

**FINAL REPORT – 2007**

***BOTRYCHIUM LINEARE* SURVEY  
WALLOWA - WHITMAN NATIONAL FOREST, OREGON**

**CINDY JOHNSON-GROH, PH.D.**  
Biology Department  
Gustavus Adolphus College  
800 W. College Ave.  
St. Peter, MN 56082

Submitted to:

Jerry Hustafa, Botanist  
USDA Forest Service  
Wallowa Valley Ranger District  
88401 Hwy 82  
Enterprise, OR 97828

**ABSTRACT**

The author conducted surveys for *Botrychium lineare* during the 2007 field season. This included identifying and searching for new locations in Lostine, Hurricane and Wallowa River drainages in the Wallowa-Whitman National Forest. The survey was conducted 8-12 July 2007. No new *B. lineare* sites were discovered.

## INTRODUCTION

*Botrychium lineare* (slender moonwort or narrow-leaved moonwort) has been known from sites in the Lostine Creek Drainage and Hurricane River Drainage since the 1990's. No systematic searches have been conducted previously and it was unknown if *B. lineare* populations existed in other areas within these drainages or other areas. The objective of this study was to identify new areas similar in habitat, substrate and vegetation to the known populations in the Wallowa Whitman National Forest and search these areas for *B. lineare* populations.

*B. lineare* is a member of the genus *Botrychium* subgenus *Botrychium*, which is found worldwide in a variety of habitats including grasslands, forests and beaches. This subgenus produces a small, single leaf (two to ten cm) which is divided into a once- or twice-pinnate sterile segment, known as the trophophore, and a twice- or tri-pinnate fertile segment, known as the sporophore. The plants generally produce one leaf annually although it is common for *Botrychium* to remain dormant belowground producing no aboveground leaf in a given year. The belowground rhizome is upright and short with mycorrhizal stem and roots and a single leaf-producing bud at the apex. The bud may contain up to five preformed leaves. Some species, including *B. lineare* reproduce asexually via belowground gemmae, small (0.5-1mm) propagule that can independently start a new plant once detached from the parent plant (Farrar and Johnson-Groh, 1990).

*Botrychium lineare* can be distinguished from other moonworts by the presence of narrow pinnae with large inter-pinnae gaps. Two other species, *B. ascendens* and *B. campestre*, both found in the Wallowa-Whitman area may be confused with *B. lineare*. *B. ascendens* has pinnae that tend to be more upswept and they broaden distally with jagged, toothed or dentate margins. *B. campestre* has relatively broader pinnae with deeper lobes that may also broaden distally. The pinnae of *B. lineare* are often bi- or trifid.

The taxonomic position of *B. lineare* is unclear. Dr. Donald Farrar, Iowa State University, has worked on the taxonomy of moonworts using electrophoretic isozyme analysis. The data are uncertain whether *B. lineare* and *B. campestre* are distinct species or varieties (personal communication). Further information on *B. lineare* may be found in Appendix A.

## METHODS

The habitats of the *B. lineare* populations in Lostine Canyon and Hurricane Creek may be characterized as well drained gravelly substrate with relatively sparse vegetation. The plants are generally clustered in areas that receive runoff and have likely been disturbed historically. The substrate pH for *B. lineare* populations appears to be significant. Several species of moonworts are considered to be calciphiles, particularly *B. lineare*. The Lostine site is a road ditch adjacent to a calcareous limestone gravel road. Several species of moonworts are found at this site including *B. ascendens* and *B. crenulatum*.

The Hurricane site is also a gravelly well drained site at the base of an old avalanche meadow which provides a rich calcareous soil that was historically disturbed. Moonworts have an affinity for sites that have been disturbed historically (roadsides, avalanche sites, and grazed meadows). A third known site is the Hurricane site on an eroding stream bench of Hurricane Creek. Positioned on the creek bank this site receives both full sun and full shade depending on the time of day. All the sites are relatively moist and dominated by *Fragaria*.

Using the characters of the known sites, new sites were selected with similar habitat parameters. Criteria for new sites include: calcareous substrate, disturbance history and soil moisture. Sites were selected based using a geology map, community vegetation descriptions and conversations with Forest Service personnel. Searches were conducted along the river corridors. Hiking north along Lostine, Hurricane and Wallowa Creek, the search party searched all potential habitats. Depending on the similarity between the habitat being searched and the known *B. lineare* sites, the length of time searching varied from 30 minutes to 2 hours.

Plants which resembled *B. lineare* or *B. campestre* were collected (tops removed without disturbance to the rhizome and roots) and sent to Dr. Donald Farrar, Iowa State University, for identification using isozyme electrophoresis.

## RESULTS

Twenty one sites were identified and searched from 8-12 July 2007 (Table 1). Eleven of the sites contained various species of *Botrychium*, however no new *B. lineare* sites were found. Four probable *B. lineare* plants were submitted to Dr. Donald Farrar for isozyme confirmation. None of these were *B. lineare*; three were *B. ascendens* and one was *B. campestre*.

Search time varied from 30 minutes to 2.5 hours depending on the promise of finding *B. lineare*, gauged by the similarity of species composition to know sites. The search was timed to coincide with the phenology of *B. lineare*, which is a little earlier than most other species (early July versus late July). *B. lineare*, from Hurricane and Lostine sites was just beginning to release spores, so the timing was good, maximizing the chances of finding new populations.

Nine species, including *B. lineare*, were found during this search. Most of the areas searched were of two geological types:

**JTRs:** sedimentary rocks, Jurassic and upper Triassic periods; Black, dark-gray, and dark-brownish-gray, thin-bedded siliceous or limy mudstone mostly consists of the Hurwal Formation in the Wallowa Mountains

**TRs:** marine sediments, Triassic period; Black, green, and gray argillite, mudstone, and shale; graywacke, sandy limestone, tuff, and some coarse volcanoclastic rocks; chert, sandstone comprised of chert clasts, and chert pebble conglomerate; thin-bedded and massive limestone.

These types were targeted because of the limestone dominance and calcareous influence. Small areas of granitic substrate are intertwined with these calcareous types and include:

**KJi:** intrusive rocks, cretaceous and Jurassic periods; Hornblende and biotite quartz diorite (tonalite), trondhjemite, granodiorite, and small amounts of norite, in batholithic masses and large dikelike bodies

**TRv:** volcanic and metavolcanic rocks, upper triassic period; Green to gray spilite and keratophyre flows and flow breccia; and subordinate amounts of coarse volcanoclastic sandstone, tuff, sandstone, siltstone, chert, conglomerate, and limestone

Though small areas of these volcanic substrates were searched (e.g. sites 9, 10) no moonworts were found in these areas.

Table 1. Location, habitat, species found and notes from search for *B. lineare*.

Site #	General Location	Search Date	Habitat	Species found (# of plants)	Associated Species	Notes	search time (hrs)
1	Hurricane Creek, Falls Creek	8-Jul-07	river bank	<i>lineare</i> (23) <i>campestre</i> (1) <i>crenulatum</i> (1)	<i>Fragaria</i> , <i>Anemone</i> , <i>Achillea</i> , <i>Abies</i> , <i>Picea</i>	concentrated along edge of eroding bank in open and in dense shade of small <i>Abies</i> and <i>Picea</i>	1
2	Hurricane Creek, Gully Site	8-Jul-07	avalanche meadow	<i>lineare</i> (25) <i>ascendens</i> (11) <i>campestre</i> (1) <i>lunaria</i> (3) <i>virginiana</i> (25) unknown (3)	<i>Fragaria</i> , <i>Anemone</i> , <i>Achillea</i> , <i>Potentilla</i> , <i>Sheperdia</i> , <i>Astragalus</i> , <i>Arctostaphylos</i>	growing along the lower edge of the avalanche meadow in a gully	2
3	Hurricane Creek, south of gully site	8-Jul-07	avalanche meadow	<i>ascendens</i> (1) <i>crenulatum</i> (2) <i>lunaria</i> (1) unknown (2)	<i>Potentilla</i> , <i>Fragaria</i> , <i>Symphoricarpos</i> , <i>Thalictrum</i>	searched higher on the hill, mostly too dry	1.5
4	Hurricane Creek, south of gully site	8-Jul-07	avalanche meadow	<i>lineare</i> (9) <i>crenulatum</i> (2) <i>lunaria</i> (2) unknown (1)	scattered <i>Abies</i> , <i>Physocarpus</i> , <i>Potentilla</i> , <i>Symphoricarpos</i> , <i>Senecioi</i> , <i>Fragaria</i> , <i>Mahonia</i>	left 2 pink flags on upper end near trail in <i>lineare</i> patches, <i>lineare</i> was downhill below the trail	1.5
5	Hurricane Creek, upper areas, higher elevation	9-Jul-07	very dry avalanche meadow	<i>ascendens</i> (23) <i>crenulatum</i> (7) unknown (2)	<i>Artemisia</i> , <i>Castellija</i> , <i>Antenaria</i> , <i>Potentilla</i> , <i>Geranium</i> , <i>Erigeron</i> , <i>Penstoemon</i> , <i>Achillea</i> , <i>Fragaria</i>	area dry, lacking forb diversity, a few spots in shade of <i>Potentilla</i> had potential, plants found under conifers on downhill side of trail	2
6	Hurricane Creek, upper areas, higher elevation	9-Jul-07	very dry avalanche meadow	<i>no Botrychium</i>	<i>Artemisia</i> , <i>Castellija</i> , <i>Antenaria</i> , <i>Potentilla</i> , <i>Geranium</i> , <i>Erigeron</i> , <i>Penstoemon</i> , <i>Achillea</i> , <i>Fragaria</i>	area dry, lacking forb diversity	0.5
7	Hurricane Creek, upper areas, higher elevation	9-Jul-07	very dry avalanche meadow	<i>no Botrychium</i>	<i>Fragaria</i> , <i>Geum</i> , <i>Symphoricarpos</i> , <i>Anemone</i> , <i>Potentilla</i> , <i>Penstemon</i>	too dark to search for moonworts, this site has good mix of prairie species and has potential, found abundant <i>Carex</i> which seems not to coincide with <i>Botrychium</i> sites	1
8	East Fork Lostine	10-Jul-07	wet meadow	<i>no Botrychium</i>	<i>Castellija</i> , <i>Dodecatheon</i> , <i>Carex</i> , <i>Juncus</i> , <i>Ranunculus</i> , <i>Aster</i> , <i>Senecio</i>	site disturbed by horses	0.5
9	East Fork Lostine	10-Jul-07	mesic alpine meadow	<i>no Botrychium</i>	<i>Carex</i> , <i>Juncus</i> , <i>Castellija</i> , <i>Sibaldian</i> , <i>Antenaria</i> , <i>Vaccinium</i> , <i>Abies</i>	very rocky soil, rock = granitic	0.5
10	East Fork Lostine	10-Jul-07	mesic alpine meadow	<i>no Botrychium</i>	<i>Antennaria</i> , <i>Sibbaldia</i> , <i>Dodecatheon</i> , <i>Castellija</i> , <i>Aster</i> , <i>Potentilla</i> , <i>Ranunculus</i>	mesic meadow, similar to site 9, looks good, but didn't find plants	1
11	Pole Bridge, Lostine Creek	11-Jul-07	river bank	<i>no Botrychium</i>	<i>Equisetum</i> , <i>Athyrium</i> , <i>Linnaea</i> , <i>Fragaria</i>	looked for sites similar to Hurricane riverbank site, but found nothing, too much floodplain influence	1

Site #	General Location	Search Date	Habitat	Species found (# of plants)	Associated Species	Notes	search time
12	Lostine Creek	11-Jul-07	open dry meadow	<i>no Botrychium</i>	<i>Potentilla, Fragaria, Symphoricarpos,</i>	similar to Lapover, but dryer	0.5
13	Lapover, Lostine	11-Jul-07	dry road ditch	<i>lineare (1) ascendens (26) creulatum (7) unknown (4)</i>	<i>Fragaria, Linnaea, Antennaria, Abies, Picea</i>	4 old flags with no plants, 1 flag with plant that looks like <i>B. ascendens</i> but is too small to confirm	1
14a	Upper Turkey Flat, Lostine	11-Jul-07	open dry meadow	<i>lanceolatum (2) pinnatum (1)</i>	<i>Fragaria, Linnaea, Antennaria, Abies, Picea</i>	east side of Lostine road at end of side road south of picnic area and parking, searched farther up slopes, lots of granitic substrate	1
14b	lower Turkey Flat, Lostine	11-Jul-07	open dry meadow	<i>ascendens (17) lanceolatum (14) pinnatum (10)</i>	<i>Fragaria, Antennaria, Potentilla, Achillea, Pinus, Abies</i>	lower meadow adjacent to Lostine road (east side)	1
15	roadside meadow	11-Jul-07	open dry meadow	<i>no Botrychium</i>	<i>Fragaria, Antennaria, Potentilla, Achillea, Pinus, Abies</i>	roadside meadow similar to Turkey Flats, looks like limestone substrate	0.5
16	old road bed between road and river	11-Jul-07	open dry Pinus woods	<i>no Botrychium</i>	<i>Fragaria, Antennaria, Potentilla, Achillea, Pinus, Abies</i>	dry open woods	0.5
17	Iron Dyke, Lostine	11-Jul-07	open dry Pinus woods	<i>no Botrychium</i>	<i>Fragaria, Antennaria, Potentilla, Achillea, Pinus, Abies</i>	high moss coverage, similar to Lapover	0.5
18	Campsite, Lostine	11-Jul-07	open, dry Pinus woods	<i>pedunculosum (1)</i>	<i>Fragaria, Ranunculus, Carex, Smilacina, Antennaria</i>	along old road on north side of campsite underneath Abies on edge of road	1
19	meadow, Lostine	11-Jul-07	dry dusty roadside	<i>no Botrychium</i>	<i>Fragaria, scattered Abies in ditch. Achillea, Anophales</i>	dusty site similar to Lapover	0.5
20	Wallowa East Trail	12-Jul-07	open meadow	<i>ascendens (16) campestre (10) crenulatum (10) lunaria (1) pinnatum (30) unknown (15)</i>	<i>Fragaria, Potentilla, Ranunculus, Carex, Penstemon, Poa, Senecio</i>	large open meadow dominated by <i>Fragaria</i> , found largest populations adjacent to trail on either side at north end of meadow many plants were eaten off and impossible to identify	2.5
21	Wallowa East Trail	12-Jul-07	open meadow with scattered Pinus	<i>crenulatum (1)</i>	<i>Fragaria, Taraxacum, Achillea, Senecio, Pinus, Abies</i>	searched from bottom of meadow, plant found ~halfway up meadow in area with scattered <i>Pinus</i> , Site appears to have good potential despite inability to find plants	2

## DISCUSSION

There appears to be a strong association between *B. lineare* distribution and the calcareous substrates. The ridge between Lostine and Hurricane drainage is almost entirely calcareous sedimentary rocks of the Hurwal Formation. Similarly the upper reaches of the Wallowa East Fork includes a large area of this formation coinciding with moonwort distribution. Though this correlation appears to sustain moonwort population clearly other factors are also involved. Soil moisture, drainage and mycorrhizal communities impact the distribution of moonworts.

The inability to discover new sites in this survey must be interpreted in the context of moonwort ecology. The belowground biology and the ability to remain dormant for several years make moonworts particularly difficult to find. Aboveground *Botrychium* populations fluctuate independently within and between populations as well as between years and between different sites. These differences reflect microsite differences such as soil moisture, herbivory, or mycorrhizae. Fire, herbivory, herbicide and timber harvest have short-term impacts on the aboveground sporophytes. Long-term however, the populations are fairly resilient and rebound following perturbations though it may take several years (Johnson-Groh, unpublished data).

Long term (16+ years) monitoring of midwestern species has revealed large variations in population and vigor of individual populations (Johnson-Groh, 1999). Some populations have declined to the point of extinction while others have maintained extremely stable populations. *Botrychium* populations are best characterized as metapopulations in which small satellite populations are likely to go extinct and stable source populations maintain a reserve of individuals capable of reestablishing new satellite populations. This metapopulation model appears to fit *Botrychium*, however consideration must be given to the time scale. *Botrychium* spores percolate underground and may lie dormant for many years before they germinate under suitable conditions. From germination to emergence above ground it probably takes 3-5 years (unpublished data). The extinction and recolonization of new *Botrychium* populations likely is on a time scale of 10's of years rather than years.

In addition to the population variability, the belowground biology further compounds surveying for moonworts. Populations of several species were investigated by Johnson-Groh et al (2002). They concluded that the density of individuals in the belowground structure bank greatly exceeds the aboveground population and that the size and health of the belowground structure bank is critical in sustaining the long-term aboveground population and in buffering it from extinction. Because moonworts may remain dormant belowground for long periods of time, it is not possible to definitely conclude that moonworts are not present in any given site after searching only one year.

## RECOMMENDATIONS

Though no new *Botrychium lineare* sites were located it is possible that some of the sites visited still have good potential for future discoveries. However the absence of any other *Botrychium* species in some of these sites makes it less probable that *B. lineare* would be discovered. Of the sites visited in this study, site 20 in the Wallowa drainage is worth revisiting. This site had several species of *Botrychium*, similar associated species (*Fragaria*, etc.), well-drained moist soils and history of disturbance.

Because of limited time and difficulty of access, high elevation sites were not investigated in this survey. These sites require one to two days to access and so were eliminated as survey sites

in order to maximize search of other sites which were accessible. In the future it would be worthwhile to search some of the high elevation or less accessible sites including: Upper drainage of Silver Creek, Adam Creek, East Fork Eagle Creek, and the South Fork Imnaha River.

Because the known populations (Lostine, Hurricane) of *B. lineare* are relatively small and because it is unknown if these sites are stable (source population) or satellite populations, it is recommended that permanent monitoring be established on these populations. Monitoring would reveal the general trend of population growth / decline, the annual variation in population size, the size variance and the phenology. The author has visited the *B. lineare* Lapover site repeatedly over a period of ten years and, though anecdotal, the populations have seemed to decline.

### LITERATURE CITED

- Farrar, Donald and C. L. Johnson-Groh. 1990. Subterranean sporophytic gemmae in moonwort ferns, *Botrychium* subgenus *Botrychium*. *Amer. J. Bot.* 77: 1168-1175.
- Johnson-Groh, C. 1999. Population Ecology of *Botrychium* (Moonworts): Status Report on Minnesota *Botrychium* Permanent Plot Monitoring. Report to the Minnesota DNR.
- Johnson-Groh, C. L., C. Riedel, L. Schoessler and K. Skogen. 2002. Belowground distribution and abundance of *Botrychium* gametophytes and juvenile sporophytes. *American Fern Journal* 92:80-92.

**Appendix A: Description of *Botrychium lineare*, Dr. Donald Farrar  
(<http://www.public.iastate.edu/~herbarium/botrychium.html>)**

### ***Botrychium lineare***

**Family:** Ophioglossaceae  
**Genus:** *Botrychium*  
**Subgenus:** *Botrychium* (syn. *Eubotrychium*)  
**Species:** *Botrychium lineare* W. H. Wagner  
**Common name:** Slender Moonwort  
**Ploidy:** Diploid



**Published description:** A small *Botrychium*, the leaf 6-18 cm long above the upright subterranean stem 0.5-3.0 cm long. Trophophore sessile to stalked up to 1 cm. Blade oblong, 1-pinnate. Pinna pairs 4-6, strongly separated by 2-5 times the width of segments, to moderately ascending, approximately equal in length, except for shorter apical 1-4 pairs of segments. Pinnae mostly straight, slightly upcurved, narrowly linear (narrowest in small plants), often expanded at the truncate apex or rarely linear-spatulate, commonly bifid with linear lobes. Color pale green; texture thick chartaceous, rigid. Sporophore 1-2 times the length of trophophore, with a single major axis. (Wagner and Wagner, 1994)

## Habitat

Wagner and Wagner (1994) described one of the Quebec *Botrychium lineare* habitats as "a steep limestone cliff with narrow grassy horizontal terraces" on which the plants were supposed to have grown. The other Quebec site was described by the collector as "a gravelly beach". The New Brunswick collection lacked details of habitat other than "mountain".

Habitats of western populations of *Botrychium lineare* are highly varied, including heavily forested sites and grassy meadows, fen-like seeps and gravelly roadsides. The sites agree only in their relatively high elevation or northern latitude. The largest known extant populations near Pikes Peak in Colorado and Glacier National Park in Montana are in sparse to dense meadow and roadside grasses and forbs on gently sloping terrain. In Idaho plants are on high elevation scree slopes with little vegetation. In the most remarkable sites, near Glacier NP and in the Lostine Canyon in Northeast Oregon, plants grow through packed gravel of roadside shoulders and ditches. Along Hurricane Creek, also in northeastern Oregon, plants grow in boulder-laden substrate of an old avalanche meadow. In Alaska and the Yukon it grows along hard-packed dirt trails.

There is some indication that *Botrychium lineare* as well as other moonwort species tend to occur on limestone influenced substrates. For example, one of the Quebec sites was on a limestone cliff, and the two Oregon sites are on either side of a mountain ridge capped with limestone. It may be that the gravel of the roadside sites also contains limestone. This association warrants further study. Minimally, the pH of known sites should be determined (most limestone influenced soils have a neutral pH (pH = 6-8), and other soil elements could be also be determined. Such analysis may serve to disqualify non-calcareous, low pH areas as probable sites for occurrence of *B. lineare*.

---

---

### Identification

The pinnae of *Botrychium lineare* have the narrowest pinna span of all moonworts, hence the common name, slender moonwort. They broaden scarcely at all toward their outer margin except as they divide, usually into two lobes diverging at an angle of about 45°. Only two other species approach this morphology, both of them closely related to *B. lineare*. *Botrychium campestre* has broader pinnae that are less deeply lobed and a rachis that is broader relative to the total leaf width. Narrow-pinnae forms of *B. ascendens* may be similarly lobed, but the lobes broaden toward an outer margin that is dentate. At maturity the sporophore stalk of *B. ascendens* is usually greater than half the length of the trophophore whereas it is less than half the length of the trophophore in *B. lineare*.

Plants from several localities appear intermediate between *B. lineare* and *B. campestre*. Possibly these are an allotetraploid taxon formed by chromosome doubling following hybridization between these two species. If this is found to be the case, these tetraploid plants may warrant taxonomic distinction.

### Distribution

*Botrychium lineare* is among the least frequently sighted of all moonwort species. It is known from 12 collections prior to Wagner's first sighting of the species in Montana in 1978. It remains known from only 34 sites, more than half of these (18) not known to be extant. The species has not been seen in eastern North America since its collection in Quebec in 1902 and 1947 and in New Brunswick in 1904. Recent documentation of *B. lineare* in the Black Hills of South Dakota and Wyoming along with other eastern species supports possible continued existence of the species in other eastern sites.

In western mountains, *B. lineare* is historically known from California and Utah and currently known from Colorado northward to Washington and Montana. It has recently been found in Alaska and the Yukon Territory. These discoveries indicate the possibility of additional occurrences throughout the mountains of western Canada where it has not heretofore been sought.

Because of its distinctive morphology it is unlikely that *B. lineare* has been overlooked or misidentified more so than other moonworts. Rather, its sporadic occurrence is probably a true reflection of its rarity.

---

Additional photographs of *Botrychium lineare*:



Above photographs by Drake Barton

Photo below right is hybrid between  
*B. lineare* and *B. campestre*

