suitable Categories:
      1. Present
   Continuous __ .
      Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? Growing season

4. Elevation
   categorical _
      Suitable Categories:
      1.
   Continuous ✓
      Unit of Measure: feet . Minimum: 5000 Maximum: 6000
   Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity

Threats

(Indicate L - M - H)

Change in fire regime: H (fire suppression)
Grazing: H Mining: H Exotics: M
Development: M Timber harvest: M
Roads (explain): roads through meadows = M; subsequent improved access and development = H .
Others: Recreation impacts: trampling, camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H; depending on size of site
Others: Succession = H

Key Assumptions

Narrative on form based primarily 'oti familiarity' with species at 2 sites in Oregon.
In 100-500 year time scale: requires long-term maintenance of meadows, or natural "catastrophic" creation of new meadows n&y as existing meadows revert to forest.
Oregon populations face threats from commercial grazing and commercial recreational interests on FS land,

Comments

Diverse *Botrychium* community probably indicates rich biodiversity of vascular and non-vascular plants.
Long-term protection and management needed for large populations in Montana (Vanderhorst 1993).

Dispersal

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
Requirements for dispersal: minimal. exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses extirpated populations in past 150 years.
Explanation'for widely scattered populations of species (besides obvious wind-dispersal of spores)
Nature of reiations with fungal & vascular associates; native & introduced fauna.
Systematics; long-term effects of botanical collecting and trampling.
Demography
Monitoring needs: Follow life history for 10+ years in undisturbed "control" situations, to provide baselin for management de&ions.
Monitor in variety of successional habitats over time;
Monitor populations (and recruitment) in natural disturbances (fire-maintained wilderness meadows)
Monitor populations' (and recruitment) in unnatural 'disturbances (grazed meadows).
Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion, of plar
More inventory to locate new populations & habitats:
Establish undisturbed genetic reserves at type station and populations of more than 100 individuals for baseline research on systematics and management needs.
Improve taxonomy. Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi X_ medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing X_ unknown _

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Panelist Name: Zika

Species or Species Group: ***Botrychium pedunculosum***

Province and/or Section: CRB004 subalpine herbaceous Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Exposure
   Categorical ✓
   Suitable Categories:
   1. No tree cover
   2. Partial shade, meadow margins
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which 'seasons?

2. Soil moisture
   Categorical ✓
   Suitable Categories:
   1. Mesic
   Continuous __
   Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season

3. Summer precipitation
   Categorical ✓
   Suitable Categories:
   1. Present
   Continuous __
   Unit of Measure: Minimum: Maximum:.
   Applies seasonally? Yes ✓ No __ Which seasons? Growing season

4. Elevation
   Categorical _
   Suitable Categories:
   1.
   Continuous ✓
   Unit of Measure: feet Minimum: 2500 Maximum: 6000
   Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity
2. Possible food source for small mammals

Threats

(Indicate L - M - I-I)

Change in fire regime: H (fire suppression)
Grazing: H
Mining: H
Exotics: M
Development: M
Timber harvest: M
Roads (explain): roads through meadows =M; subsequent improved access and development = I-I
Others: Recreation impacts: trampling, camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H; depending on size of site
Others: Succession = H

Key Assumptions

Narrative on form based primarily on familiarity with species at 2 sites in Oregon.
In 100-500 year time scale: requires long-term maintenance of meadows, or natural "catastrophic" creation of new meadows nearby as existing meadows revert to forest.
Oregon populations face threats from commercial grazing and commercial recreational interests on FS land.

Comments

Diverse *Botrychium* community probably indicates rich biodiversity of vascular and non-vascular plants.
Long-term protection and management needed for type populations in Oregon (Zika 1994b).

Dispersal

Pollinators: Not applicable
Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)
Requirements for dispersal: minimal exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If grazing excesses extirpated populations in past 150 years.
Explanation for widely scattered populations of species (besides obvious wind-dispersal of spores)
Nature of relations with fungal & vascular associates, native & introduced fauna.
Systematics; long-term effects of botanical collecting and trampling.
Population biology, demography

Monitoring needs:' Follow life history for 10+ years in undisturbed "control" situations; to provide baseline for management decisions.
Monitor in variety of successional habitats over time.
Monitor populations (and recruitment) in natural disturbances (fire-maintained wilderness meadows).
Monitor populations (and recruitment) in unnatural disturbances (grazed meadows).

Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of plant
More inventory to locate new populations & habitats.
Establish undisturbed genetic reserves at type station and populations of more than 100 individuals for baseline research on systematics and management needs.
Improve taxonomy. Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi ✓ medium __ med-lo __ low
Trend: increasing __ stable __ habitat decreasing ✓ unknown _

Columbia River Basin Scientific Assessment
Plant Panel Species Information

Date: January 1995 Panelist Name: Zika

Species or Species Group: ***Botrychium pumicola***

Province and/or Section: CRB004 subalpine herbaceous + Life Form: LF4 (Cryptophytes)

Key Environmental Correlates

1. Exposure
   Categorical ✓
      Suitable Categories:
      1. No tree cover
      2. Partial shade, meadow margins
      3. Open forest
   Continuous __
      Unit of Measure: Minimum: Maximum:
   Applies seasonally? Yes __ No ✓ Which seasons?

2. Soil moisture
   Categorical ✓
      Suitable Categories:
      1. Xeric
   Applies seasonally? Yes ✓ No __ Which seasons? spring & summer growing season

3. Elevation
   categorical __
      Suitable Categories:
   Continuous ✓
      Unit of Measure: feet Minimum: 4000 Maximum: 8100
   Applies seasonally? Yes __ No ✓ Which seasons?

Key Ecological Functions

1. Primary productivity
2. Possible food source for small mammals

Threats
(Indicate L - M - H)

Change in fire regime: H (fire suppression, mountain pine beetle [*Dendractous ponderosae*] kill of pines, high fuel loads)
Grazing: H Mining:, H Exotics: M
Development:. M Timber harvest: H
Roads (explain): roads through meadows = M; subsequent improved access and development = H
Others: Recreation impacts: Off-road vehicle use', human trampling (Crater Lake National Park & Mt. Bachelor), camping, compaction, fire-building, associated backcountry livestock trampling-grazing-exotic introduction = M to H; depending on size of site
Others: Succession = H; Firewood cutting = M;
Others: Long-term potential threats from power generation via thermal development (Newberry Craters

National Monument) and wind generators (Bachelor Butte).

Key Assumptions

Early successional species relies on natural openings and natural disturbance to create and maintain habitat, but probably intolerant of human disturbance in the growing season, due to small size of plants and xeric habitat.

Narrative on form based primarily on familiarity with species at type locality in Oregon, supplemented by ONHP data.

Numerous populations in lodgepole forest may rely on maximum 100-200 fire return interval to maintain open forest of *Pinus contorta.* Fire suppression, high-grading logging, and recent beetle attacks have led to abnormal fuel loads and atypical successional mosaics.

Selective logging in winter with snow cover may be beneficial; logging, road building, brush piling, burning when ground is not frozen and snow-covered likely to destroy populations on site.

Tolerant of frost-worked exposed pumice soils that desiccate early in growing season.

Comments

Long-term protection from hikers and management plan needed for type population, in a proposed RNA in Crater Lake National Park.

Endemic to Oregon, 99% of the 112 documented populations are on federal land.

Many sites threatened by proposed salvage operations, routine logging, and plant succession.

Long-term risks include potential roads and site disturbance from thermal or wind power generators.

Off-road vehicle trails threaten some populations, hikers and ski installations threaten others; trail maintenance threatens some populations, expanding recreational facilities in National Parks and Monuments may threaten others.

Dispersal

Pollinators: Not applicable

Dispersal mode: water drops facilitate gamete movements; spores ride wind (& animal guts?)

Requirements for dispersal: minimal exotic livestock trampling/grazing/competition?

Key Unknowns and Monitoring or Research Needs

Unknown: If fire suppression extirpated populations in past 150 years.

Explanation for limited range of species in genus characterized by widespread and disjunct populations.

Nature of relations with fungal & vascular associates, native & introduced fauna.

Systematics; long-term effects of botanical collecting and trampling.

Population biology, demography.

Why population appears to fluctuate so greatly year to year.

Monitoring needs: Continue monitoring programs on National Forests.

Follow life history for 10+ years in undisturbed "control" situations, to provide baseline for management decisions.

Monitor in variety of successional habitats over time. Determine optimal habitat re: pine density and age.

Monitor populations (and recruitment) in natural disturbances (fire and frost maintained openings).

Monitor populations (and recruitment) in unnatural disturbances (old roads, second growth, salvage).

Research needs: Explain mechanism allowing less-than-annual appearances of above-ground portion of plant

More inventory to locate new populations & habitats.

Establish undisturbed genetic reserve at type station: formalize approval of proposed Llao Rock RNA, write & implement management plan to discourage recreational use of RNA by hikers.

Establish undisturbed genetic reserves for at least 15 populations of more than 100 individuals for baseline research on systematics and management needs.

Improve identification skills and documentation of field workers.

Degree of confidence in knowledge of species: high __ med-hi _ medium ✓ med-lo __ low

Trend: increasing stable __ habitat decreasing ✓ unknown _

Table 15. Forest structural stages.

Structural Stage	Habitat Type
Stand Initiation	Meadow species group
Stem Exclusion: Open Canopy	Forest species group
Stem Exclusion: Closed Canopy	Forest species group
Understory Reinitiation	Forest species group *Botrychium pumicola*
Young Forest: Multi Strata	Forest species group *Botrychium pumicola*
Old Forest: Multi Strata	Forest species group *Botrychium pumicola* *Botrychium crenulatum*
Old Forest: Single Stratum	Forest species group *Botrychium pumicola* *Botrychium crenulatum*

Table 16. Rangeland structural stages.

Structural Stage	Habitat Type
Open herbland	Meadow species group *Botrychium ascendens* *Botrychium lineare* *Botrychium paradoxum* *Botrychium pedunculosum* *Botrychium pumicola*
Closed herbland	Meadow species group *Botrychium ascendens* *Botrychium lineare* *Botrychium paradoxum* *Botrychium pedunculosum* *Botrychium pumicola*
Open low-medium shrub	-
Closed low-medium shrub	-
Open tall shrub	-
Closed tall shrub, single stratum	-
Closed tall shrub, multi-strata	-

Table 17. *Botrychium* in Bailey's sections.

Botrychium Species or Group	Bailey's Section	Section Title
ascendens	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333D	Bitterroot Mountains Section
campestre	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
crenulatum	M242C	Eastern Cascades Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S. Oregon)
hesperium	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
lanceolatum ssp. lanceolatum	M242C	Eastern Cascades Section
	M261D	No title provided (SW Oregon)
	M261G	No title provided (SW Oregon)
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
lineare	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section

Botrychium Species or Group	Bailey's Section	Section Title
lunaria	M242C	Eastern Cascades Section
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	342B	No title provided (desert plain of S Oregon)
minganense	M242C	Eastern Cascades Section
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
montanum	M242C	Eastern Cascades Section
	M261G	No title provided (SW Oregon)
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
multifidum	M242C	Eastern Cascades Section
	M261D	No title provided (SW Oregon)
	M261G	No title provided (SW Oregon)
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section

Botrychium Species or Group	Bailey's Section	Section Title
paradoxum	M242C	Eastern Cascades Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
pedunculosum	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
pinnatum	M242C	Eastern Cascades Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
pumicola	M242C	Eastern Cascades Section
simplex	M242C	Eastern Cascades Section
	M261D	No title provided (SW Oregon)
	M261G	No title provided (SW Oregon)
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
spathulatum	M332B	Bitterroot Valley Section
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section

Botrychium Species or Group	Bailey's Section	Section Title
virginianum	M242C	Eastern Cascades Section
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section

Botrychium Species or Group	Bailey's Section	Section Title
Meadow Species Group	M242C	Eastern Cascades Section
	M261D	No title provided (SW Oregon)
	M261G	No title provided (SW Oregon)
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
Marsh Species Group	M242C	Eastern Cascades Section
	M261D	No title provided (SW Oregon)
	M261G	No title provided (SW Oregon)
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)
Forest Species Group	M242C	Eastern Cascades Section
	M261D	No title provided (SW Oregon)
	M261G	No title provided (SW Oregon)
	M331A	Yellowstone Highlands Section
	M331D	Overthrust Mountain Section
	M332A	Idaho Batholith Section
	M332B	Bitterroot Valley Section
	M332E	Beaverhead Mountains Section
	M332F	Challis Volcanic Section
	M332G	Blue Mountains Section
	M333A	No title provided (N Washington and Idaho)
	M333B	Flathead Valley Section
	M333C	Northern Rockies Section
	M333D	Bitterroot Mountains Section
	342B	No title provided (desert plain of S Oregon)

Table 18. Frequency in Bailey's sections.

Code	Title	No. of Species
M332G	Blue Mountain Section	14
M333B	Flathead Valley Section	14
M333A	No title provided (N Washington and Idaho	14
M333C	Northern Rockies Section	13
M242C	Eastern Cascades Section	11
M332B	Bitterroot Valley Section	11
M332E	Beaverhead Mountains Section	9
M333D	Bitterroot Mountains Section	9
M332A	Idaho Batholith Section	8
342B	No title provided (desert plain of S Oregon)	7
M331A	Yellowstone Highlands Section	6
M331D	Overthrust Mountain Section	6
M332F	Challis Volcanic Section	4
M261G	No title provided (SW Oregon)	4
M261D	No title provided (SW Oregon)	3

Table 19. Wetland indicators in USFWS Region 9.

Based on Reed (1988), these are plants used by regulators to determine jurisdictional wetland boundaries in the Pacific Northwest, Region 9 of the US Fish & Wildlife Service. Their 'Region 9 covers all of the EEMP study area except Nevada and Utah. Their synonymy has been interpreted here to bring it up to date with Wagner and Wagner (1993). The observant reader will immediately notice the conspicuous absence of *Botrychium crenulatum*, the eastern bias which does not place *B. virginianum* more commonly in wetland situations in Region 9, and the conspicuous absence of *B. crenulatum*.

Botrychium species	Indicator status
B. lanceolatum ssp. *lanceolatum*	FACW
B. lunaria	FAC
B. matricariifolium	FACU
B. multifidum	FAC
B. pinnatum (*B. boreale*)	FAC
B. simplex	FACU
B. virginianum	FACU

Explanation of codes (Reed 1988):

FAC = Facultative. Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU = Facultative Upland. Usually occur in nonwetlands (estimated probability 67%-99 %), but occasionally found in wetlands (estimated probability 1 %-33 %).
FACW = Facultative Wetland. Usually occur in wetlands (estimated probability 67%-99 %), but occasionally found in nonwetlands.