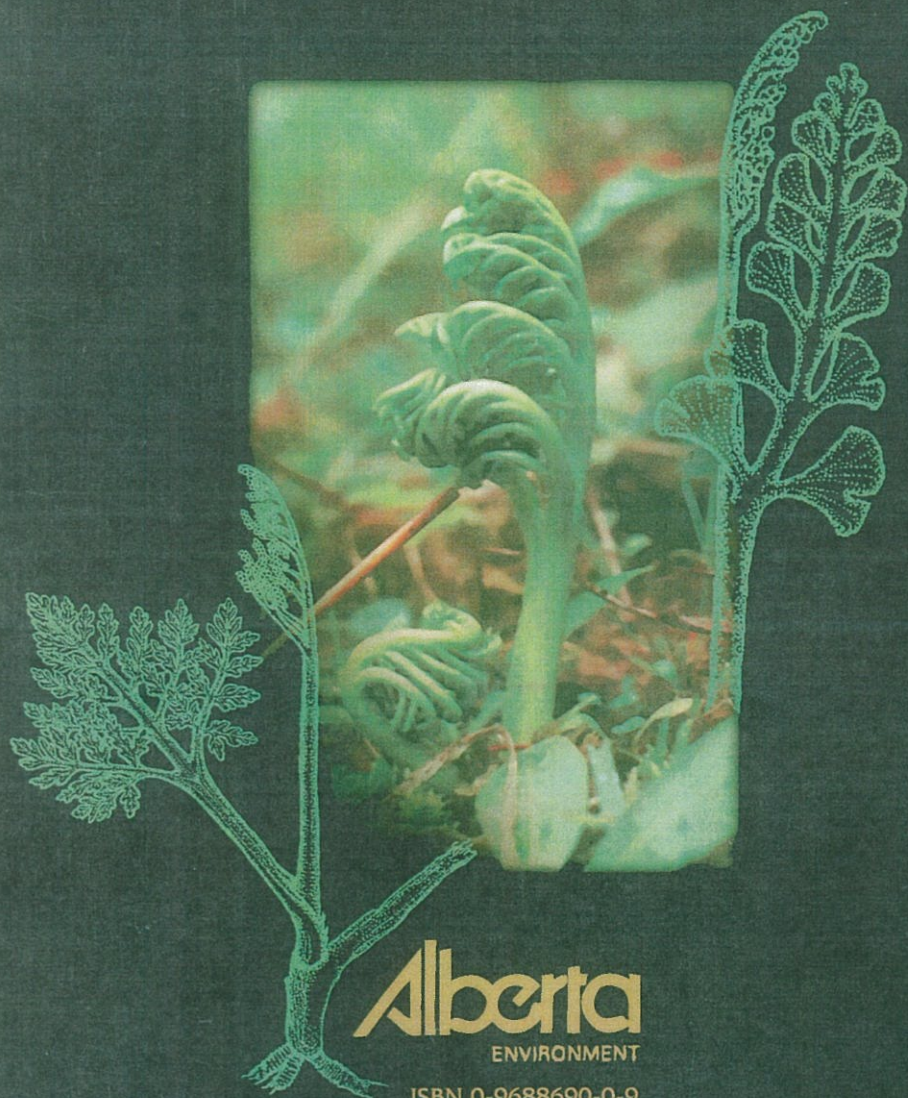


With an identification key, illustrations, photographs, and maps, this field guide summarizes our knowledge of the biology and distributional ecology of the Botrychiaceae, a family of rare and uncommon ferns within the province of Alberta. The information provided here is intended to help those with an interest in rare plant conservation, from naturalists to resource managers, appreciate the diversity of our biological heritage and find ways to ensure its continued existence.



Alberta
ENVIRONMENT

ISBN 0-9688690-0-9

The Botrychiaceae of Alberta



by Patrick Williston

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MNIUM ECOLOGICAL RESEARCH

With support from:



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First printed 2001
Printed in Canada

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The Publisher
Alberta Natural Heritage
Information Centre

Alberta Environment
2nd Floor, 9820-106 St.
Edmonton, AB, T5K 2J6

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National Library of Canada Cataloguing in Publication Data
Williston, Patrick, 1972-
Main entry under title:
The Botrychiaceae of Alberta

Includes bibliographical references.
ISBN 0-9688690-0-9

1.Ophioglossaceae--Alberta--Identification I. Title.
QK524.O7W56 2001 587'.33 C2001-910433-2



Horses that feeding on the grassy hills,
Tread upon moonwort with their hollow heels,
Though lately shod, at night goe barefoot home,
Their maister musing where thir shooes be gone.
O Moonwort tell us where thou hid'st the smith,
Hammer and pincers, thou unshodst them with?

Alas, what lock or iron engine is't
That can thy subtile secret strength resist,
Sith the best farrier cannot set a shoe
So sure, but thou so shortly cans't undoe?

Guillaume de Salluste du Bartas (1578)
—Devine Weeks

(Translated from French by Joshua Sylvester –1598)

The Botrychiaceae of Alberta

Contents	Page
Acknowledgements.....	v
Introduction.....	1
History.....	3
Habitats.....	5
Priorities in Conservation.....	6
Future Research.....	11
Rarity Status.....	12
Essays:	
The Life History of the Botrychiaceae.....	7
W.H. and F. S. Wagner.....	9
Fossils of the Botrychiaceae Discovered in Alberta ...	13
Key to the Botrychiaceae of Alberta.....	15
Note on Troublesome Determinations.....	19
Botrychium.....	22
Botrypus.....	39
Sceptridium.....	40
A List of the Botrychiaceae of North America.....	41
Rare Native Plant Form.....	42
Bibliography.....	43
Photographic illustrations.....	58

Acknowledgements

This project has benefited greatly from the contributions of several people. Joyce Gould, Keith Ainsley, and Patsy Cotterill at Alberta Environment generously provided the support that made it possible. Not only did they initiate the project, but also much was gained from their collections and their assistance in obtaining specimens and information. Herb and Florence Wagner, and Peter Achuff also made numerous important collections.

Mary Stensvold, Adolf and Oluna Ceska, Warren Hauk, Ruth Stockey, and Norio Sahashi provided information about their research on the Botrychiaceae; Wilf Schofield, Karen Golinski, Carla Rydholm, and Olivia Lee provided support at the UBC herbarium; Bob Preston and Florence Wagner were helpful at the University of Michigan; and Karen McKeown, Allen Banner, Will MacKenzie, Jen Morran, Marty Kranabetter, Jim Pojar, and Paula Bartemucci offered their knowledge from more northerly realms. Duke Hunter prepared the base maps for the species distributions. The manuscript benefited tremendously from suggestions by Jim Pojar, Adolf Ceska, Joyce Gould, and Paula Bartemucci.

I am also deeply grateful to both Herb and Florence Wagner for sharing their knowledge and love of plants.

Photographs and illustrations

Photographs are by the author except for those provided by Joyce Gould (Alberta Natural Heritage Information Centre), Harvey Janszen (Ophioglossum Consulting), Jim Pojar (B.C. Ministry of Forests), Ruth Stockey (University of Alberta), Florence Wagner (University of Michigan), Börje Wernersson (Swedish Museum of Natural History), and Steve Wirt (Montana Natural History Program). Paul Nelson's wonderful illustrations (pp. 32, 36) were provided by Colleen Matula of the USDA National Forest Region 9. All other illustrations are by the author.

Cover

The cover was designed by Sandra Smith of Wordsmith Writing and Design, Smithers, B.C. using illustrations and photographs by the author.

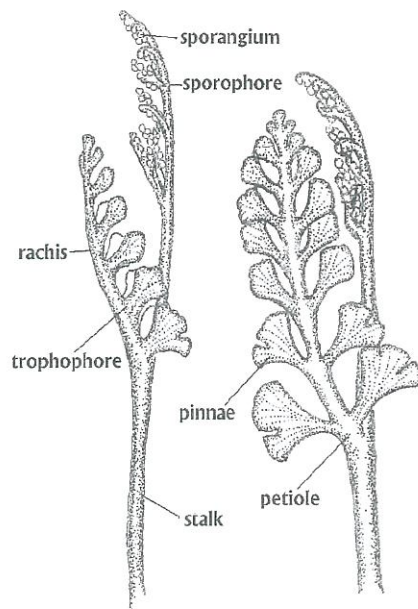
Introduction

The Botrychiaceae is a family of small, inconspicuous, and enchanting ferns with 5 genera and approximately 70 species that are more or less globally distributed. Alberta supports three genera: *Botrychium* (the moonworts), *Botrypus* (the rattlesnake ferns), and *Sceptridium* (the grapeferns). The other two genera, *Japanobotrychium* and *Helminthostachys*, occur in India, Nepal, China, Japan, Southeast Asia, and Australia.

Alberta contains 17 species within the Botrychiaceae, of which 15 are considered to be rare. Many of these are endemic to western North America, in fact, because the area is so rich in numbers of species, southern Alberta and the adjacent regions of the United States and British Columbia have been called the world's centre of *Botrychium* diversity (Wagner et al. 1983).

The Botrychiaceae are perennials that consist of a spore bearing branch (sporophore) and a vegetative blade (trophophore) borne on a common stalk. The trophophore has a main axis (rachis) that may be pinnately lobed or branched. The pinnae themselves may be divided into pinnules that may further divide into pinnulets. These ferns tend to be morphologically simple and yield relatively few characters useful for taxonomic purposes, making them particularly difficult to identify.

A defining characteristic of this family is the development of large (1-2 mm) sporangia that are derived from a cluster of cells and form a sporangial jacket that is several cells thick. This type of development is called eusporangiate and is also found in three other fern families, the Marattiaceae, the Ophioglossaceae, and the Psilotaceae (Gifford and Foster 1996). Eusporangiate development is considered primitive and in many ways bears a closer resemblance to cycads and early gymnosperms than to other ferns.



The sporangia of all other ferns are much smaller (generally <1 mm) and are derived from a single cell to produce a jacket that is one cell thick in what is known as leptosporangiate development.

The taxonomy of the Botrychiaceae is an active field of research. Though first described in 1949 by Nakai, recognition of these ferns as a distinct family in North American publications is relatively new. Earlier treatments grouped the Botrychiaceae with the adder's tongue ferns, the Ophioglossaceae. While the two families share eusporangiate development, they differ in several easily distinguishable ways. The sporangia in the Ophioglossaceae are symmetrically arranged on an unbranched sporophore, while in the Botrychiaceae the sporangia are irregularly arranged on a branching sporophore; the leaf venation is reticulate, or net-shaped in the Ophioglossaceae, and free in the Botrychiaceae; and the leaf blade is simple in the Ophioglossaceae and pinnately or otherwise divided in the Botrychiaceae. Furthermore, the Ophioglossaceae appear to be more diverse in sub-tropical climates, while the Botrychiaceae have a greater number of species in temperate regions.

There are also developments within the genera of the family. Based upon several features such as the positioning of the sporophore, the inability to form hybrids, differences in chromosome numbers, and the ornamentation of the spores, subgenera of *Botrychium* are now widely recognized as distinct genera: *Botrychium*, *Botrypus*, and *Sceptridium*, (Sahashi 2000).

In spite of advances in microscopy and molecular techniques, the taxonomy of the species continues to rely heavily upon a small number of morphological characters such as the shape and venation of the pinnae. This is augmented by other features including the length and branching of the sporophore, habitat characteristics, and phenology (the timing of emergence, spore development, spore release, etc.). Genetic approaches using chromosome counts and isozyme analyses have contributed to the reconstruction of evolutionary relationships among species (Wagner 1993; Hauk and Chase 1993; Hauk and Haufler 1999; Farrar 2000), however these types of analyses are of limited use in the field where immediate identification is often required.

Since the treatment of the Ophioglossaceae in the Flora of North America (Wagner and Wagner 1993), there have been many changes in the botanical nomenclature and at least one newly described species. Furthermore, many new collections have since been made, resulting in important range extensions and several new and puzzling specimens. The identification of some specimens has been somewhat impeded by a lack of representative specimens of newly described species in most herbaria.

Together with the recent taxonomic developments, the new collections, and a greater concern regarding their conservation, it appears timely to review Alberta's collection of the Botrychiaceae and to produce a field guide containing an updated treatment that reviews the status of these ferns within the province.

This field guide includes a short history of the classification of these ferns, discusses their life history, their distribution, and conservation. An illustrated key is provided with species descriptions, maps, and photographs to assist in field identification. Their rarity, taxonomic complexity, and unique morphology make the Botrychiaceae a fascinating and rewarding group to study. There is still much more to learn!

History

The first of the Botrychiaceae to be described was *Lunaria minor*, now known as *Botrychium lunaria*, which was drawn and characterized by Leonhard Fuchs in 1542. In the 1600's the French brothers, C. and J. Bauhin, introduced the name *Lunaria botrytis* (again for *B. lunaria*) and provided the root word for the genus *Botrychium*. 'Botrys' is Greek for cluster, referring to the sporangia that are grouped at the terminus of the sporophore, and 'Lunaria' is an allusion to the delicate, crescent-shaped pinnae, though its distinctive green colour is also somewhat ethereal. Linneaus subsequently lumped many species together with the genus *Osmunda* in his famous work "Species Plantarum", published in 1753.

"A considerable part of the difficulty in recognising a variable species in our systematic works, is due to its varieties mocking, as it were, some of the other species of the same genus."

--Charles Darwin, *On the Origin of Species By Means of Natural Selection* (1859)

Folklore from about this time suggested that the 'moonwort', *B. lunaria*, was an especially useful magical herb for opening doors and picking locks, presumably because of its key-shaped appearance. Another popular belief held this plant responsible for the unintended unshoeing of horses, thus riders had to be wary when traveling through fields where it grew (Frye 1934). Furthermore, with the appropriate observances such as harvesting the plant by moonlight, the bearer of a moonwort was said to be capable of becoming invisible, or of being protected from daggers and bullets (Frye 1934); clearly, a very useful plant! Scientific research substantiating this ancient lore has proven elusive. Even in the day, the lore was not held by all:

Gadskill (the thief): "We steal as in a castle, cocksure; we have the receipt [recipe] of fern seed, we walk invisible."

The Champlain: "Nay, by my faith, I think you are more beholding to the night than to fern seed for your walking invisible."

Gadskill: "Give me thy hand; thou shalt have a share in our purchase, as I am a true man."

The Champlain: "Nay, rather let me have it, as you are a false thief."

--William Shakespeare, *King Henry IV: Act II scene 1*

Many species were published in the 1800's and were lumped or split by leading pteridologists such as Presl, Milde, Hooker, and Baker (Clausen 1938). In North America, Frère Marie-Victorin, author of the *Flore Laurentienne* (1935) and instigator of the Montreal Botanical Gardens, described *B. minganense* from the Mingan Islands in the mouth of the St. Lawrence River (Marie-Victorin 1927). Clausen updated the taxonomy and summarized all previous work in his 1938 "A Monograph of the Ophioglossaceae". Frustrated by descriptions based upon trivial characters, Clausen sought to improve the characterization of the species by making detailed morphological studies. Like his predecessors, Clausen ultimately resorted to leaf blade and vein divisions, pubescence, size, and habitat for his descriptions. Clausen's monograph remains a valuable historical survey of these ferns.

In the last 25 years, W.H. and F.S. Wagner have made significant contributions to our taxonomic understanding of this group and have described 17 new species of *Botrychium* from North America (see bibliography). Many of these species belong to the fan-leaf moonworts and were formerly all called *B. lunaria*. The similarities among these species have made identifications difficult; key characters are subtle and variation in morphology appears to be great within

species and among populations. The best summary of this complex group is found in the *Flora of North America* (Wagner and Wagner 1993).

Undoubtedly stimulated by the enthusiasm of W.H. and F.S. Wagner, research on the Botrychiaceae is active, particularly in the United States and Japan. Farrar (2000) has used isozyme analysis to clarify relationships between taxa that are morphologically confusing. Johnson-Groh and others (2000), Lescica and Ahlenslager (1996), and Stensvold (pers. comm.) conducted long-term monitoring studies that have provided valuable information about the phenology of these ferns and the prominence of asexual reproduction. Approaches using DNA sequencing to understand phylogenetic relationships, currently one of the most productive realms of botany, have been the focus of Hauk (2000), who is investigating the cladistics of both *Botrychium* and *Sceptridium*. In Japan, Sahashi (see bibliography) has published numerous morphological studies on the genus *Sceptridium*, and has shown that genera within the Botrychiaceae can be clearly separated based upon spore ornamentation. Though Canada is unusually rich in the Botrychiaceae, studies here are few, and most regional floras include taxonomic treatments that are incomplete and out of date.

The Botrychiaceae is still fertile ground for study. Recent collections of *Botrychium* spp. from Alaska and Michigan are presently being considered for species status (Stensvold pers. comm.), and the genus *Sceptridium* is also undergoing taxonomic revision. Alberta has already been shown to contain a genetically distinct population that has received taxonomic recognition (e.g. *Botrychium* x *watertonense*), and it is possible that still others await discovery.

These ferns can be difficult to find and are generally poorly represented in most herbaria. Focused efforts in the past 6 years to document these ferns in Alberta and Montana have resulted in more than doubling their collections from these areas. Distributions are far from complete and are probably broader than current records suggest.

Habitats

Within the province of Alberta, the Botrychiaceae are found in four natural regions: the Rocky Mountains, the foothills, the boreal forest, and the parkland. The Rockies harbour much of the diversity but the other regions also support rare species and important populations and have probably been less intensively surveyed. At present, there are no collections of the Botrychiaceae from the Alberta grasslands though several species, such as *Botrychium campestre*, *B. lineare*, and *B. pallidum* are known from grassland habitats in central Canada and the U.S. and have probably been overlooked in the West.

The Rocky Mountains

In Alberta, alpine, subalpine, and montane habitats contain several species of the Botrychiaceae including *Botrychium ascendens*, *B. campestre*, *B. hesperium*, *B. lanceolatum*, *B. lunaria*, *B. 'michiganense'*, *B. minganense*, *B. paradoxum*, *B. pinnatum*, *B. simplex*, *B. spatulatum*, *B. x watertonense*, *Botrypus virginianus*, and *Sceptridium multifidum*. These generally occur as mixed populations in meadows, forest clearings, and along trails, old roads, and road cuts.

The Foothills

Populations of *Botrychium ascendens*, *B. lunaria*, *B. minganense*, *B. pinnatum*, and *Botrypus virginianus* are all known from the foothills. These ferns are most frequently found in forest openings or glades; however, *Botrychium minganense* and *Botrypus virginianus* have also been collected in moist woodlands.

The Boreal Forest

Wetlands, moist forests, and sand dunes are likely habitats in which to find the five species that are known from the boreal forest: *Botrypus virginianus* is the most common, followed by *Sceptridium multifidum*, *Botrychium lunaria*, *B. minganense*, and *B. lanceolatum*. It is possible that *B. crenulatum* may also occur in these forests, particularly in wetland habitats dominated by willows.

The Parkland

Among the least collected species are *Botrychium campestre*, *B. 'michiganense'*, and *B. pallidum*. These rare *Botrychium* species have been collected from two parkland localities north and east of Edmonton and represent the northern-most distributions of these three species. Other parkland species include *B. simplex* and *Sceptridium multifidum*.

Priorities for Conservation

In Alberta, the genus *Botrychium* (with 15) is second only to *Carex* (with 41!) in numbers of rare species among vascular plants (Gould 2000). However, conservation efforts for species within the Botrychiaceae has been impeded by several factors: identifying specimens is difficult; acquiring representative material of newly described species has been problematic; our knowledge of their distributions is incomplete; and their distributional ecology is still not fully understood.

The Life History of the Botrychiaceae

The life history of the Botrychiaceae is fascinating and complex. To begin with, the haploid spores (with one half of the total number of chromosomes of the mature plant) germinate below ground to form non-photosynthetic (achlorophyllous) gametophytes. In the soil, gametophytes form obligate associations with endophytic mycorrhizal fungi. The gametophytes are whitish, generally subspherical, oblong, or kidney-shaped, and bear numerous short projections or cilia.

The Botrychiaceae are hermaphroditic, which means that each gametophyte produces both male and female gametangia: the antheridia produce sperm, while the female archegonia each enclose a single egg. Self-fertilization is not only possible, but rather common, as high as 95% (Soltis and Soltis 1992). Hybridization is also relatively frequent, facilitated by the tendency for the species to occur in mixed populations. Hybrids are usually sterile unless a chromosome doubling event occurs, which may result in a fertile polyploid (bearing multiple copies of chromosomes). Several of the more recently described species are fertile polyploids with different parental species. Hybridization within *Botrychium* species is well documented. *Botrychium* x *watertonense*, first described from Alberta's Waterton Lakes National Park, is thought to have originated from a hybrid between *B. paradoxum* and *B. hesperium* (Wagner et al. 1983). Hybrids are not known between genera within the Botrychiaceae.

The Botrychiaceae tend to occur in wet habitats, or at least those that are moist in the spring during the snow melt (some become dry as summer progresses). Though little research has investigated this part of their life history, it is probable that the motile sperm are released in spring when the soil is wettest. Once the sperm has fertilized the egg, the developing sporophyte, the diploid spore-producing plant, can take several years before breaking the soil surface. The sterile blade, or trophophore, can emerge alone in species such as *Botrypus virginianus* and *Sceptridium multifidum*, but is more frequently accompanied by a fertile sporophore, the spore-bearing branch, even in young plants. Sheathed at the base of mature plants are partly developed primordia for following season; however, individuals do not emerge every year, and can remain below ground for several years before reappearing. Studies on plants that were tagged and monitored for several years suggest that individuals have an above-ground longevity of 5-10 years (Farrar 2000).

Asexual reproduction has been documented in several species of *Botrychium* and could be more important to their distributional ecology than previously thought (Johnson-Groh et al. 2000). Asexual propagules called gemmae develop among the roots of the plant, breaking off to initiate new individuals. This form of reproduction may explain why several species of *Botrychium* are often found in disturbed habitats where the gemmae could be mechanically dispersed.

Sporangia are borne in clusters on a branched or unbranched sporophore. Meiosis takes place inside the sporangia to produce haploid spores which are released from May to October depending upon the species. And so the cycle of life continues.

In the past few years the genus *Botrychium* has been the focus of several conservation assessments, particularly in Montana, Washington, and Oregon (Achuff 1992; Vanderhorst 1993, 1997; Zika 1992, 1994, 1995). These assessments have stimulated numerous studies resulting in an increase in the number of known localities and the concomitant development of new ecological information (Ahrensleger and Lesica 1995; Lesica 1987; Lesica and Ahrensleger 1996; Lesica and Steele 1994; Zika 1996). In considering the conservation of the Botrychiaceae it is necessary to discuss the role of disturbance, the prospects of restoration, conservation in natural regions, and the value of sensitive areas with multiple rare species.

Disturbance

Several *Botrychium* species, including some that are considered rare, appear to be successful colonizers of disturbed habitats. Species that are often found on the edges of trails or old roads include *B. ascendens*, *B. lanceolatum*, *B. pinnatum*, and *B. simplex*. *B. ascendens*, *B. lunaria*, *B. pallidum*, and *B. spathulatum* have been collected in abandoned fields. Human-created habitats such as these are abundant and are unlikely to decline in the near future.

Asexual propagules have been documented in several of the above-mentioned species and may relate to their abundance in disturbed habitats. While small disturbances may be important to the local distribution of several *Botrychium* species, the rarity of these ferns suggests that disturbance alone does not fulfill their ecological requirements.

Restoration

There have been no reported attempts to restore populations of *Botrychium* species to extirpated localities. Garden transplants have been largely unsuccessful. Transplants have been observed to reappear one year following planting, and never again afterward (F.S. Wagner pers. comm.). One exception is a small number of *Botrychium lunaria* plants that a colleague observed growing in a botanical garden in Iceland (C. Rydholm pers. comm.). The germination of spores in the laboratory has been more successful, but not without significant hurdles (Whittier 1981). No indications were made as to how the laboratory germinants survived subsequent planting. Given the poor record, transplanting rare species of *Botrychium* is not considered to be a viable management strategy.

W.H. and F.S. Wagner

During the past twenty-five years, W.H. and F.S. Wagner, known to many as Herb and Florence, have made major contributions to the ecology and taxonomy of the Botrychiaceae. In so doing, they stimulated much interest in this relatively obscure family of ferns. Together, they described more than 17 species and produced numerous publications relating to the family. But equal to their research has been their ability to teach and engage their students, both at the University of Michigan in Ann Arbor and abroad.

The Wagners' numerous collections from a broad geographical range are a testament to their tremendous enthusiasm for field studies. They collected in almost every Canadian province and made at least four important forays to Alberta in 1980, 1981, 1983, and 1999. They established Waterton Lakes National Park as a *Botrychium* 'Shangri La' by finding several mixed populations of rare species and by naming the hybrid that they discovered among them *Botrychium x watertonense*.

Herb died on Jan. 8, 2000 at the age of 80. This was mere months after a rigorous summer of collecting and teaching field courses, including a course in July in the Canadian Rockies along the B.C.-Alberta border. Herb was in full stride before he died, with many projects underway including several species descriptions. With the help of several colleagues, Florence continues working on several of these projects.

Florence presently teaches at the University of Michigan as she pursues pteridological research, focusing on the Botrychiaceae with a special interest in chromosomal studies. She is also completing the fern flora of the Hawaiian Islands, a project that she and Herb initiated some years ago.



Conservation Concerns in Natural Regions

Many rare species occur in alpine, subalpine, and montane ecosystems that are generally well represented in national and provincial parks and wilderness areas. Potential threats to these habitats include overgrazing and the introduction of non-native plants by domestic livestock, disturbance by off-trail hiking and camping in sensitive areas, and infilling of natural meadows by tree encroachment because of fire suppression. Regulating access to livestock in sensitive areas with fencing and educating backcountry users with appropriate signage are ways to address some of these concerns. Tree encroachment is a subtle and powerful agent of change that is difficult to document and even more challenging to control. Tree encroachment has been linked to the suppression of fire which has been an especially effective since the turn of the century. Fire control is a complicated issue with multiple competing values. The gradual reduction of meadows by tree encroachment and the associated loss of rare species habitats is a conservation issue that requires attention (Lesica and Ahlenslager 1996).

Parkland and grassland ecosystems support species such as *Botrychium campestre* and *B. pallidum* that are among the least documented plants in the province. These ecosystems probably support more species and populations than collections indicate. Further research in these regions is encouraged.

Species in the Botrychiaceae also occur in wetlands and sand dunes, habitats that are vulnerable to human disturbances. Wetlands are generally susceptible to negative impacts from overuse by domestic livestock, while sand dunes tend to be popular locations for recreational motor vehicle use and are subjected to a wide range of associated detrimental effects. These habitat types require protection and are good candidates for parks and ecological reserves.

It is fortunate that most of the populations of rare *Botrychium* species now known in Alberta are within national or provincial parks. However, this is at least partially due to sampling bias, since research efforts have traditionally focused upon parks for the purposes of developing species inventories and park management strategies. It is probable that populations of rare *Botrychium* species have yet to be discovered both on unprotected crown land and on private land, particularly in parkland and grassland habitats. Sensitive populations within parks are subject to management options that may not be available to unprotected lands. Conservation efforts should not solely depend upon parks, but should address all lands. This can be facilitated by providing extension materials and educational support to natural history groups, stewardship programs, and regional land managers.

Sensitive Areas

A select few localities are known to harbour mixed populations of especially rare species and must be recognized as sensitive areas with high value for conservation. Waterton Lakes National Park supports no fewer than 10 species in the Botrychiaceae: *B. hesperium*, *B. lanceolatum*, *B. lunaria*, *B. 'michiganense'*, *B. minganense*, *B. paradoxum*, *B. pinnatum*, *B. simplex*, *B. x watertonense*, and *Scepstridium multifidum*. Close by, South Drywood Creek also has many rare species (*B. hesperium*, *B. lanceolatum*, *B. 'michiganense'*, *B. minganense*, *B. paradoxum*, *B. pinnatum*, and *B. x watertonense*). Castle Junction in Banff National Park, Fort Saskatchewan, and Elk Island National Park are other localities that contain significant mixed populations. Many of these populations represent the distributional extremes of globally rare species. As climate change puts new pressures on species distributions, populations in Alberta may prove to possess the combination of genetic variability, climatic conditions, and geographic features necessary to ensure the continued existence of these rare ferns. It is therefore especially important for conservation strategies to include consideration for impending climate change and to recognize the significance of Alberta's populations.

Future Research

The following is a list of suggestions for research initiatives that would further our understanding of the Botrychiaceae in Alberta and enhance our ability to manage for their conservation.

1. Increase the documentation of species by encouraging collections, photographs, and herbarium submissions, particularly of the 15 species that are listed by the Alberta Natural Heritage Information Centre.
2. Characterize the ecology of localities rich in species of the Botrychiaceae. Why are certain places unusually rich? Can we predict where populations might occur?
3. Analyze the biogeography of the family. Species such as *Botrychium paradoxum* show very restricted distributions, while others, such as *Botrychium lunaria*, occur in temperate regions throughout the world. Presumably *B. lunaria* is a much older species than *B. paradoxum* and has had a longer time to disperse, but it may also have a broader tolerance to climatic conditions. It is not yet known from where the genus as a whole originated. The diversity of western North America suggests that it is an active region of speciation, but does not necessarily implicate this region as

a centre of origin. Where have they come from and what are their full ranges? Are their ranges increasing or decreasing? How will these ranges be affected by climate change? What has led to the endemism found in western North America?

4. Investigate the relationship between habitat specificity and habitat availability. Is tree encroachment reducing the prevalence of meadow ecosystems? Which species/habitats require conservation management strategies?
5. Monitor existing populations to document population growth or decline and to make basic phenological observations. Are populations stable? When are sporangia produced? When are spores shed? Can species that are similar be differentiated by their phenology?
6. Investigate the relationship between gametophytes and their associated mycorrhizae. Do *Botrychium* species share the same species of mycorrhizae? How do spores encounter compatible fungal partners? What are the ecological requirements of the mycorrhizae? Could these requirements be a limiting factor in the distribution of these ferns?

Rarity Status

The ranking currently used to evaluate rare plants in Alberta follows the system developed by The (US) Nature Conservancy (Gould 2000).

RANK (G=Global; S=State or Provincial)

- G1 S1: less than 5 occurrences or only a few remaining individuals.
G2 S2: 6-20 occurrences or with many individuals in fewer occurrences.
G3 S3: 21-100 occurrences; may be rare and local throughout its range, or in a restricted range.
G4 S4: apparently secure under present conditions; typically more than 100 occurrences but may be fewer with many large populations; may be rare in parts of its range, especially peripherally.
G5 S5: demonstrably secure under present conditions; more than 100 occurrences; may be rare in parts of its range, especially peripherally.
GU SU: status uncertain often because of low search effort or cryptic nature of the element; possibly in peril; unrankable; more information needed.
GH SH: historically known; may be relocated in the future.

Fossils of the Botrychiaceae Discovered in Alberta

The Botrychiaceae have long been thought to be among the earliest of pteridophytes; however, it was not until 1989 when Rothwell and Stockey described the paleo-species *Botrychium wightonii* that there was definitive proof of the ferns' antiquity (Rothwell and Stockey 1989). Earlier reports of fossilized *Botrychium* spores were difficult to validate, but the vegetative and reproductive structures found in these fossils unmistakably belonged to the Botrychiaceae.

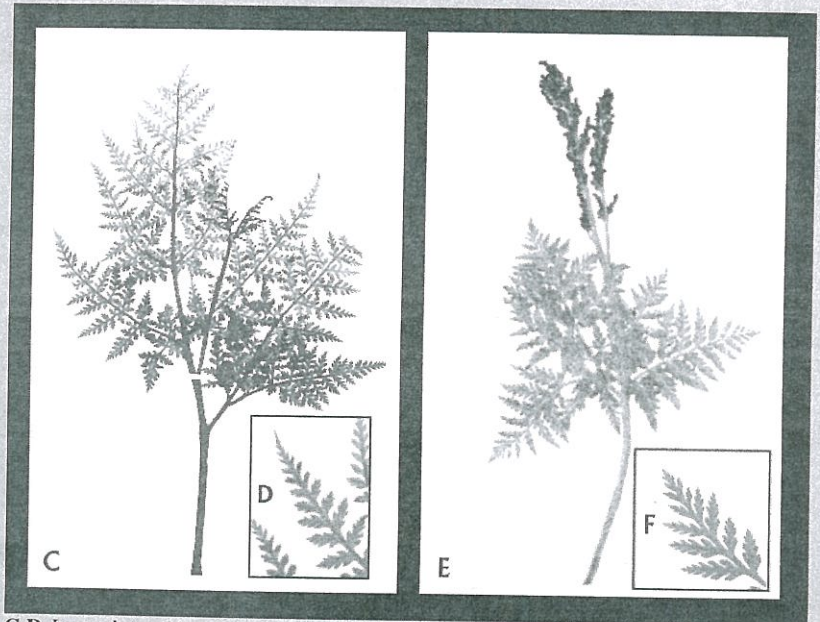
The paleo-species was given the name *Botrychium wightonii*, after Dennis Wighton, a paleontologist from the University of Alberta who collected the fossils from a deposit southwest of Edmonton (54°21'N 114°24'W). The fossils were formed during the Paleocene, approximately 65 million years before present, during a time when the climate of this region was much warmer (as high as 13°C mean annual temperature [Graham 1993]). The general shape and form of the fossilized plant bears a resemblance to two species: *Botrypus virginianus*, a plant that occurs widely within Alberta, and *Japanobotrychium lanuginosum*, known throughout southeast Asia, including Nepal, India, China, Thailand, and New Guinea (Sahashi 1999). A comparison of the spores of the plants gave a clue as to the identity of the fossils. The spores of *Botrypus virginianus* are verrucate, or warty in appearance, and not at all ridged (Sahashi 2000). *Japanobotrychium lanuginosum* spores have distinct ridges which frequently become reticulate, or net-shaped (Sahashi 1986). The fossilized spores were also strongly ridged, though the ridges did not form a reticulate pattern (Rothwell and Stockey 1989).



A-B *Botrychium wightonii* Rothwell et Stockey: A leaf, B sporangia (photographs by R. Stockey).

Because the fossils were fragmented, it was not possible to determine where the sporophores attach to the rachis. The point of attachment could also provide a clue to determining which genus this fossil most closely resembles because in *Japanobotrychium*, the sporophore attaches on one side of the rachis above the lowermost pinnae, while in the closely related genus *Botrypus*, the sporophore attaches below the lowest pinnae. Perhaps further investigations of the fossil deposit will yield specimens bearing the necessary information.

Fossil deposits from other parts of North America indicate the existence of an ancient flora that once spanned Asia and North America in the Paleocene (Graham 1993). Though *Botrypus virginianus* presently occurs in Alberta near to where the fossils were found, climatic conditions have changed dramatically since the formation of these fossils. It is tempting to suggest that *Botrychium wightonii* is related to *Japanobotrychium lanuginosum* and is a remnant of this ancient flora from when the continents were joined and the regional climate was warmer (Rothwell and Stockey 1989, Graham 1993). Even more enticing is the possibility that these fossils represent a common ancestor to both genera.



C-D *Japanobotrychium lanuginosum*, E-F *Botrypus virginianus* (photographs by P. Williston).

Key to the Botrychiaceae of Alberta

The following key is a synthesis of previous publications (Frye 1934; Taylor 1963; Hitchcock and Cronquist 1973; Ceska 1990; Douglas et al. 1991, 1998; D.H. Wagner 1992; F.S. Wagner 1993; and Wagner, W.H., and F.S. Wagner 1981, 1983, 1986, 1990, 1993, 1994) and draws from a review of specimens from the University of Alberta (ALTA), the University of Lethbridge (LEA), Alberta Environment (PP), the Canadian Museum of Nature (CAN), the University of Michigan (MICH), and the W.H. Wagner collection. These specimens were annotated, illustrated, photographed, mapped, and compared for characters to be used here.

The key includes the following species. Square brackets indicate species suspected of occurring in the province, but which lack adequate documentation.

The Botrychiaceae of Alberta	Global Rank	Provincial Rank
<i>Botrychium ascendens</i> W.H. Wagner	G3	S2
[<i>Botrychium boreale</i> J. Milde]	G5	S?
<i>Botrychium campestre</i> W.H. Wagner & Farrar	G3	S1
<i>Botrychium crenulatum</i> W.H. Wagner	G2	S1
<i>Botrychium hesperium</i> (Maxon & Clausen) W.H. Wagner & Lellinger	G3	S1
<i>Botrychium lanceolatum</i> (Gmel.) Angstr.	G5	S2
[<i>Botrychium lineare</i> W.H. Wagner]	G1	S?
<i>Botrychium lunaria</i> (L.) Sw.	G5	S5
<i>Botrychium 'michiganense'</i> W.H. Wagner	G2G3	S1
<i>Botrychium minganense</i> Vict.	G5	S2S3
<i>Botrychium pallidum</i> W.H. Wagner	G2G3	S1
<i>Botrychium paradoxum</i> W.H. Wagner	G2	S1
<i>Botrychium pedunculatum</i> W.H. Wagner	G2	S1
<i>Botrychium pinnatum</i> St. John	G5	S2
<i>Botrychium simplex</i> E. Hitchc.	G5	S2
<i>Botrychium spathulatum</i> W.H. Wagner	G3	S1
<i>Botrychium x watertonense</i> W.H. Wagner	G1	S1
<i>Botrypus virginianus</i> (L.) Holub	G5	S5
<i>Sceptridium multifidum</i> (Gmel.) Nishida ex Tagawa	G5	S2

Key to the Botrychiaceae of Alberta

1a Trophophore 3 to 5 times pinnate. 2

2a Trophophore attached to sporophore at ground level, lacking a common stalk. Plants evergreen. *Sceptridium multifidum*

2b Trophophore attached to sporophore above ground on a common stalk. Plants not evergreen. *Botrypus virginianus*

1b Trophophore less than 3 times pinnate. 3

3a Trophophore absent, replaced by a second sporophore. 4

4a Sporophores minute, usually less than 10 (15) cm tall, and more or less equal in height. Sporophores lacking laminal tissue. *Botrychium paradoxum*

4b Sporophores larger, usually 10 to 20 cm tall, and of unequal heights. Sporophores with laminal tissue bearing marginal sporangia. *Botrychium x watertonense*

3b Trophophore present, occasionally bearing sporangia on the lowest pinnae. 5

5a Trophophore 2 times pinnate, or pinnate-pinnatifid. 6

6a Trophophore with 3 distinct axes. Pinnae and pinnae lobes long and narrow. *Botrychium lanceolatum*

6b Trophophore with a single main axis. Pinnae and pinnules not long and narrow. 7

7a Trophophore with a distinctively broad apical pinna. Pinnae not pinnatifid above the basal pair. *Botrychium simplex*

7b Trophophore without a distinctively broad apical pinna. Pinnae usually pinnatifid above the basal pair. 8

8a Trophophore with a peduncle 1/4 to 1/2 length of blade. Lowermost pinnae occasionally bearing sporangia.

Botrychium pedunculosum

8b Trophophore sessile, or with a short peduncle, less than 1/4 the length of the blade. Pinnae rarely bearing sporangia.

9

9a Pinnae with many lobes, lowest pinnae symmetrical, lacking exaggerated lower lobes. Pinnae at right angles to the main stem or at most, weakly angled.

Botrychium pinnatum

9b Pinnae with few lobes, lowest pinnae asymmetrical with exaggerated lower lobes. Pinnae at less than a right angle to the stem.

10

10a Lowest pair of pinnae distinctly larger than all subsequent pairs.

Botrychium 'michiganense'

10b Lowest pair of pinnae equal or only slightly larger than subsequent pinnae.

10 11

11a Pinnae broadly deltoid, about as long as broad.

(Botrychium boreale)

11b Pinnae deltoid-ovate, longer than broad.

Botrychium hesperium

5b Trophophore once pinnate or entire, not pinnatifid.

12

12a Plants bearing broad, overlapping, semi-circular pinnae that are occasionally incised but not conspicuously crenulate. (Note: young plants may show reduced forms of these characters).

Botrychium lunaria

12b Pinnae occasionally overlapping, but more commonly separate. If pinnae are semi-circular, then they are also conspicuously crenulate.

13

13a Pinnae more or less linear or rhombic. If somewhat fan-shaped, then also with a broad rachis, up to 1/3 the width of the trophophore. Most pinnae incised.

14

14a Trophophore noticeably thickened, up to 1/3 the width of the trophophore. Pinnae rhombic to somewhat fan-shaped and shallowly to deeply incised.

Botrychium campestre

14b Trophophore rachis not noticeably thickened. Pinnae linear and generally deeply incised.

(Botrychium lineare)

13b Pinnae fan-shaped, entire to crenulate. Pinnae, particularly lowest pair, occasionally incised.

15

15a Pinnae margins crenulate or dentate.

16

16a Pinnae narrowly fan-shaped with both margins conspicuously ascending. Pinnae margins usually dentate. Lowermost pinnae occasionally bearing marginal sporangia.

Botrychium ascendens

16b Pinnae broadly fan-shaped to semi-circular, not conspicuously ascending. Pinnae margins usually crenulate. Lowermost pinnae not bearing marginal sporangia.

(Botrychium crenulatum)

15b Pinnae entire, occasionally lobed or incised, but not crenulate or dentate.

17

17a Trophophore simple when young. Older plants with a distinctively broad apical pinna. Pinnae frequently overlapping. Occasionally more than 1 trophophore per plant.

Botrychium simplex

17b Trophophore without a broad apical pinna. Pinnae rarely overlapping. Only one trophophore per plant.

18

18a Outline of the trophophore deltoid-ovate. Lowest branches of sporophore with side branches, sporophore more or less the same length as the trophophore.

Botrychium spathulatum

18b Outline of the trophophore oblong. Lowest branches of the sporophore lacking side branches, sporophore 1.2 to 4 times the length of the trophophore.

19

19a Trophophore whitish, appearing glaucous, with uneven basal pinnae. Sporophore 1.5 to 4 times the length of the trophophore. Pinnae shallowly lobed. Spores released in late July. *Botrychium pallidum*

19b Trophophore dull green, basal pinnae more or less even. Sporophore 1.5 to 2.2 times the length of the trophophore. Pinnae variously lobed. Spores released in late August. *Botrychium minganense*

Notes on Troublesome Determinations

The easiest way to make determinations of difficult taxa is to make good specimens. This might not be possible when populations are small and potentially susceptible to decline from collecting. While some advocate collecting the above-ground portion of the plants regardless of numbers (reasoning that the primordia for the following year remains safely concealed in the soil), I prefer to observe the 10:1 rule: if there are ten individuals then it should be possible to collect one without threatening the longevity of the population. Smaller populations can be adequately documented by photographs. It is important to take careful notes about the date, the locality, the habitat (associated plants), the phenology of the plants, the coordinates (lat. and long. or UTM), and elevation (see Rare Native Plant Report Form, page 42). Generally speaking, more information is better. Some species are difficult to segregate and may not be possible to identify if they are only represented by juvenile forms. Using sealable plastic bags for collecting in the field keeps the plants turgid until they are pressed. W.H. and F.S. Wagner have always promoted the use of heavy phone books for pressing specimens but a regular plant press works fine if the plants are checked and rearranged after 2 hours of drying. The following are some clues that might help differentiate confusing taxa.

Botrychium ascendens, *B. minganense*, and *B. spathulatum*

Typic material of this group is distinctive; however, immature specimens with intermediate features are common, especially at high elevations. In some cases, immature specimens may not be identifiable without molecular tools.

Knowledge of past collections from the same locality is helpful. *B. ascendens* tends to be a darker colour and should have at least weakly dentate pinnae margins; it also commonly bears sporangia on the lowest pinnae. The outline of the trophophore of *B. spathulatum* is deltoid-ovate rather than oblong as in *B. minganense*. Phenology may also help distinguish these species. For instance, W.H. and F.S. Wagner (1993) report that *B. spathulatum* routinely releases

spores about 10 days after *B. minganense*. In alpine localities in British Columbia, *B. minganense* does not release spores until early September. More field-based observations and detailed data about the phenology of these species will facilitate identification in the future.

Botrychium minganense and *B. pallidum*

These species are much easier to distinguish in the field than from herbarium sheets. *B. pallidum* is distinctly whitish and matures in early summer, while *B. minganense* can be light-coloured but is generally not whitish and matures in late summer.

B. boreale, *B. hesperium*, *B. 'michiganense'*, and *B. pinnatum*

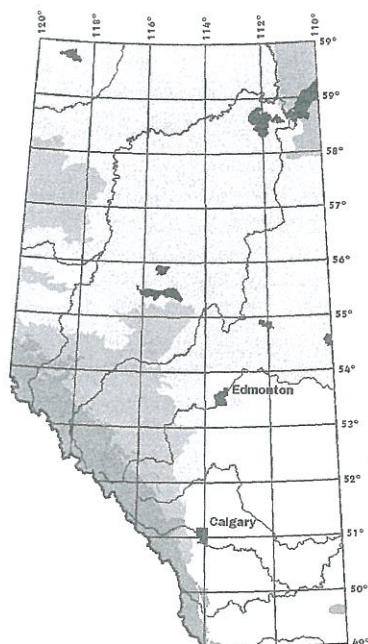
This group is problematic, even with well-developed specimens. There is still uncertainty as to whether or not *B. boreale* occurs in North America. Until a detailed comparison has been made with material from Greenland or northern Europe, it is probably wise to exclude this species from the North American Flora. *B. 'michiganense'* has yet to be described, but with its exaggerated basal pinnae, it is usually easy to distinguish. *B. pinnatum* appears to occur regularly throughout the western mountain ranges, at least in Canada, and has many lobes on each pinnae, particularly the basal pair. The pinnae tend to be at right angles to the rachis. The current hypothesis is that *B. pinnatum* is a hybrid between *B. lunaria* and *B. lanceolatum* (Farrar 2000). Another species that is in the process of being described, *Botrychium 'alaskanum'* (Grant 2000), may also represent the same hybrid cross but from a different event (time and place). It tends to be somewhat larger than *B. pinnatum*, bears linear pinnae lobes, and is presently only known from Alaska. *B. hesperium* has few lobes which are generally more developed on the lower side of each pinna than on the upper side. The pinnae branches are ascending and the outline of the trophophore is deltoid. Many specimens of *B. hesperium* have been reidentified as other species. Further clarification of the group is required.

"As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications."

--Charles Darwin, *On the Origin of Species By Means of Natural Selection* (1859)

Maps

The distribution maps accompanying the species descriptions include a depiction of the following natural regions.



NATURAL REGIONS

Boreal Forest

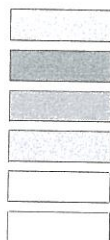
Rocky Mountain

Foothills

Canadian Shield

Parkland

Grassland



Botrychium Swartz

Botrychium ascendens W.H. Wagner

Common name: upswept moonwort

Description: trophophore once pinnate; up to five pairs of well-separated pinnae; margins usually ascending, basal pair approximately equal in size to the adjacent pair. Pinnae less than 1/3 circular with dentate margins; lowermost pinnae occasionally bearing marginal sporangia. Sporophore equal to twice the height of the trophophore. Plants 5 to 15 cm tall.

Habitat: low elevation to subalpine grassy fields, roadside clearings, and wetland meadows.

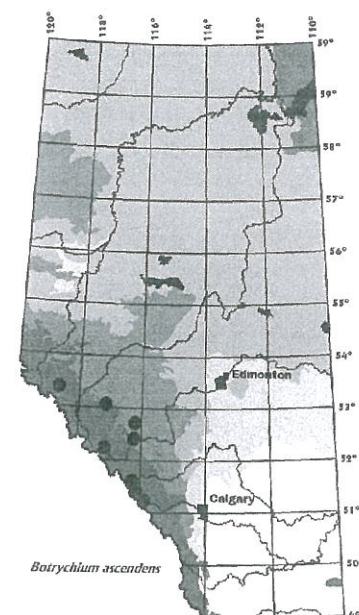
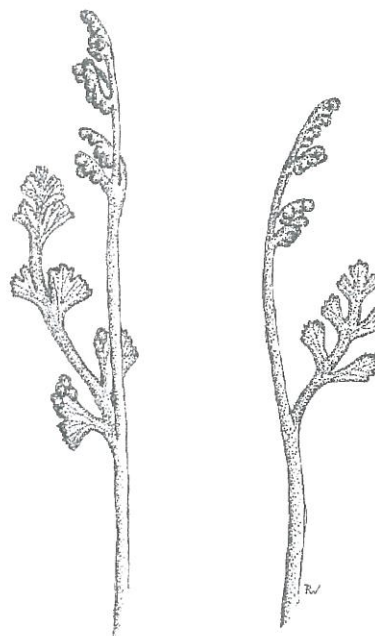
Distribution in Alberta: occurring in the Rocky Mountains and foothills of western Alberta.

Global Distribution: endemic to western North America; from Alaska to California with an apparent disjunct population northwestern Ontario.

Rarity status: G3 S2

Chromosome number: $2n=180$

Notes: young plants or those from high elevations can resemble *B. minganense* or *B. spathulatum*. Accurate determinations may improve with further phenological investigations.



(Botrychium boreale J. Milde)

Common name: boreal moonwort

Description: trophophore twice pinnate to pinnate-pinnatifid with a deltoid outline. Pinnae equidimensional, about as long as broad; usually with more lobes on the lower edge; apices somewhat pointed. Sporophore 1 to 1.5 the length of the trophophore. Plants usually less than 15cm tall.

Habitat: moist meadows.

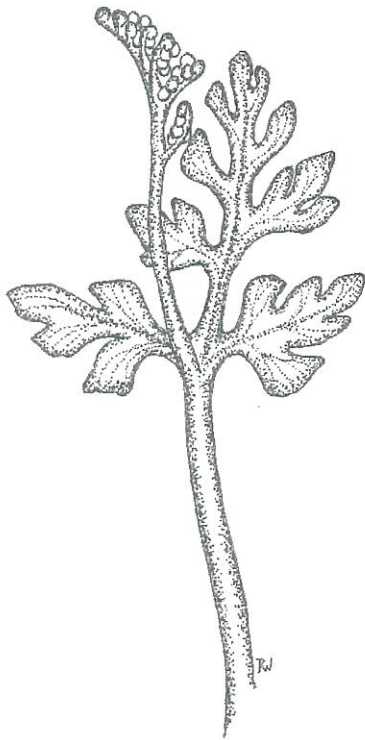
Distribution in Alberta: one or two specimens bearing a resemblance to this species have been collected from the Rocky Mountains of Alberta and B.C.

Global Distribution: Greenland, northern Europe and Asia.

Rarity Status: G5 S?

Chromosome number: unknown

Notes: recent collections from the Canadian Rockies have been tentatively called *B. boreale*, however these specimens require a closer comparison to European material. *B. boreale* should probably be excluded from the provincial flora until determinations are verified.



Botrychium campestre W.H Wagner & Farrar

Common name: prairie moonwort

Description: trophophore once pinnate with a distinctly broad rachis. Pinnae rhomboid to weakly fan-shaped and usually incised. Sporophore 1 to 1.5 the length of the trophophore. Plants usually less than 15cm tall.

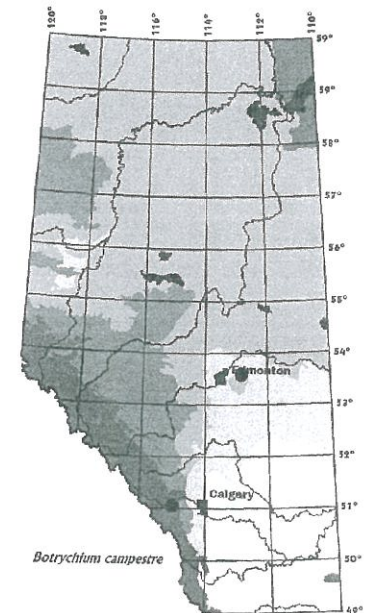
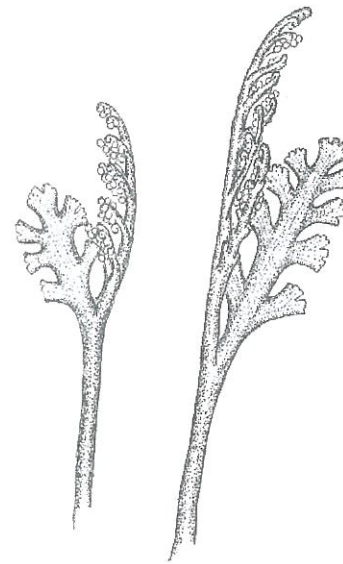
Habitat: fields, sand dunes, and over limestone.

Distribution in Alberta: known in Alberta from one parkland locality and one locality in the Rocky Mountains. This plant probably also occurs in the grasslands.

Global Distribution: endemic to North America; known from the Great Lakes and the prairies.

Rarity Status: G3 S1

Chromosome number: 2n=90



(Botrychium crenulatum W.H. Wagner)

Common name: dainty moonwort

Description: trophophore once pinnate; generally thin and 'leggy'; up to 5 pairs of pinnae well separated on the rachis. Sporophore equal to three times the length of the trophophore. Plants to 20cm tall.

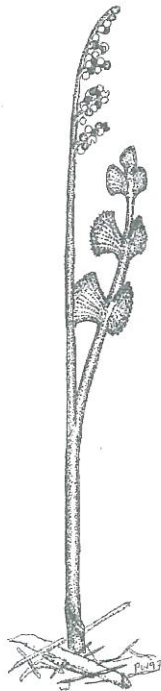
Habitat: drier places within wet meadows, bogs, and marshes.

Distribution in Alberta: suspected to occur in Alberta, though not yet adequately documented.

Global Distribution: endemic to western North America; from California to B.C. and east to Montana and Wyoming.

Rarity Status: G3 S?

Chromosome number: $2n=90$



Botrychium hesperium (Maxon & Clausen) W.H. Wagner & Lellinger

Common name: western moonwort

Synonym: *Botrychium matricariifolium* (Döll) Koch subsp. *hesperium* Maxon & Clausen

Description: trophophore pinnate-pinnatifid; up to six pairs of approximate pinnae. Pinnae generally more numerous lobed on the lower edge than on the upper; apices somewhat pointed. Sporophore to 3 times the length of the trophophore. Plants to 15cm.

Habitat: middle and high elevation grassy slopes and roadsides.

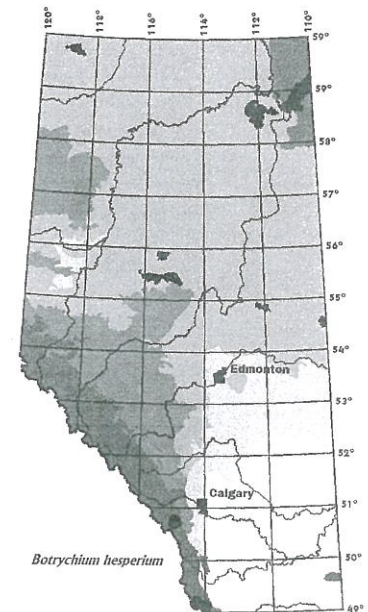
Distribution in Alberta: known from Waterton Lakes National Park and nearby at South Drywood Creek.

Global Distribution: endemic to western North America; found mainly in the Rocky Mountains and adjacent foothills.

Rarity status: G3 S1

Chromosome number: $2n=180$

Notes: with the expected description of *B. 'michiganense'*, and with the similar species *B. pinnatum*, *B. boreale*, *B. echo* and now *B. 'alaskanum'*, there are relatively few remaining specimens of *B. hesperium* that have not been re-identified as another species.



***Botrychium lanceolatum* (Gmel.) Angstr.**

Common name: triangle moonwort

Description: trophophore pinnate-pinnatifid; divided into three main axes to form a deltoid trophophore outline. Pinnae lobes elongate. Sporophore commonly taller than trophophore. Plants 10 to 20cm tall.

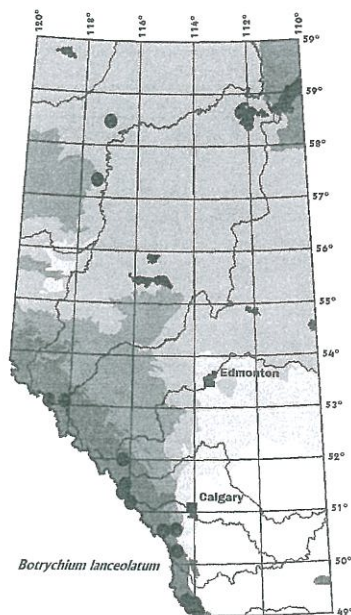
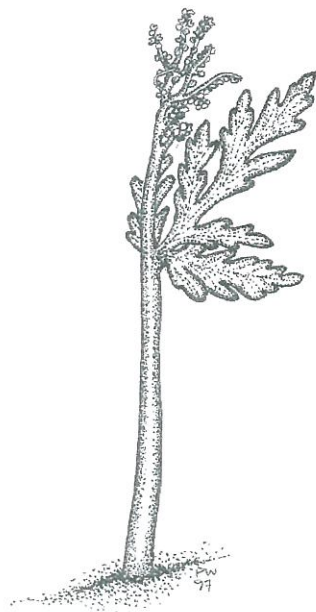
Habitat: mesic to rocky slopes, meadows, stream banks, and woods, montane to alpine. Also occurring on disturbed roadsides and old fields.

Distribution in Alberta: most collections in Alberta are from the Rockies and the adjacent foothills. Scattered collections from the boreal forest coupled with a broad global distribution suggest that this fern may be more common than shown here.

Global Distribution: throughout Canada and the U.S., northern Europe, and northern Asia.

Rarity status: G5 S2

Chromosome number: 2n=90



(*Botrychium lineare* W.H. Wagner)

Common name: straight-leaf moonwort

Description: trophophore once pinnate; pale green and somewhat thickened. Pinnae are well separated and slightly ascending; linear and often deeply incised. Sporophore taller than the trophophore. Plants to 20cm tall.

Habitat: grassland meadows and open forests with a grass understorey.

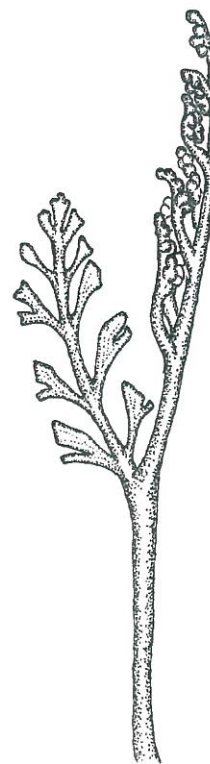
Distribution in Alberta: suspected to occur in Alberta but not adequately documented.

Global Distribution: endemic to North America; known from Quebec, New Brunswick, Montana, Idaho, Colorado, Oregon, and California.

Rarity Status: G2 S?

Chromosome number: unknown

Notes: two specimens from Alberta bearing a resemblance to this species have been examined, however, it is probably best to exclude this species from the provincial flora until another population is found. Populations have been documented in nearby Idaho and Montana.



***Botrychium lunaria* (L.) Sw.**

Common name: common moonwort

Description: trophophore once pinnate; often with more than four pairs of pinnae. Pinnae overlapping and broadly fan-shaped pinnae (semicircular). Sporophore more or less the length of the trophophore. Plants small, commonly less than 10 (15)cm tall.

Habitat: mesic and moist woods, and old fields. Infrequent but widespread from boreal forest lowlands to the alpine.

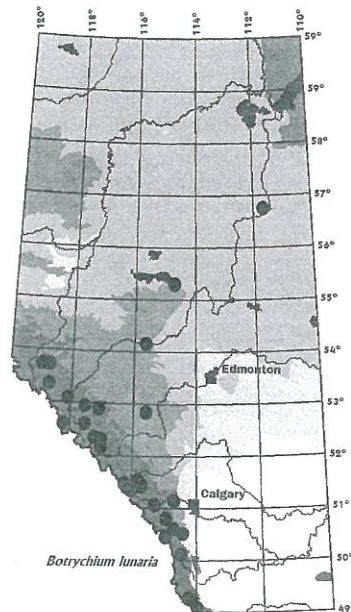
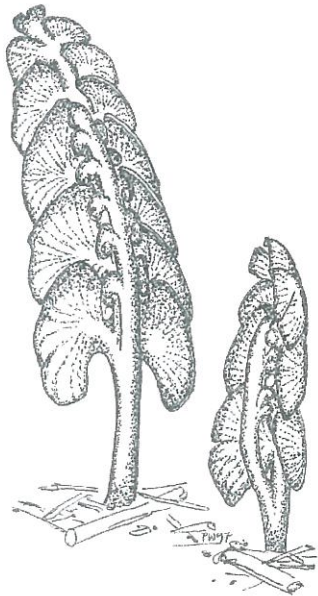
Distribution in Alberta: widespread throughout Alberta though most frequent in the Rocky Mountains.

Global Distribution: throughout Canada and the northern U.S., Greenland, northern Europe and Asia, Patagonia, New Zealand, and Tasmania.

Rarity status: G5 S5

Chromosome number: $2n=90$

Notes: One of the most common and widespread species in the family.



***Botrychium 'michiganense'* W.H. Wagner**

Common name: Michigan moonwort

Description: trophophore pinnate-pinnatifid though usually merely undulate above the basal pinnae; exaggerated basal pinnae that are distinctly larger than the subsequent pairs. Sporophore frequently twice pinnate. Plants to 15cm tall.

Habitat: natural and disturbed meadows and fields from lowlands to the subalpine.

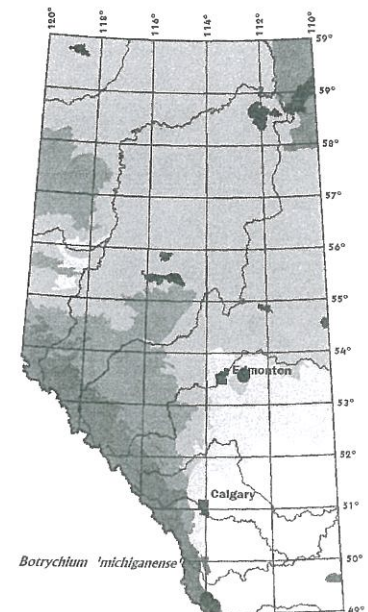
Distribution in Alberta: known from three localities in Alberta: Waterton Lakes National Park, South Drywood Creek, and Elk Island National Park near Edmonton.

Global Distribution: endemic to North America; known from the Great Lakes, the southern Canadian prairies and the adjacent U.S.

Rarity Status: G2 S1

Chromosome number: unknown

Notes: this species was formerly combined with *B. hesperium*. *Botrychium 'michiganense'* is expected to be described by F.S. Wagner and colleagues in the near future. It is easily recognized by the difference in size between the basal pinnae and the adjacent pair.



Botrychium minganense Vict.

Common name: Mingan moonwort

Synonym: *Botrychium lunaria* (L.) Sw. var. *minganense* (Victorin) Dole

Description: trophophore once pinnate; narrowly ovate in outline; up to 10 pairs of separated pinnae. Pinnae with dichotomous venation; margins irregular or sometimes entire. Sporophore somewhat taller than trophophore. Plants 5 to 15cm tall.

Habitat: mesic to wet woods, wet meadows from the boreal forest to the alpine.

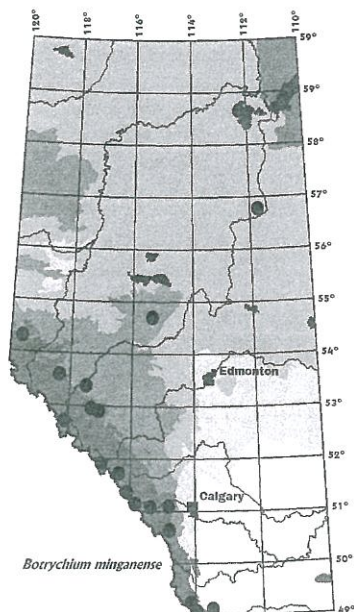
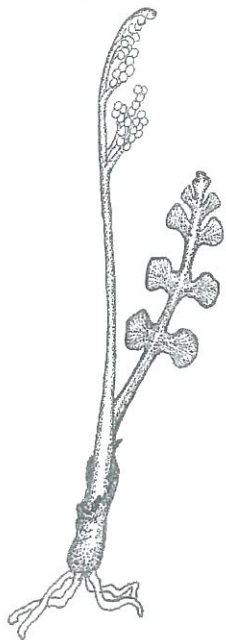
Distribution in Alberta: most frequently found in the Rocky Mountains but also known from the foothills and the boreal forests of central Alberta.

Global Distribution: endemic to North American; known throughout Canada and the western U.S.

Rarity status: G5 S2/S3

Chromosome number: $2n=180$

Notes: this plant was described by the famous Québécois botanist Frère Marie-Victorin. His specimens from the Mingan Islands are remarkably diverse in form; from rather large (greater than 20cm tall) plants with deeply lobed pinnae, to small (less than 10cm tall), simple specimens without lobes. Whether or not the diminutive specimens from the western Rockies are the same plants as those from the Mingan Islands deserves further study.



Botrychium pallidum W.H. Wagner

Common name: pale moonwort

Description: trophophore once pinnate; distinctly pale coloured. Pinnae weakly lobed, well separated; basal pinnae strongly asymmetric. Sporophore 1.5 to 4 times taller than the trophophore.

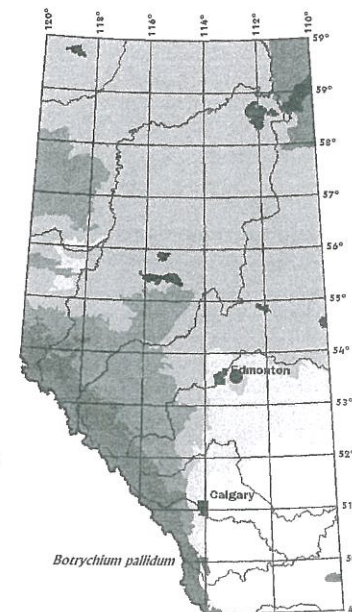
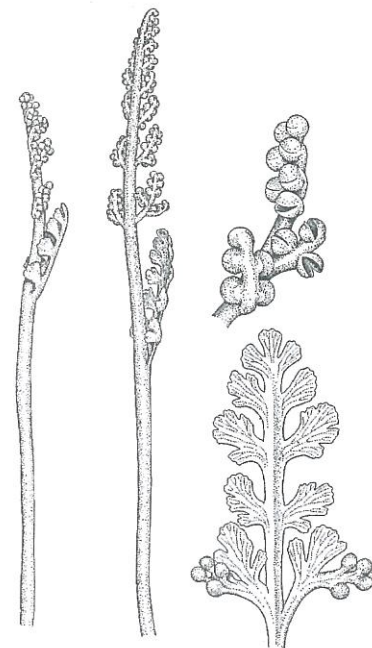
Habitat: open fields and occasionally in shaded habitats.

Distribution in Alberta: known from a single locality in Alberta in Elk Island National Park.

Global Distribution: endemic to North America; known from Michigan and adjacent Ontario, Manitoba, Saskatchewan, and Colorado.

Rarity Status: G3 S1

Chromosome number: $2n=90$



***Botrychium paradoxum* W.H. Wagner**

Common name: two-spiked moonwort

Description: trophophore developing into a second sporophore of about equal length to the sporophore. Plants 5 to 15cm tall.

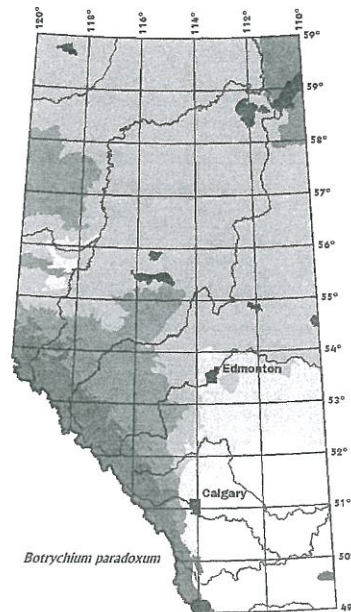
Habitat: mesic to moist subalpine grass or sedge meadows.

Distribution in Alberta: known in Alberta from two localities within Waterton Lakes National Park.

Global Distribution: endemic to western North America; known from only a few localities in Saskatchewan, Alberta, Montana, and Colorado.

Rarity status: G2 S1

Chromosome number: $2n=180$



***Botrychium pedunculatum* W.H. Wagner**

Common name: stalked moonwort

Description: trophophore pinnate-pinnatifid; up to five pairs of separated pinnae. Pinnae occasionally bearing marginal sporangia on the lowermost pair. Petiole to the length of the trophophore. Sporophore two or more times the length of the trophophore. Plants 10 to 20cm tall.

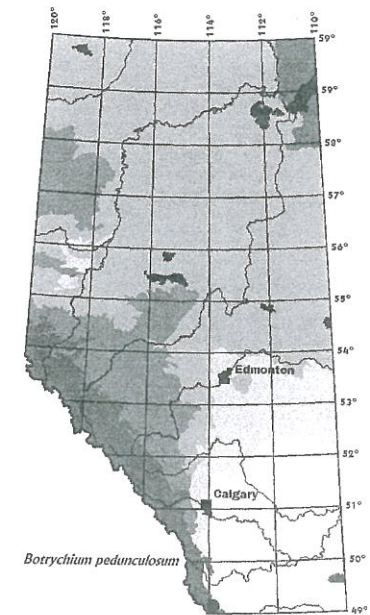
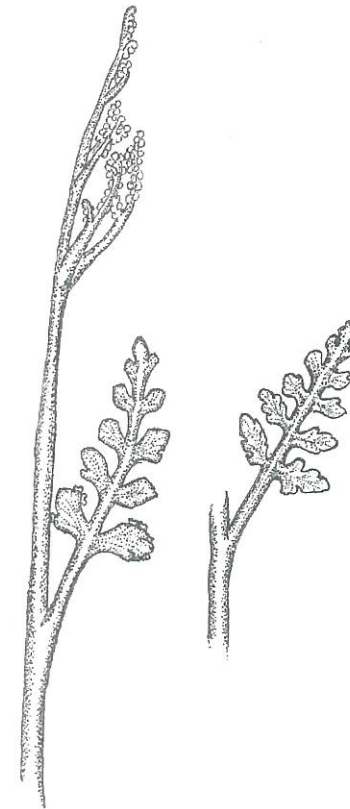
Habitat: brushy second growth along streams.

Distribution in Alberta: collected once from Waterton Lakes National Park.

Global Distribution: endemic to western North America; known from only a few collections in Saskatchewan, Alberta, B.C., Montana, Idaho, Washington, and Oregon.

Rarity status: G2 S1

Chromosome number: $2n=180$



Botrychium pinnatum St. John

Common name: northwestern moonwort

Synonym: *Botrychium boreale* Milde subsp. *obtusilobum* (Rupr.) Clausen

Description: trophophore twice pinnate or pinnate-pinnatifid; up to seven pairs of pinnae; usually arranged at a right angle to the rachis. Sporophore more or less the length of the trophophore. Plants 8 to 15cm tall.

Habitat: mesic to moist stream banks, meadows, trail sides, and heath communities in montane, subalpine, and alpine regions.

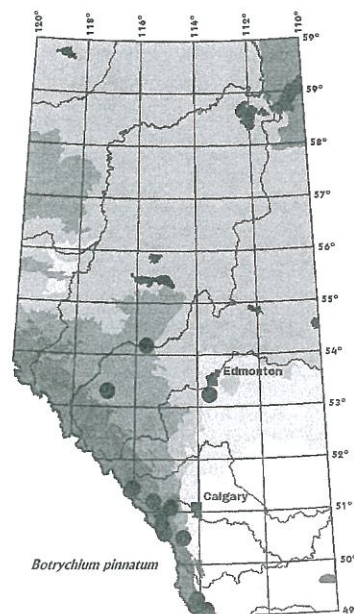
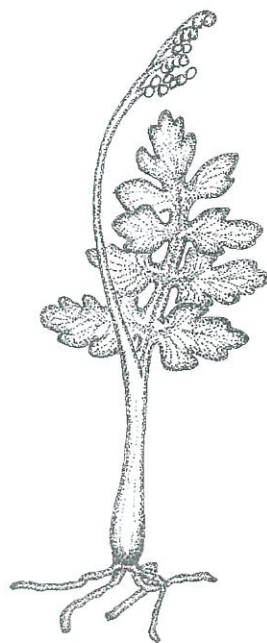
Distribution in Alberta: most frequently found in the Rocky Mountains, but also known from scattered populations in the foothills and parkland of central Alberta.

Global Distribution: endemic to western North America; known from Alaska to California and east to Colorado.

Rare status: G4 S2

Chromosome number: $2n=180$

Notes: most specimens labeled as *B. boreale* are actually *B. pinnatum*. There is still uncertainty as to whether *B. boreale* occurs in North America. Conversely, *B. pinnatum* appears to be widespread in mountainous regions of the west.



Botrychium simplex E. Hitchc.

Common name: least moonwort

Synonym: *Botrychium tenebrosum* A.A. Eaton

Description: trophophore simple to pinnate-pinnatifid; with a distinctively broad apical pinna; up to 7 pairs of pinnae. Sporophore equal to several times taller than trophophore. Plants to 15 cm tall.

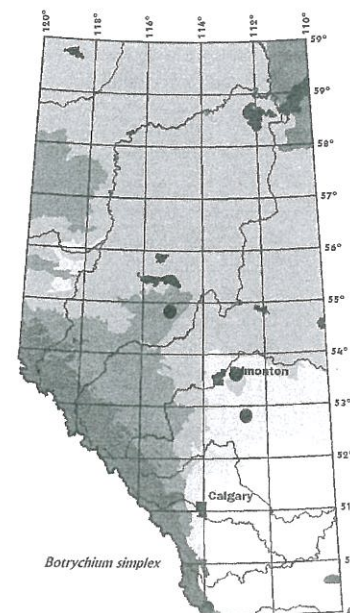
Habitat: vernal pools and ephemeral seepages from lowlands to montane. Also found along roadsides and in meadows.

Distribution in Alberta: occurring in the parkland near Edmonton and also in Waterton Lakes National Park.

Global Distribution: known from throughout western North America from B.C. to California. Also present in the Great Lakes and eastern coastal regions, Greenland, and northwestern Europe.

Rare status: G5 S2

Chromosome number: $2n=90$



Botrychium spathulatum W.H. Wagner

Common name: spatulate moonwort

Description: trophophore once pinnate; up to 8 pairs of pinnae; outline narrowly triangular. Pinnae ascending and separate; basal pinnae spatulate and with or without notches apices. Sporophore twice pinnate; 1 to 1.5 times the length of the trophophore.

Habitat: grassy railroad sidings, cutbanks, and open meadows. Middle elevation to subalpine.

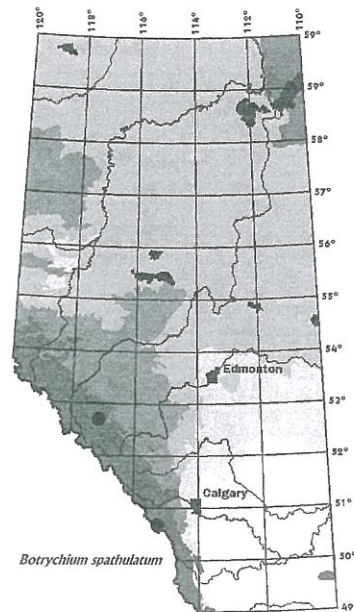
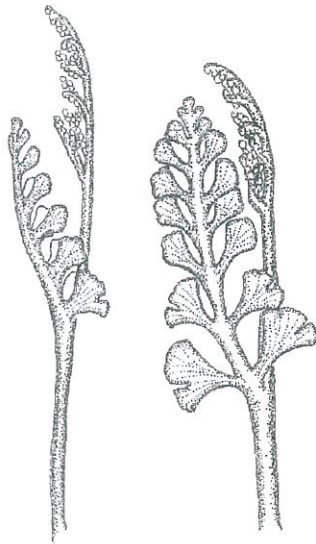
Distribution in Alberta: known from a few scattered collections in mountainous western Alberta.

Global Distribution: endemic to North America; known from Alaska and the Yukon, the Canadian Rockies, the Great Lakes region, and the Gaspé Peninsula.

Rare status: G3/G4 S1

Chromosome number: $2n=180$

Notes: the similarities between *B. spathulatum* and *B. minganense* make determinations of these species difficult, particularly among juvenile specimens which appear to be common in high elevation habitats. Phenological clues may help. For instance Wagner and Wagner (1993) suggest that the spores of *B. spathulatum* routinely mature about 2 weeks after *B. minganense*.



Botrychium spathulatum

Botrychium x watertonense W.H. Wagner

Common name: Waterton moonwort

Description: trophophore once pinnate with rudimentary laminal tissue and bearing numerous marginal sporangia. Sporophore can also have laminal tissue and will appear similar to the modified trophophore though the sporophore will usually be somewhat taller. Plants 10 to 15 (20)cm tall.

Habitat: subalpine meadows.

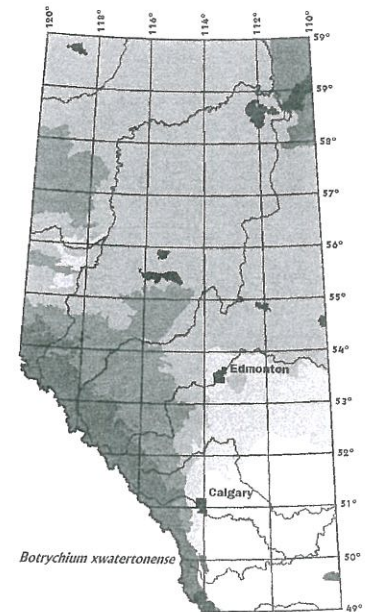
Distribution in Alberta: known from three localities within Alberta: two in Waterton Lakes National Park and one at South Drywood Creek.

Global Distribution: endemic to western North America. The only population known outside Alberta occurs in neighbouring Montana.

Rarity Status: G1 S1

Chromosome number: $2n=180$

Notes: this hybrid was described from and named after Alberta's Waterton Lakes National Park. The parental species of this hybrid are believed to be *B. paradoxum* and *B. hesperium*.



Botrychium x watertonense

Botrypus Michaux

Botrypus virginianus (L.) Holub

Common name: rattlesnake fern

Synonym: *Botrychium virginianum* (L.) Sw.

Description: trophophore 4 to 5 times pinnate; deltoid; and branching from the sporophore midway up the stem. Sporophore occasionally absent, when present often twice the length of the trophophore. Plants 10 to 50cm tall.

Habitat: wet alluvial forests, wet meadows, and old fields.

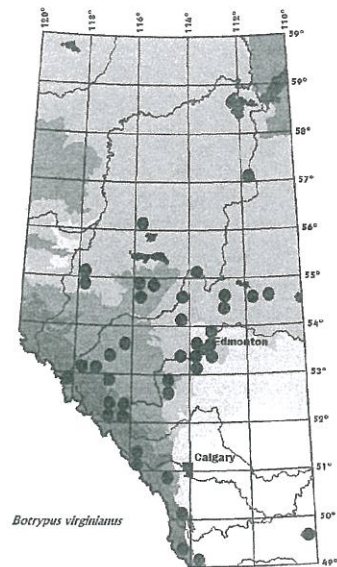
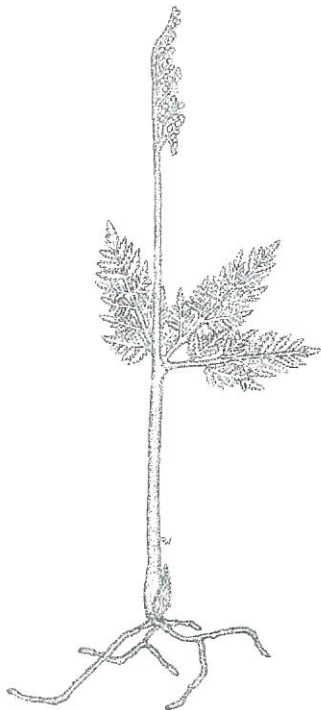
Distribution in Alberta: widespread throughout western and central Alberta.

Global Distribution: throughout Canada and northern U.S. Also in Europe, Asia, and South America.

Rare status: G5 S5

Chromosome number: $2n=184$

Notes: the most common representative of the Botrychiaceae in Canada and well represented in most herbaria.



Sceptridium Lyon

Sceptridium multifidum (Gmel.) Nishida ex Tagawa

Common name: leathery grapefern

Synonyms: *Botrychium multifidum* (Gmel.) Rupr.

Description: trophophore 3 to 4 times pinnate; evergreen; branching from sporophore at ground level. Sporophore occasionally absent, when present then taller than trophophore. Plants 5 to 25cm tall

Habitat: wet meadows, bogs, and lake-sides, sand dunes; lowlands to montane.

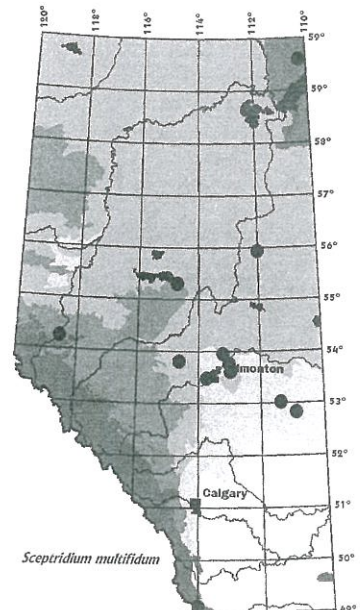
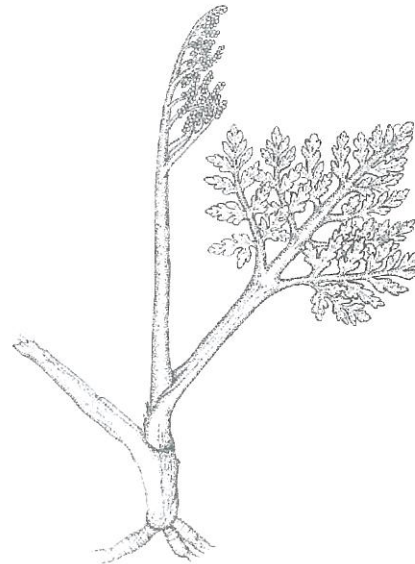
Distribution in Alberta: known from sand dunes, wetlands, and wet meadows from scattered populations throughout Alberta.

Global Distribution: throughout Canada and the northern U.S. Also in Greenland, northern Europe, and northeastern Asia.

Rarity status: G5 S2

Chromosome number: $2n=90$

Notes: the taxonomy of this genus is under investigation. It is likely that *Sceptridium multifidum* is a species complex with intermediates that make the group confusing. Some populations are distinctly prostrate; are most commonly fertile; have thickened petioles; and bear two summertime trophophores, one of which survives winter. Other populations grow erect; are less commonly fertile; have thin petioles; and frequently bear a single trophophore during the summer. Further research is needed.



A List of the Botrychiaceae of North America

Botrychium Swartz

Botrychium acuminatum W.H. Wagner
Botrychium angustisegmentum (Pease & Moore) Fernald
Botrychium ascendens W.H. Wagner
Botrychium campestre W.H. Wagner & Farrar
Botrychium crenulatum W.H. Wagner
Botrychium echo W.H. Wagner
Botrychium gallicomontanum Farrar & Johnson-Groh
Botrychium hesperium (Maxon & Clausen) W.H. Wagner & Lellinger
Botrychium lanceolatum (Gmel.) Angstr.
Botrychium lineare W.H. Wagner
Botrychium lunaria (L.) Sw.
Botrychium matricariifolium (Döll) A. Braun ex Koch
Botrychium minganense Vict.
Botrychium montanum W.H. Wagner
Botrychium mormo W.H. Wagner
Botrychium pallidum W.H. Wagner
Botrychium paradoxum W.H. Wagner
Botrychium pedunculatum W.H. Wagner
Botrychium pinnatum St. John
Botrychium pseudopinnatum W.H. Wagner
Botrychium pumicola Coville in Underw.
Botrychium simplex E. Hitchc.
Botrychium spathulatum W.H. Wagner
Botrychium xwatertonense W.H. Wagner

Botrypus Michaux

Botrypus virginianus (L.) Holub

Sceptridium Lyon

Sceptridium bitermatum (Savigny) Lyon
Sceptridium dissectum (Spreng.) Lyon
Sceptridium jenmanii (Underw.) Lyon
Sceptridium lunarioides (Michx.) Holub
Sceptridium multifidum (Gmel.) Nishida ex Tagawa
Sceptridium oneidense (Gilb.) Holub
Sceptridium robustum (Rupr.) Lyon
Sceptridium rugulosum (W.H. Wagner) Skoda & Holub
Sceptridium silaifolium (Presl) Lyon

RARE NATIVE PLANT REPORT FORM

Please enter all information available to you and attach a detailed sketch or map showing the location of the population.

SCIENTIFIC NAME: _____

COMMON NAME: _____

OBSERVER NAME, ADDRESS AND TELEPHONE NUMBER: _____

OBSERVATION DATE(S): _____

PHOTOGRAPH TAKEN: Y / N

SPECIMEN COLLECTED: Y / N COLLECTION NUMBER: _____

IF YES, NAME HERBARIUM WHERE DEPOSITED: _____

LOCATION INFORMATION

SITE NAME: _____

TOPOGRAPHIC MAP NUMBER: _____

DIRECTIONS TO POPULATION (include descriptions of landmarks and distances if possible): _____

ELEVATION (Please do not use elevation from GPS unit): _____

(Complete one of the following and accompany with map or sketch)

UTM EASTING: _____ UTM NORTHING: _____ GRID ZONE: _____

NORTH AMERICAN DATUM: 27 / 83 (circle one)

LEGAL: TWP: _____ RGE: _____ W: _____ M: _____

SECTION: _____ LSD: _____

LATITUDE: _____ LONGITUDE: _____

Was the location determined using a GPS? Y / N

POPULATION INFORMATION (include information on extent in cm²/m² (circle one), number of individuals): _____

PHENOLOGY (vegetative and reproductive) _____

SITE/HABITAT DESCRIPTION (include information on habitat [alpine, aquatic, cliff, forest, grassland, peatland], plant communities / dominant species / associated species / other rare species / substrate / soils / phenology of dominant species): _____

ASPECT: _____ SLOPE: _____ MOISTURE: _____

OWNERSHIP OF PROPERTY (if known include name/address/phone number): _____

CURRENT LAND USE: _____

HABITAT THREATS/MANAGEMENT CONCERNS: _____

Return to: Alberta Natural Heritage Information Centre, 2nd Floor, 9820 106 Street, Edmonton, AB T5K 2J6 (780) 427-5209. Thank You.

Bibliography

This bibliography is a collection of papers encountered while conducting a literature review for this field guide. These references, drawn from studies from around the globe, are provided for those who wish to learn more about the biology of the Botrychiaceae. This is not a complete survey of the literature, it is a work in progress and clearly under-represents studies from before 1970, which are rarely incorporated into digital databases. Suggestions for additions or corrections can be forwarded to the author for inclusion in future publications.

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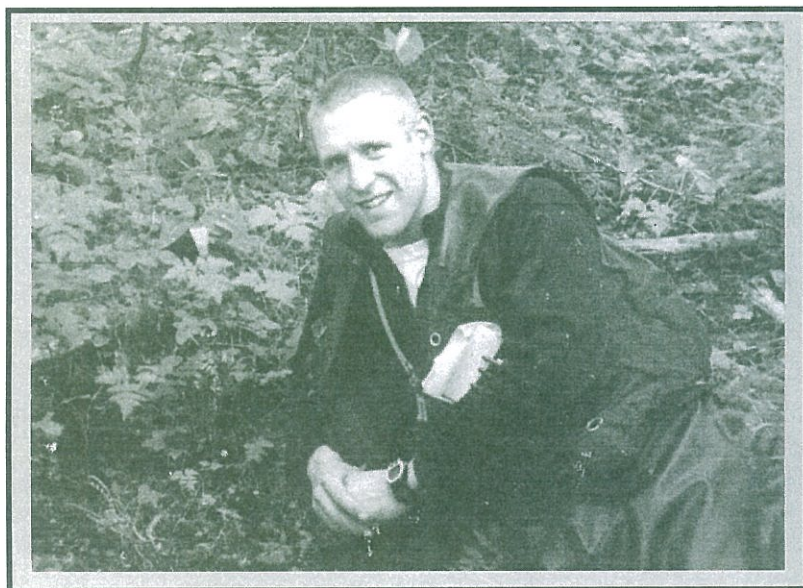
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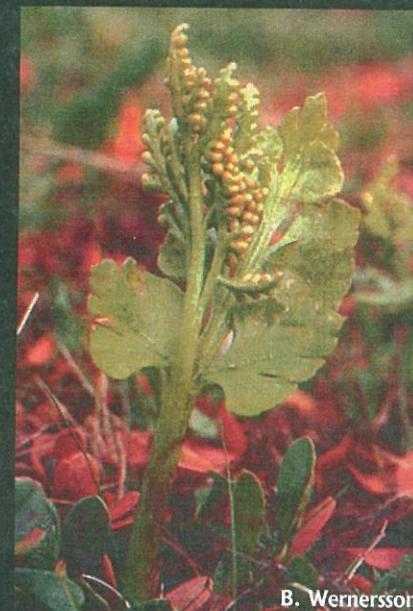
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About the Author

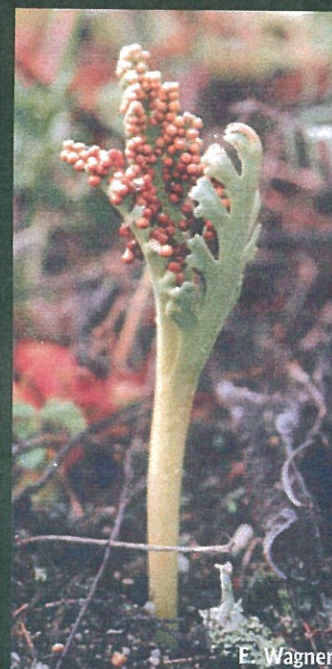
Patrick Williston is a graduate of the University of British Columbia where he completed a Master's degree in lichen ecology. As a consultant, he has worked on a wide array of projects relating to the distributional ecology of lichens and bryophytes. In his spare time he pursues rare plant biology, focussing on ferns and alpine plants. The Botrychiaceae is one of a number of photosynthetic obsessions. Patrick lives deep in the British Columbian hinterland, in a town called Smithers.



B. ascendens



B. boreale



B. campestre



B. crenulatum



P. Williston

B. hesperium



H. Janszen

B. lanceolatum



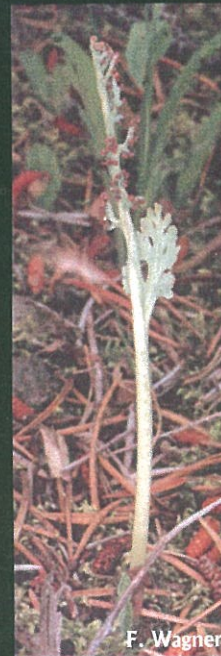
F. Wagner

B. lineare



P. Williston

B. minganense



F. Wagner

B. pallidum



J. Gould

B. paradoxum



P. Williston

B. lunaria



P. Williston

B. 'michiganense'



P. Williston

B. pedunculatum



J. Gould

B. pinnatum



P. Williston

B. simplex



P. Williston

B. spathulatum



S. Wirt-

B. x watertonense



J. Pojar

Botrypus virginianus



P. Williston

Sceptridium multifidum