

Moonwort Fern Surveys in the Wrangell-St. Elias Mountains
and Genetic Analysis with an Emphasis on
Botrychium tunux* & *Botrychium lineare

Submitted to:

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Introduction

Moonwort ferns (genus *Botrychium*) are interesting, strange-looking, yet often overlooked little plants. The plant consists of a single deciduous leaf that is divided into two segments, a leaf-like sterile segment divided into several pairs of linear to fan-shaped pinnae, and a fertile segment bearing clusters of spherical sporangia. Normally, each spring, the plant's short, vertical underground stem produces this single leaf. Depending on the species, moonworts can range in height from ½ inch to ten inches.

Moonworts tend to grow in well drained open areas dominated by perennial, herbaceous vegetation, composed largely of native species. Such mid-successional meadow-like vegetation is often associated with recovery from human-caused and natural disturbance regimes. Human activities such as mowing and grazing may maintain this type of vegetation by preventing succession to woody vegetation that is less supportive of moonworts. By this process, old (>20 years) roadsides, landing strips, logging roads, etc. mimic natural meadows developing on avalanche chutes, stream outwash and flood plains, talus slopes, etc. where moonworts are also found.

There are about 30 species of moonworts worldwide, with most growing in cool temperate and boreal areas of the Northern Hemisphere. About 13 taxa are known from and adjacent to the Wrangell-St. Elias Mountains of Canada and Alaska. In recent years there has been increasing interest in moonworts, consequently more people have been looking for and finding them. As moonworts are studied more intensely, new species are being identified, such as *Botrychium lineare* W. H. Wagner and *Botrychium tunux* Stensvold & Farrar. Genetic analysis has shown moonwort taxa to be genetically distinct. However, they can be variable and not always morphologically distinct. This morphological variability sometimes makes identification difficult. The use of enzyme electrophoresis to verify the identities of moonworts genetically is an important component of moonwort study. Field surveys during the past ten years have shown the Wrangell-St. Elias Mountains to be a "hot spot" for *Botrychium* diversity.

The following collections are of particular note:

- *B. tunux*, Wrangell-St. Elias National Park, Gold Hill. (genetically similar but not as morphologically robust as *B. tunux* from Yakutat).
- *B. tunux*, Kluane National Park, Soldiers Summit Trail. (genetically similar but not as robust as *B. tunux* from Yakutat).
- *B. lineare*, Kluane National Park, Soldiers Summit Trail.
- *B. lineare*, Wrangell-St Elias National Park, Chisana airstrip.
- *B. montanum* W.H. Wagner, Wrangell-St. Elias National Park, Yakutat area.
- *B. yaaxudakeit* Stensvold & Farrar, Kluane National Park, Kluane Lake.
- *B. hesperium* (Maxon & Clausen) Wagner & Lellinger, Kluane National Park, Auriel Trail.

The field work and genetic analysis documented here concentrated on *B. lineare* and *B. tunux* because there are conservation concerns for these moonworts because of their apparent rarity and because some plants were found in areas of existing and potential human disturbance. For example, realignment of the Alaska Highway in the Soldiers Summit area of the Kluane National Park in the Yukon Territory potentially jeopardizes both taxa. In the Chisana area of the Wrangell-St. Elias National Park there are questions about whether grazing by pack horses¹ affects moonworts.

Botrychium lineare, the slender moonwort, was named in 1994 (Wagner & Wagner) based on specimens from Oregon. It is now known to occur from the California Nevada border to the southwestern Yukon Territory to the Wrangell-St. Elias Mountains of adjacent Alaska. It is also known from disjunct populations in Eastern Canada's Quebec and New Brunswick (Wagner & Wagner, 1994) and existing currently in Minnesota and South Dakota. This rare fern is tiny and easily overlooked. In 2001 *B. lineare* officially became a candidate for listing under the Endangered Species Act by the U. S. Fish and Wildlife Service. In late autumn of 2007 it was dropped as a candidate for listing in consideration of research by Farrar, Stensvold and others showing it to be more common and more widespread than previously thought.

Botrychium tunux, moosewort fern, was named in 2002 (Stensvold *et al.*, 2002) based on material from the Yakutat forelands of south coastal Alaska. A specimen from Gold Hill near Chisana, in Wrangell-St. Elias National Park being genetically similar to *B. tunux* was also noted

¹ Grazing is authorized by permit from the National Park Service.

in the paper naming the taxon. Recent genetic work indicates that the Gold Hill specimen and others from the mountains of the west and coast of Alaska are genetically similar enough to *B. tunux* to be considered within that taxon. Based on current genetic information, the geographic distribution of *B. tunux* extends from Alaska's Pribilof Islands to the Aleutians, east to insular southeastern Alaska, north and east to the Wrangell-St. Elias Range, and south and east to the Rocky Mountains of Montana and Alberta. A genotype occurring in Nevada and Colorado is a distinct variety, as is a genotype in northern Norway (our publication of these varieties is pending). *B. tunux* is being considered for candidate status by the U. S. Fish & Wildlife Service.

The purpose of this project is to better understand the abundance, distribution and habitat of *B. lineare* and *B. tunux* in the Wrangell-St. Elias Mountains.

Methods and Materials

Field surveys were conducted between June 23 and June 29, 2007 in and adjacent to the Wrangell-St. Elias Mountains by Donald R. Farrar of Iowa State University, Department of Ecology, Evolution and Organismal Biology, and Mary Stensvold of the USDA Forest Service, Alaska Region. Many survey sites were selected based on previous collections of *B. lineare*, *B. tunux* and other moonworts. In the Yukon, many of these collections are located along the Alaska Highway, on previous alignments of the Highway, and on the abandoned pipeline route generally paralleling the Highway. In Alaska, survey sites were selected in the vicinity of previous collection sites in the Chisana Area of the Wrangell-St. Elias National Park. Other sites were chosen because they appeared to have moonwort habitat. These sites are generally well-drained mesic areas. They are generally treeless areas such as forest openings, meadows, airstrips or roadsides with vegetation dominated by grasses and perennial herbs.

To reach the sites we drove the Haines and Alaska Highways between Haines and Tok, Alaska. At Haines Junction, Yukon Territory, we coordinated with Parks Canada to visit sites in the Kluane National Park. From Tok, Alaska, we flew into the Wrangell-St. Elias National Park to reach several sites in the Chisana area and near the White River. At each site we carefully

searched the area for moonworts, often crawling on hands and knees to find the plants. When plants were found they were marked with pin flags, this allowed for convenient estimations of abundance. At most sites some specimens were collected for morphological and genetic study (since moonworts are sometimes difficult to identify morphologically, genetic analysis was used to verify identification). To collect specimens, leaves were cut at ground-level; this collection method does not damage the stem and future year's primordial leaves. Leaves were sent to the Department of Ecology, Evolution and Organismal Biology at Iowa State University where Don Farrar did genetic analysis (enzyme electrophoresis) and used the results for identification verification. Electrophoresis was conducted during September through November of 2007, using standard electrophoresis methodology. With the exception of *B. lanceolatum* and one population of *B. minganense*, one or more specimens from each population of each species were analyzed to verify each population's identity. Cooperating partners are the U. S. Fish and Wildlife Service, who funded the project; Iowa State University, who provided personnel and laboratory facilities; USDA Forest Service, provided personnel, logistical support and transportation; National Park Service, Wrangell-St. Elias National Park, who provided personnel, travel and logistics; Parks Canada, Kluane National Park, who provided personnel, logistics and helicopter transportation, Yukon Territory, who authorized land use and the Kluane Lake Research Station, who provided personnel and logistics.

Results

Travel routes and collection sites are shown on the maps in Figures 1 and 2. Only a small area of the Wrangell-St. Elias Mountains was investigated during this project, and the selection of survey sites was generally biased toward areas accessible by car or airplane². Due to logistical and time constraints many sites where moonworts had been collected in the past were not visited during this field trip. Collection sites and collections made during this project are summarized in

² The top of the Sheep Bullion Trail was accessed via helicopter.

Table 1 and described below. They are arranged in general order from the Yukon-British Columbia border, northwest toward the Wrangell-St. Elias National Park to Tok, Alaska.

A total of 336 specimens were collected, 209 in the Yukon and 127 in Alaska. We found *B. lineare* at two sites in the Yukon and at one site in Alaska, *B. tunux* was found at eight sites in the Yukon and five sites in Alaska. Including these taxa, nine *Botrychium* taxa were documented. In addition, moonworts introgressed between *B. lunaria* and the yet undescribed *B. neolunaria* (the American genotype of *B. lunaria*) were found at several sites.

Voucher specimens will be deposited in herbaria according to the wishes of appropriate land management agencies.

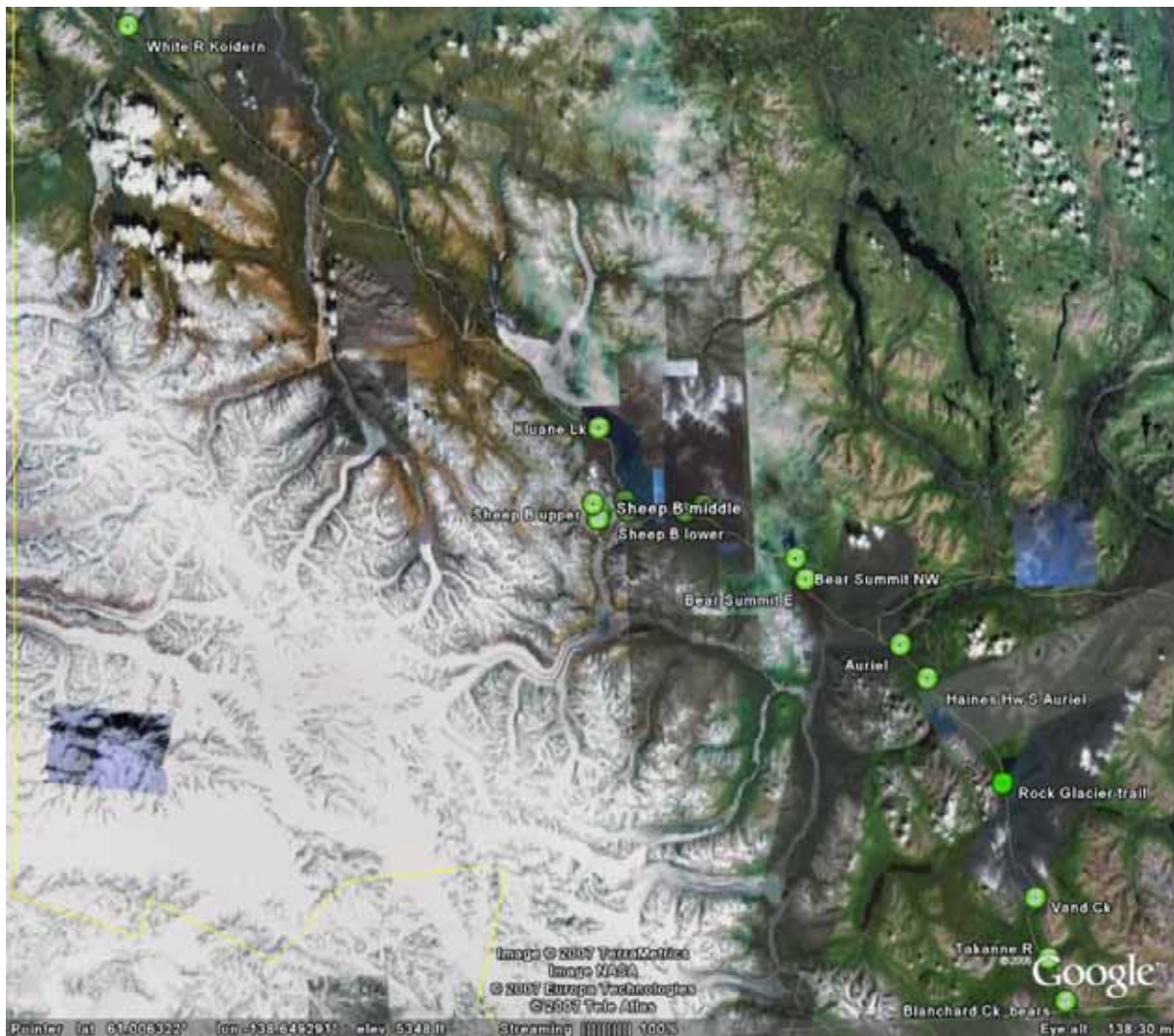


Figure 1. General map showing moonwort collection sites in the Yukon Territory.



Figure 2. General map showing moonwort collection sites in the Alaska.

Table 1. Summary of *Botrychium* found during the Wrangell-St. Elias Mountains study. Locations are listed in approximate order from southeast (Yukon) to northeast (Alaska). The number of specimens collected is not reflective of the population size or ratio of taxa at a site.

Location and Number of Specimens Collected	Taxon									
	<i>B. alaskense</i>	<i>B. lanceolatum</i>	<i>B. lineare</i>	<i>B. "neolunaria"</i> × <i>B. lunaria</i> (introgressed)**	<i>B. minganense</i>	<i>B. "neolunaria"</i> *	<i>B. pinnatum</i>	<i>B. spathulatum</i>	<i>B. tunux</i>	<i>B. yaaxudakeit</i>
Yukon 209										
Blanchard Creek 5						x	x			x
Takanne Creek 11					x	x			x	x
Vand Creek 19	x	x				x	x			
Rock Glacier trailhead 11					x				x	x
South of Auriel Trail 17				x	x			x	x	x
Auriel Pipeline 9					x	x				
Bear Creek Summit East 10					x	x		x		
Bear Creek summit 23					x				x	x
Bunny Trap bog 14				x						
Radio Tower shrubs 10						x				
Radio Tower clearing 32				x		x				
Sheep Bullion Trail upper 5						x			x	
Sheep Bullion Trail middle 4								x		x
Sheep Bullion lower Trail 4								x	x	
Soldiers Summit Trail 9			x		x			x	x	
Kluane Lake pull-off 1								x		
White River, Koidern 25			x		x	x		x	x	
Alaska 127										
Chisana, Commissioner's Res. 16				x				x	x	
Chisana, Women's Jail 19					x			x		
Chisana, Too Much Johnson 3			x					x		
Chisana, ATV trail 17								x	x	
Chisana, Airstrip 3								x		
Chisana, Floodplain 5								x	x	
Chicken Creek Strip 7				x	x					
Baultoff Strip 20				x	x				x	
Solo Strip 35				x				x	x	
Tok, east 2						x				

* *Botrychium "neolunaria"* is the tentative new name for the North American plants of *B. lunaria* soon to be published. This name change is necessitated by the discovery of Farrar & Stensvold (Stensvold, 2007 and Stensvold & Farrar (in preparation), that most North American plants are genetically distinct from European plants named *Botrychium lunaria*.

** *Botrychium. "neolunaria"* × *B. lunaria* (introgressed) are fertile diploid plants containing alleles of both *B. neolunaria* and *B. lunaria* resulting from introgressive hybridization.

Yukon Territory

Blanchard Creek, (60.020132° N, 136.865039° W), elevation 876 meters, June 28, 2007. Forb meadow on the east side of the road and roadside ditch at the upper edge of the roadcut. *Botrychium* uncommon to common.

B. "neolunaria"
B. pinnatum
B. yaaxudakeit

Takanne, (60.10655° N, 136.921676° W), elevation 765 meters, June 28, 2007. Open area on the west side of the road in a clearing formerly part of the Haines pipeline. *Botrychium* is uncommon in the area, vegetation is dominated by *Oxytropis*, with about 10% open bryophyte cover.

B. minganense
B. "neolunaria"
B. tunux
B. yaaxudakeit

Vand Creek, (60.22805° N, 136.96016° W), elevation 711 meters, June 28, 2007. West side of the road in a clearing that was part of the Haines pipeline. Substrate, 60% lichen encrusted gravel, dominant vascular plants include *Populus* seedlings 20%, *Salix* 10%, and *Epilobium angustifolium* 5%. *Botrychium* is common in the area adjacent to the deciduous forest, which is dominated by *Populus*.

B. alaskense
B. lanceolatum var. *lanceolatum* (red morphotype)
B. "neolunaria"
B. pinnatum

Rock Glacier trailhead, (60.45551° N, 137.06108° W), elevation 748 meters, June 28, 2007. Open area on the west side of the road in a clearing formerly part of the Haines pipeline adjacent to the Rock Glacier trailhead. *Botrychium* is relatively common, with *Taraxacum*, *Oxytropis*, *Festuca* and about 10% bryophyte encrusted substrate. *Populus* appears to be encroaching into this site.

B. minganense
B. tunux
B. yaaxudakeit

South of Auriel Trailhead, (60.647483° N, 137.326833° W), elevation 783 meters, June 23, 2007. *Botrychium* is common on the west side of the road in a well drained grassy area adjacent to the road and on the gravel of the road prism.

B. minganense
B. "neolunaria" × *B. lunaria* (introgressed)
B. spathulatum
B. tunux
B. yaaxudakeit

Auriel trail pipeline, (60.716631° N, 137.427019° W), elevation 781 meters, June 24, 2007. *Botrychium* is common in the open grassy area at the intersection of the Auriel Trail and the route of the old Haines pipeline, as well as along the pipeline route. Figure 3 shows the moonwort habitat and flags marking the 2007 moonwort population, this is also the 2004 collection site of *B. hesperium*. *B. hesperium* was not relocated in 2007.
B. minganense
B. "neolunaria"



Figure 3. Auriel Trail collection site. View to the southeast, directly down the Haines pipeline route. Flagging marks individual *Botrychium* plants. Moonworts also common in pipeline route on far side of opening.

Bear Summit East, (60.854759° N, 137.793528° W), elevation 993 meters, June 27, 2007. West side of the road growing on the road shoulder and flat area adjacent to the road. *Botrychium* is uncommon at this site. Gravelly substrate with about 30% exposed gravel, sparse vegetation dominated by *Oxytropis*, *Potentilla*, *Epilobium latifolium* and *Hedysarum*. This roadside area clearly has been brushed.
B. minganense
B. "neolunaria"
B. spathulatum

Bear Creek Summit, (60.896378° N, 137.829384° W), elevation 943 meters, June 24, 2007. *Botrychium* growing on both sides of the road. On the east side they were widely scattered in open roadside meadow. On the west side of the road, *Botrychium* was common on the gravel of the road prism (Figure 4) 50 to 80% bare gravel.

B. minganense

B. tunux

B. yaaxudakeit



Figure 4. Bear Creek Summit. View to the southeast toward road prism and road. Individual *Botrychium* plants are marked with pin flags.

Bunny Trap Bog Northwest Arctic Institute plot area, (61.0093° N, 138.189295° W), elevation 989 meters, June 23, 2007. About 0.45 km NE of parking spot at north side of clearing on the north side of the Alaska Highway. *Botrychium* are uncommon in a natural grassy meadow in east-west meandering swale. Growing with low-growing *Salix*.

B. "neolunaria" × B. lunaria (introgressed)

Radio Tower shrubs Northwest Arctic Institute, (60.99752° N, 138.2637° W), elevation 999 meters, June 23, 2007. Microwave tower site, 1.45 km south of the Alaska Highway. *Botrychium* common in an area about 11 meters southeast of the clearing around the microwave site. At the ecotone between a *Picea glauca* forest and the clearing. *Festuca* dominates this habitat with some *Epilobium angustifolium* and *Salix*.

B. "neolunaria"

Radio Tower clearing Northwest Arctic Institute, (60.9981° N, 138.2644° W), elevation 999 meters, June 23, 2007. Microwave tower site, 1.45 km south of the Alaska Highway. Artificially maintained 150 meter-wide clearing (firebreak) around the tower. Dry well drained herbaceous meadow with hundreds of *Botrychium*. About 90% of the substrate covered with an organic crust of lichens and bryophytes.

B. "neolunaria"

B. "neolunaria" × B. lunaria (introgressed)

Sheep Bullion Trail, Kluane National Park. June 22, 2007. This abandoned mining road now maintained as a trail. The trail receives light ATV traffic related to Park maintenance and subsistence use by First Nation's people. Material from previous surveys sent by Phil Caswell to Iowa State University for genetic analysis revealed the Sheep Bullion trail to be particularly rich in *B. tunux*. During our 2007 surveys, plants were collected on three parts of the trail, an "upper", "middle" and a "lower" site. Because of the relatively high elevation and early collection time, the plants were not mature, thus, electrophoresis was particularly important for identifying these specimens.

Upper site (61.02267° N, 138.63487° W), elevation about 1560 meters.

B. "neolunaria"

B. tunux

Middle site (61.01417° N, 138.62695° W), elevation about 1415 meters.

B. spathulatum

B. yaaxudakeit

Lower site (61.0255° N, 138.5071° W), elevation about 1210 meters.

B. spathulatum

B. tunux

Soldiers Summit Trail, Kluane National Park, (61.02557° N, 138.50703° W), elevation 808 meters, June 23, 2007. *B. lineare* was collected in 2003 (identity confirmed genetically in 2003 (Enum-8348³)), seen again in 2004 (Figure 5a), and relocated in 2007. The leaf had been damaged, so was not collected, but was photographed. (Figure 5b). Growing in bare hard-packed soil (Figure 5 and 6). A second *B. lineare* was found growing in a well-drained grassy area about 10 meters up the Soldiers Summit Trail. *Botrychium* is relatively uncommon in well-drained grassy areas along this portion of the Soldiers Summit Trail. Surveys were made further along the trail toward the Soldiers Summit site and no *Botrychium* were found, although *Botrychium* were found in these areas during surveys in 2004.

B. lineare (two plants one of which was observed but not collected in 2007)

B. minganense

B. spathulatum

B. tunux

Kluane Lake pull off, (61.16898° N, 138.59837° W), elevation 824 meters, June 24, 2007. Highly disturbed area, adjacent to former route of Alaska Highway. *Botrychium* rare on gravel and soil substrate. Exposed gravel and soil 50% cover; dominant vegetation includes *Shepherdia canadensis* 30% cover, *Artemessia* 10% with traces of *Hedysarum* and grasses. *B. yaaxudakeit* had been documented from this area (and identity verified through electrophoresis), however we did not relocate that species. Based on the site characteristics it appears as though we did not relocate the *B. yaaxudakeit* collection site.

B. spathulatum

³ The Enum is a tracking number assigned to each specimen at the electrophoresis laboratory at Iowa State University.

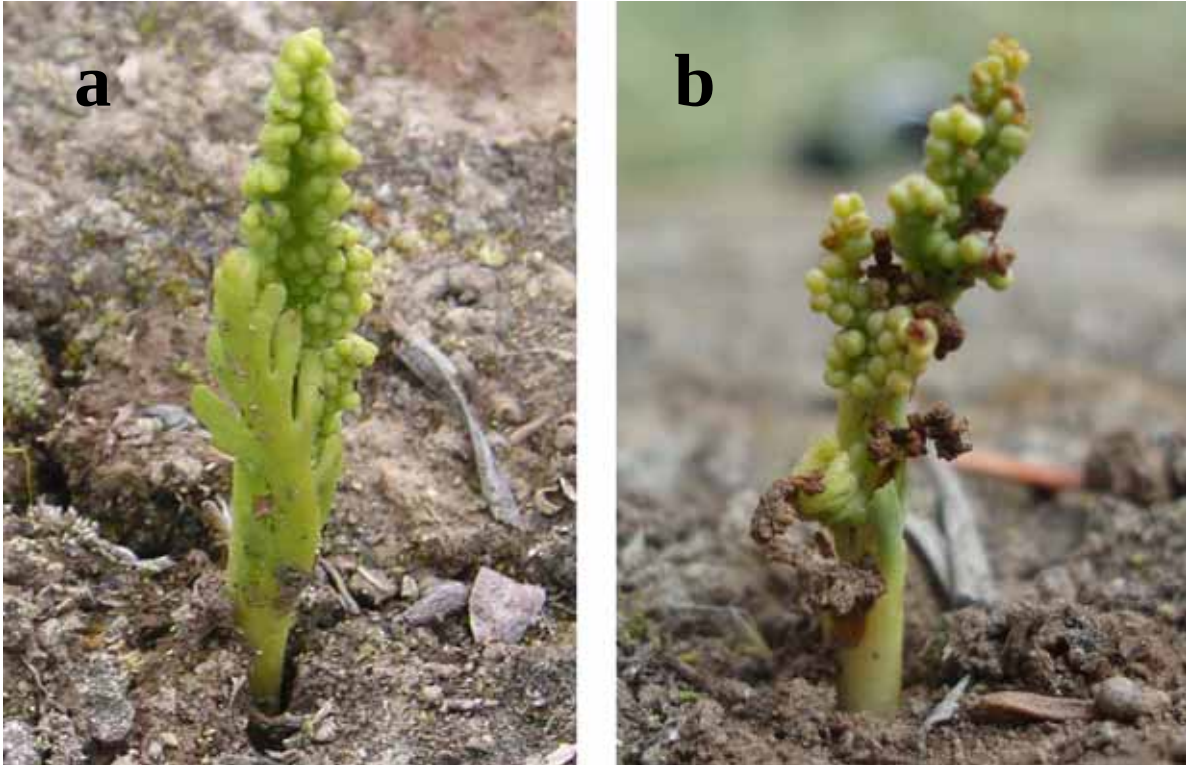


Figure 5. *Botrychium lineare* growing in bare soil along the Soldiers Summit Trail. 5a. 2004 photo (photo by Lloyd Freese); 5b. 2007 photo.



Figure 6. Along Soldiers Summit Trail. Arrow points to *Botrychium lineare*. *Botrychium* are flagged.

White River, (61.98417° N, -140.50298° W), elevation 701 meters, June 27, 2007. Koidern, Yukon Territory. *Botrychium* are common in a broad roadside meadow maintained by brush removal. Mesic meadow with occasional sprouting *Populus* this habitat is dominated by open soil and duff (Figure 7).

B. lineare

B. minganense

B. "neolunaria"

B. spathulatum

B. tunux



Figure 7. View to the east from the “White River” site. *Botrychium* marked with flags. Note chipped wood on the ground from roadside brush removal.

Alaska

Chisana area, Wrangell-St. Elias National Park

Chisana, Lawns around Commissioner's residence (62.06596° N, 142.04816° W), elevation 1015 meters, June 25, 2007. *Botrychium* was found to be relatively common in this area. Open mesic meadows on gravelly substrate of the Chisana River floodplain. Ten to 20% bare gravelly, soil, about 50% *Arctostaphylos*. Forest was cleared and cabins constructed in the early part of the 20th century. Substrate again disturbed several years ago. The area is not mowed, grazing horses help maintain the open meadows.

B. lunaria × *B. "neolunaria"* (introgressed)

B. spathulatum

B. tunux

Women's Jail (62.066156° N, 142.047667° W), elevation 1015 meters, June 25, 2007. Habitat similar to that around Commissioner's residence. Figure 8 is a photo of the general habitat in the residence, jail and cabin area.

B. minganense

B. spathulatum

Too Much Johnson Cabin (62.06582° N, 142.04646° W), elevation 1015 meters, June 25, 2007. Habitat similar to that around Commissioner's residence.

B. lineare

B. spathulatum



Figure 8. Chisana, *Botrychium* habitat in the vicinity of the Commissioner's residence and Women's Jail. Women's Jail in background. Photo taken about halfway between the residence and the Jail.

ATV Trail parallel to Chisana airstrip trail between 62.06628° N, 142.04442° W and 62.07031° N, 142.04902° W, elevation 1015 meters, June 25, 2007. *Botrychium* is infrequent, adjacent to and on the ATV trail. Well drained substrate much of which is covered by a thin mat of bryophytes. *Salix* and *Populus* are cut back to maintain the trail. Typical habitat is shown in Figure 9.

B. lineare was collected in this area in 2003 and genetically confirmed in 2004 (Enum-8415). We did not relocate *B. lineare* at the site adjacent to the runway as indicated on Park Service GIS maps, however the point on the map may have been moved when the map was made.

B. spathulatum

B. tunux



Figure 9. *Botrychium* habitat on and adjacent to ATV trail paralleling the Chisana airstrip.

Chisana airstrip (62.0689° N, 142.0468° W), elevation 1015 meters, June 25, 2007. The airstrip is mowed annually. Few *Botrychium* were found along cleared edge of the airstrip. Well drained substrate with short shrubs (*Dryas integrifolia*), *Oxytropis*, seedling *Populus*, few forbs and about 10% bare soil.

B. spathulatum

Chisana, Stabilized floodplain of Chisana River (62.06517° N, 142.04726° W), elevation 1015 meters, June 25, 2007. Natural habitat, not disturbed by humans. *Botrychium* rare, dominant plants include *Dryas integrifolia* 80%, *Picea glauca* 10-20%, *Shepherdia canadensis* 15%, *Populus* & *Salix* each 10% and bare soil 5-10%

B. spathulatum

B. tunux

Other areas, Wrangell-St. Elias National Park

Chicken Creek (62.1215° N, 141.8578° W), elevation 1475 meters, June 26, 2007. This site was chosen because in 1999 *B. tunux* was documented from open alpine scree slopes in this vicinity. We did not reach the scree slopes, which are at least 1 km northeast of the area we surveyed. Our survey area was just upstream of the Chicken Creek Airstrip in a mosaic of meadows dominated by *Salix reticulata* with shrubby *Potentilla*, *Primula* and *Dryas integrifolia*. *Botrychium* is uncommon in this area. The area is grazed by horses (related to outfitter-guide operations) and moose (Figure 10).

B. "neolunaria" × B. lunaria (introgressed)

B. minganense



Figure 10. General habitat near Chicken Creek, just above airstrip, on Gold Hill above Chisana. *Salix* show evidence of heavy grazing by horses and moose.

Baultoff Strip (62.1170° N, 141.1755° W), elevation 1235 meters, June 26, 2007. *Botrychium* is uncommon along the sides of the airstrip, a more concentrated population of *Botrychium* occurs at north end of the airstrip. The substrate is well drained and gravelly, commonly with a 50% cover of lichens and bryophytes, 50% cover of *Arctostaphylos*; other dominant plants are shrubby *Potentilla*, *Epilobium latifolium* and *Salix* (Figure 11).

B. "neolunaria" × B. lunaria (introgressed)

B. minganense

B. tunux



Figure 11. *Botrychium* habitat along east side of the Baultoff airstrip, view to the northwest toward the north end of the airstrip, where the airplane is parked in the distance, near concentration of *Botrychium*.

Solo Strip, (61.7602° N, 141.7042° W), elevation 1099 meters, June 26, 2007. North side of the White River and just north of Solo Creek. *Botrychium* is common in the vicinity of the path to house within a Park inholding; and abundant in the grassy airstrip near the house. Habitats vary from grassy meadows to gravelly soil with crusts of lichens and bryophytes. Dominant vascular plants include *Festuca*, *Potentilla*, *Calamagrostis*, *Hedysarum*, *Oxytropis* and *Shepherdia canadensis*. Figure 12 shows general habitat and Figure 13 is a close-up of *Botrychium* in habitat.

B. "neolunaria" × B. lunaria (introgressed)

B. spathulatum

B. tunux



Figure 12. Gravelly meadows just north of Solo airstrip (for scale, note airplane behind shrubs in middle distance). View to the southeast toward Wrangell-St. Elias Mountains. *Botrychium* are flagged.



Figure 13. *Botrychium* common in well drained meadows near Solo Creek. Arrows indicate individual *Botrychium* plants.

Alaska Highway near Tok.

Tok, (63.329559° N, 142.901353° W), 4.35 km E of Tok's main intersection, elevation 498 meters, June 24, 2007. South side of the Alaska Highway and on the south side of an off-road vehicle track. *Botrychium* is rare in an herbaceous meadow created and maintained through human disturbance; with small *Salix*, *Populus*, *Epilobium angustifolium*, *Dodecatheon*, *Polemonium* and grasses. Another area, across the highway with appropriate-seeming habitat was intensively searched, and no *Botrychium* were found.

B. "neolunaria"



Figure 14. Herbaceous roadside meadow just east of Tok, view toward east. This meadow is maintained by ongoing roadside brush removal. Pin flag marks *Botrychium*.

Discussion

Habitat and Disturbance

We found *Botrychium* habitat to be mesic, well-drained open areas. In many instances these were in areas of past human disturbance. These disturbance areas included roadsides, trails, utility corridors, airstrips and clearings. In some areas, the construction of roads created well-

drained substrate where none had existed in the past. Airstrips are normally situated in well-drained areas. The initial disturbance caused by construction undoubtedly obliterated most vegetation, however, with passage of time, mid-successional vegetation has returned. Vegetation is generally maintained at this successional stage by management commensurate with ongoing uses, such as brush removal along roadsides, trails and utility corridors, mowing airstrips, and maintaining firebreaks. Road ditches and shoulders in the Yukon are mowed to cut back shrubs approximately once every five years; immediate roadsides are also mowed to cut back herbaceous vegetation less than once a year⁴. This cutting appears to maintain the open habitat favoring *Botrychium*. Brush is cut back along roadsides in Alaska on a regular basis, also maintaining *Botrychium* habitat. The “lawns” among the historical buildings at Chisana are not mowed but the low vegetation (Figure 8) is maintained by grazing packhorses. These types of management disturbance prevent herbaceous meadow habit from succeeding to woody vegetation less favorable to *Botrychium*, and these types of disturbances generally do not churn or disturb the soil or damage *Botrychium* plants. To the contrary, this type of management disturbance appears to maintain populations of moonworts.

The surveys in 2007 generally took place in areas that are easily accessible, thus surveys were biased toward areas of human disturbance. Only two of the 27 sites where *Botrychium* were collected were in areas not disturbed by people, these were the Bunny Trap Bog site and Chisana flood plain. However, *Botrychium* has been documented numerous times from areas in and adjacent to the Wrangell-St. Elian Mountains that have not been disturbed by people. Most of these finds were made during the past twelve years during plant surveys conducted by Wrangell-St. Elias National Park and by Kluane National Park.

Distribution and Abundance

Moonwort abundance ranged from uncommon to abundant in appropriate habitats. Based on our surveys, previous surveys and considering that the study area is so large, and that there

⁴ According to Lloyd Freese, Kluane National Park, Parks Canada.

appears to be a considerable amount of habitat, we suspect that *Botrychium* is not as rare as previously thought. Distribution of moonworts found in our surveys is shown in Table 1.

We found most widespread and abundant moonworts to be *B. minganense*, *B. “neolunaria”*, *B. spathulatum* and *B. tunux* (see table 1), all of which were found throughout the study area. The widespread *B. minganense* is distributed across Alaska, the Yukon and British Columbia, western United States and across boreal North America and east to Iceland. *B. “neolunaria”* is distributed across North America from the extreme western end of the Aleutian Islands to New Brunswick in eastern Canada and south in the east to New England and the Great Lakes, and in the western mountains to California and Arizona,. *B. spathulatum* is known from the southeast quarter of Alaska across the Yukon through southeastern Alaska, south through British Columbia and Alberta to northwestern Montana and east to the Great Lakes. Farrar’s recent genetic work indicates that plants previously tentatively called *Botrychium* “wagneri” (Farrar, 2004) are *B. spathulatum*. *Botrychium spathulatum* is morphologically quite variable; this variation has resulted in considerable confusion since it can be very similar in appearance to *B. lineare* (Figures 15 and 16) and to *B. ascendens* (both *B. spathulatum* and *B. ascendens* are allotetraploid species having *B. lineare* as one parent). The distribution of *B. tunux* covers a large area extending from Alaska’s Pribilof Islands in the west to Unalaska in the Aleutians, east to insular southeastern Alaska, north and east to the Wrangell-St Elias Range, and south to Colorado and Nevada. We suspect we will find *B. tunux* to be more widespread as more moonwort surveys are conducted in western North America.

Another relatively widespread and abundant moonwort is a genotype that is introgressed between *B. “neolunaria”* and *B. lunaria*. Surprisingly enough, we found no pure *B. lunaria*⁵ during these surveys. However, past surveys in the study area have found this taxon (identity verified through enzyme electrophoresis). In the Wrangell-St. Elias Mountains of Alaska, *B. lunaria* has been found near Ping Pong Mountain, and in the Yukon, found in the vicinity of

⁵ *Botrychium lunaria* is circumpolar in distribution.

Aishihik, the Duke River Bridge crossing along the Alaska Highway, and Cache Lake. In his report documenting a genetic study of Yukon *Botrychium*, Farrar (2004) noted the paucity of *B. lunaria* in the Yukon.

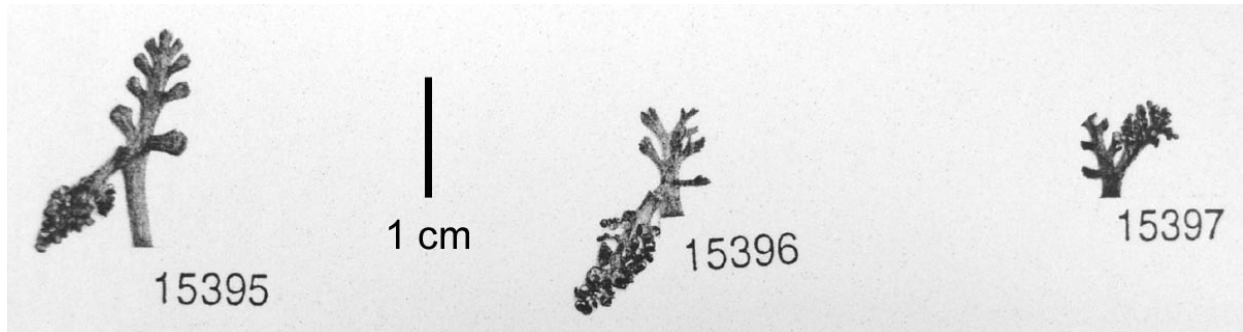


Figure 15. *Botrychium spathulatum* on the left and two *B. lineare* on the right. Note *B. spathulatum*'s rounded pinnae. Plants collected in Alaska at Chisana, Too Much Johnson Cabin.

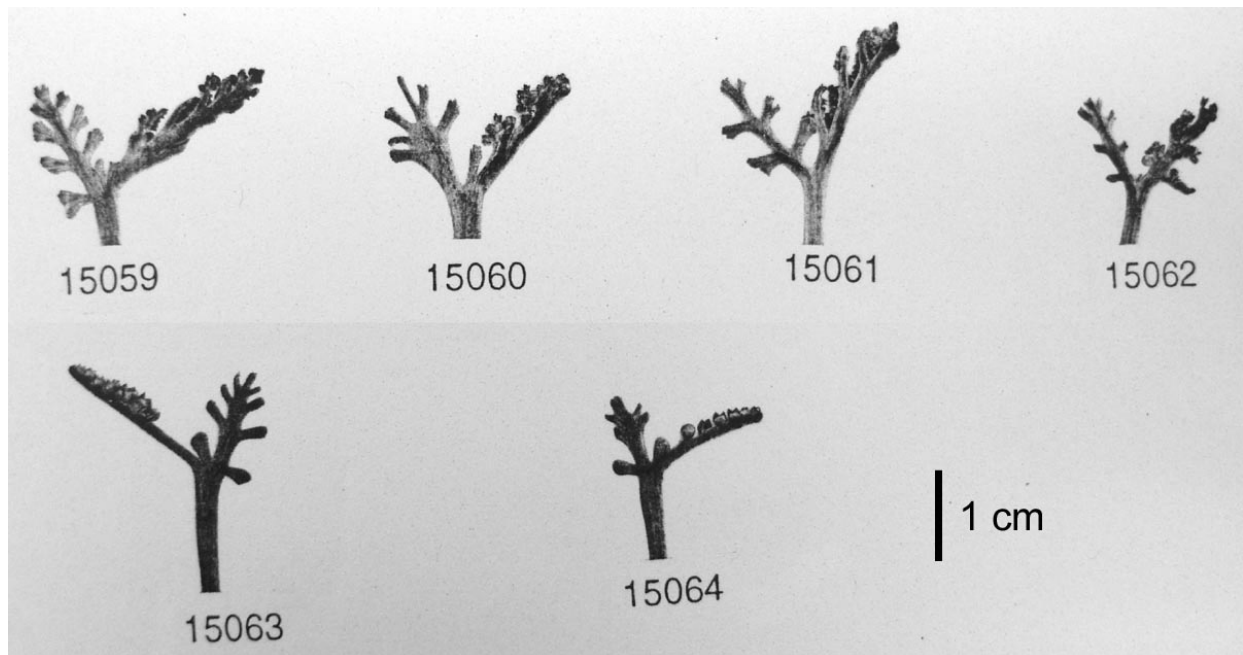


Figure 16. *Botrychium lineare* in the top row and *B. spathulatum* in the bottom row. Note *B. spathulatum*'s rounded pinnae. Plants collected along the Alaska Highway near Koidern, Yukon Territory.

Botrychium yaaxudakeit was only moderately widespread, but relatively abundant. This fern is distributed from the Wrangell-St. Elias Mountains of Alaska, Yukon and British Columbia to central British Columbia, Alberta, Montana, Oregon and California. *Botrychium lineare* was found at three sites, relatively distant from each other and at each site it is rare. From

previous collections it is also known from a site adjacent to the Chisana airstrip (that population was not relocated during our surveys) and from the base of Mt. Allen, North of Medicine Creek (about 15 km north of Chisana). Because *B. lineare* is so tiny (Figure 15 & 16), it is very likely that this fern has been overlooked during past botanical surveys throughout its potential range. *Botrychium lineare* occurs with some regularity in roadside and airstrip habitats similar to those in which it was found during this study.

Our surveys found the least widespread and least abundant moonworts to be *B. alaskense*, *B. lanceolatum* and *B. pinnatum*, which were only found in the southeastern part of the study area. Although *B. alaskense* is relatively widespread in central and southern Alaska, this is the first report of *B. alaskense* for the Yukon. Since our collection in June, *B. alaskense* was documented from the central Yukon, growing in a rockpit along the Klondike Highway. (Bruce Bennett, personal communication, October 2007). A photo was taken of this *B. alaskense* as well as a *B. pinnatum*. *B. lanceolatum* is circumpolar in distribution and *B. pinnatum* occurs across Alaska, through the Yukon and south to the northwestern United States.

Conclusions

- *Botrychium tunux* and *B. lineare* are both more widespread and abundant than previously thought.
- Vegetation maintenance, such as brush removal, mowing and grazing do not appear to negatively affect *Botrychium*, and these non-soil disturbing disturbances maintain the mid-successional open habitat required by *Botrychium*.
- We can expect to find *Botrychium* growing at the many areas in and adjacent to the Wrangell-St. Elias Mountains where these types of ongoing disturbances maintain openings in mesic well drained areas.
- Further surveys will be valuable for refining our knowledge about the distribution, abundance and habitat of *Botrychium*.

Genetic and morphological data resulting from these field surveys will be valuable for comparison purposes in future analysis of moonwort distribution and abundance from Alaska and the Yukon as well as in other parts of the world.

References

- Farrar, D. R. 2004. (Unpublished Report) *A genetic study of Botrychium in Yukon Territory, Canada – 2002 & 2003*. Prepared for Parks Canada, Kluane National Park.
- Shephard, M. E. 1995. *Plant community ecology and classification of the Yakutat Foreland, Alaska*. Technical Report R10-TP-56. Juneau, Alaska: U.S. Department of Agriculture, Forest Service, Alaska Region. 206 pp.
- Stensvold, M. C. 2007. A taxonomic and phylogeographic study of the *Botrychium lunaria* complex. Ph.D. dissertation, Iowa State University, Ames, Iowa.
- Stensvold, M. C., D. R. Farrar. (in preparation) Genetic diversity in the *Botrychium lunaria* (Ophioglossaceae) complex.
- Stensvold, M. C., D. R. Farrar and C. Johnson-Groh. 2002. Two new species of moonworts (*Botrychium* subgenus *Botrychium*) from Alaska. *American Fern Journal* 92:150-160.
- Wagner, W. H. Jr. and F.S. Wagner. 1994. Another widely disjunct, rare and local North American moonwort (Ophioglossaceae: *Botrychium* subg. *Botrychium*). *American Fern Journal* 84:5-10.