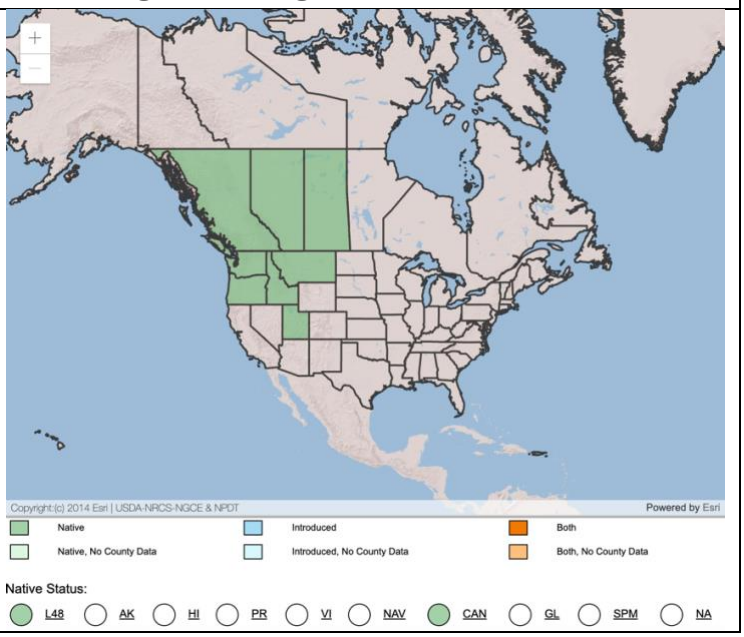
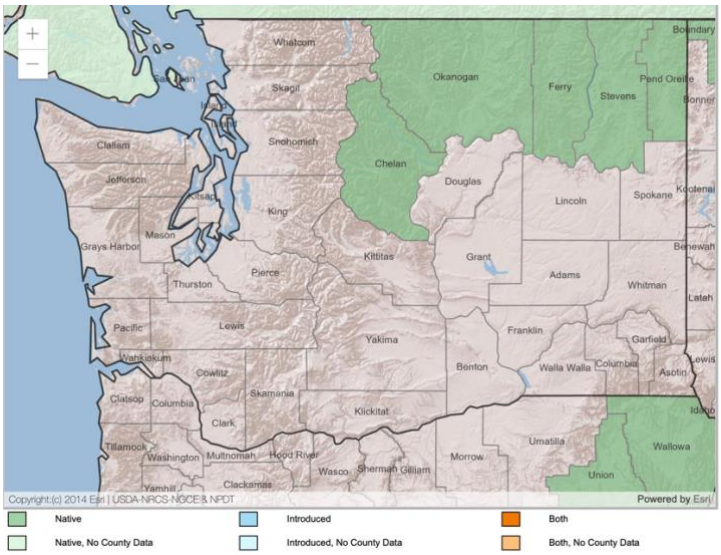
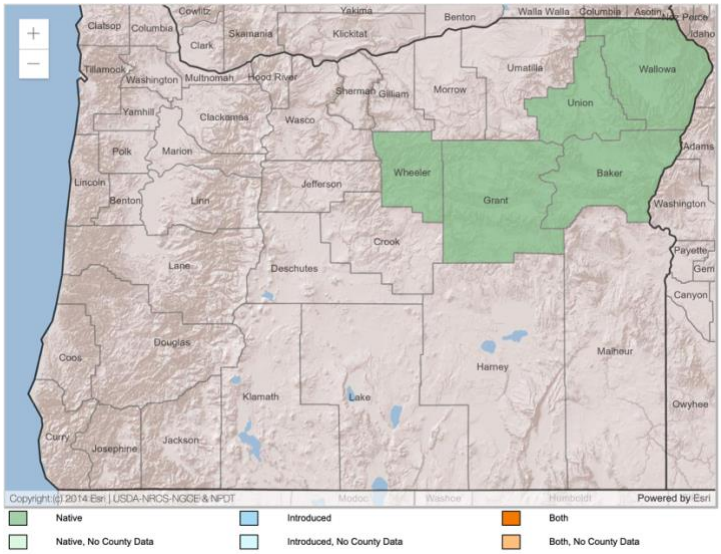
Plant Propagation Protocol for *Botrychium paradoxum*
ESRM 412 – Native Plant Production
URL: https://courses.washington.edu/esrm412/protocols/*2023*/*BOPA9.pdf*

TAXONOMY	
Plant Family	
Scientific Name	Ophioglossaceae Martinov
Common Name	Adder's-tongue family
Species Scientific Name	
Scientific Name	*Botrychium paradoxum* W.H. Wagner
Varieties	N/A
Sub-species	N/A
Cultivar	N/A
Common Synonym(s)	N/A However, the two most similar species are: 1. *B.* x *watertonense*, a sterile hybrid of *B. hesperium* and *B. paradoxum* that has sporangia around the margin of all the trophophore pinnae. 2. *B. furculatum sp. nov. ined*, which is an allotetraploid that has *B. pallidum* as one of its parents.[15]
Common Name(s)	Peculiar Moonwort, Paradox Moonwort[2], Two-spiked Moonwort[8],
Species Code (as per USDA Plants database)	BOPA9
GENERAL INFORMATION	
Geographical range	

	National Distribution[1]  Washington State Distribution[1]  Oregon Distribution[1]
Ecological distribution	Montane and subalpine zones.[3] Often found in meadows. Sometimes found in rocky, riparian, forest, grassland, and brush ecosystems.[5] Moist meadows and shrubby slopes.[10] Mostly known in subalpine meadows and high elevation willow stands. [13]
Climate and elevation range	Grows at around 8,000 to 10,000 feet in August and at around 3,000 to 5,000 feet in June.[5]

	Range from 1,500-3,000m.[9]
Local habitat and abundance	Grows in mesic meadows, commonly associated with spruce and lodgepole pine forests as well as springy western redcedar forests.[3] Supports the white-lined sphinx.[4] Difficult to find as it's usually hidden under other vegetation and snowfields.[8] Ground squirrels both pose a threat to *B. paradoxum* and help to maintain its habitat.[13] Associated with *Pinus contorta, Picea engelmannii, Abies lyallii, Pontentilla fruticosa,* and *Salix* spp.[7] Associated with fireweed.[15] *B. paradoxum* occurs in coniferous forests, shrublands, dry meadows, moist meadows, perennial streams, seeps/springs, subalpine meadows, and roadsides/roadbeds. They grow on a variety of landforms such as mid slope areas, lower slope areas, alluvial fans, benches, basins, ravines, stream terraces, and floodplains.[14]
Plant strategy type / successional stage	*Botrychium* are early successional and are able to travel to colonize disturbed areas through wind dispersal of their spores. Above ground populations tend to be resilient following disturbances, although rebounding may take several years. [14]
Plant characteristics	Forb/herb, perennial.[1] It is unique in that it produces only the fertile frond unlike other moonwort species that produce a fertile frond and a sterile frond. It likely acquires its energy from mycorrhizae.[4] Its single above ground frond varies in height and is about 15cm tall, is glaucous green, and is somewhat succulent. The frond is divided into two similar segments sharing the common stalk. Both segments are fertile and have grape-like sporangia that vary in color. In smaller plants they may be unbranched and in larger plants may be branched.[3]

B. paradoxum spores germinate underground and develop into tiny non-photosynthetic gametophytes that require endophytic fungus to take in nutrients.[3]

Its trophophores are converted entirely to the second fertile segment. Its sporophores are double with 2 per leaf, 1 pinnate. Sporophores in June to August. They are very rare teratological individuals of other moonwort species that may have trophophores partially or wholly transformed into sporophores.[9]

May be above ground for somewhere from one to six years (based on the average range of *Botrychium*), but the underground part of the plant can still be alive. This makes longevity difficult to know.[14]

B. paradoxum is one of the rarest of the moonwort species.[14]

B. paradoxum in Stevens Co., WA

PROPAGATION DETAILS

Ecotype	N/A
Propagation Goal	Plants
Propagation Method	Spores (vegetative)
Product Type	Bareroot Propagation of moonwort is difficult, but spores will lie dormant in the soil until the right conditions for germination occur (relating to moisture and mycorrhiza).[14]
Stock Type	10x20 tray or outdoor bed
Time to Grow	It may take several years for *B. paradoxum* to be able to be fully grown. Its spores take time to germinate, and it can be difficult to predict how long they will take.[14]
Target Specifications	Plants that are fully grown will be about 15cm tall.[3]
Propagule Collection Instructions	Spores are released passively from the sporangia and sifted out and spread to the soil by the wind. The spores disperse out around about a 5m radius around the plant. A moonwort spore bank accumulates in the soil until conditions are right.[14] Sporophores are present from June to August, so that would be the time to collect the spores.[9] The fronds mature in July.[3]
Propagule Processing/Propagule Characteristics	There are two sporophores per fertile frond.[9] There's an average minimum spore density of 6,000 spores per m^2 for many species of moonwort. Spore densities for moonwort are high due to the high mortality rate of spores due to the need for mycorrhizal infection after germination. Spores remain viable for long periods of time.[14]
Pre-Planting Propagule Treatments	Several years may pass before spores germinate. They require adequate mycorrhiza to provide nutrients as well as the right moisture level of the soil. When conditions are right, most of the spores will be able to germinate.[14]
Growing Area Preparation / Annual Practices for Perennial Crops	Moist media with mycorrhiza present to be able to provide nutrients to the young plants are required for successful germination. Moonwort tends to grow in soil derived from calcareous bedrock and in hardwater seeps and fens. Media for propagation of *B. paradoxum* may want to be similar to that. Media should be moist but well-drained.[14]
Establishment Phase Details	The passive release of spores from moonwort species cannot be replicated by collection, so propagation can be difficult to induce by means of propagation from

	spores. Spores are long-term investments with greater evolutionary payback.[14]
Length of Establishment Phase	Spores may stay dormant in the growing media for years before germinating. Development of spore to first above ground leaves takes 5-10 years for moonworts.[14]
Active Growth Phase	Maintain conditions for moist but well-drained soil as well as for keeping the mycorrhizal connections alive.[14]
Length of Active Growth Phase	Can continue to grow perennially for several years.[14]
Hardening Phase	N/A
Length of Hardening Phase	N/A
Harvesting, Storage and Shipping	Seedlings must be handled with care as they are delicate.[14]
Length of Storage	N/A
Guidelines for Outplanting / Performance on Typical Sites	Mineral exposed soil may be necessary for outplanting to provide the possibility of mycorrhiza in the soil.[14] Herbivory is common for moonworts.[14] Transplanting moonwort has a low success rate, so introducing spore-dense soil to a desired site may provide the highest chance of success.[14]
Other Comments	Plant observed from the 2nd week of June through the 3rd week of August.[5] Threatened in WA state and is S2.[6] Global conservation status is G3G4.[1] *Botrychium x watertonense* W.H. Wagner is the sterile hybrid of *B. hesperium* and *B. paradoxum*.[8] Herbicide should be avoided near *B. paradoxum* and only used if species is dormant and underground. Herbicides used should be able to degrade rapidly and dissipate so as not to remain potent in the soil.[13] The reason it was given the name *paradoxum* (peculiar) by Wagner and Wagner was because its morphology presented several puzzles. It has only two sporophores and no trophophore, so it wasn't photosynthetic but instead opted for producing more spores. It is an allotetraploid with no known way how this combined with its absence of a trophophore was possible. It is also possible that there is more than one species that are represented by this morphology.[15]
INFORMATION SOURCES	
References	See below

Other Sources Consulted	See below
Protocol Author	Nora Boe
Date Protocol Created or Updated	05/27/23

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[15] *Botrychium paradoxum*. (n.d.-b). Retrieved May 27, 2023, from https://www.herbarium.iastate.edu/files/inline-files/B-paradoxum_0.pdf

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