ARIZONA GAME AND FISH DEPARTMENT
HERITAGE DATA MANAGEMENT SYSTEM

Plant Abstract **Element Code:** PPOPH010Q0
Data Sensitivity: No

CLASSIFICATION, NOMENCLATURE, DESCRIPTION, RANGE

NAME: *Botrychium hesperium*
COMMON NAME: Western Moonwort
SYNONYMS: *Botrychium matricariifolium* subsp. or var. *hesperium*
FAMILY: Ophioglossaceae

AUTHOR, PLACE OF PUBLICATION: Wagner, Warren Herbert and David Bruce Lellinger. American Fern Journal 71: 92. 1981.

TYPE LOCALITY: Colorado. Glacier Lake. 8500 feet.

TYPE SPECIMEN: US Natl. Herbarium, US 135834 (holotype of *Botrychium matricariifolium* subsp. *hesperium*). Ellsworth Bethel, #s.n. July 1, 1914.

TAXONOMIC UNIQUENESS: According to NatureServe (2016), there are 35 species, two varieties and one named hybrid of *Botrychium* in the United States and Canada. Ten of these species and one of the varieties occur in Arizona.

Genus experts (Drs. Florence Wagner and Don Farrar) plan to separate the eastern plants of *B. hesperium* from the western (primarily Rocky Mountains) plants and call the midwestern plants *B. "michiganense"*. This split seems to be widely accepted, although the formal publication has not yet been made. This record refers to *B. hesperium* in the broad sense, including *B."michiganense"* plants (NatureServe 2016).

DESCRIPTION: Western Moonwort is a small perennial fern with a single erect frond, 3-13 cm high. It is divided into a sterile segment and a fertile segment. The sterile segment has a stalk 0-4 mm long, and a broadly lance-shaped to triangular blade that is pinnately divided with 1-6 pairs of closely adjacent leaflets (pinnae). The basal pinnae are usually partly to wholly pinnately divided and are larger than the lobed or entire-margined upper pinnae. The fertile segment is 2-3 times as long as the sterile segment and 1-3 times pinnately divided into linear segments that bear the spores (NatureServe 2016).

Technical: Trophophore stalk 0--3(--10) mm, to 1/4 length of trophophore rachis; blade ± gray-green, dull, oblong-linear to deltate, 1--2-pinnate, to 6 × 5 cm, firm. Pinnae to 6 pairs, ascending, usually approximate or overlapping except in shade forms, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, basal pinna pair commonly much larger and more divided than adjacent pair, lobed to tip, basal pair oblong to oblong-

lanceolate with lobed margins, remainder broadly spatulate with entire margins or 1 or more shallow lobes, apex rounded, venation pinnate. Sporophores 1--3 pinnate, 2--3 times length of trophophore. 2 n =180. Flora of North America 2016.

AIDS TO IDENTIFICATION: *B. hesperium* is similar to other *Botrychium* spp. but is a duller green color than *B. echo*, and has ovate to oblong lower pinnae. The deeply pinnately lobed basal pinnae help separate this species from most others in its range. NatureServe 2016.

According to Anderson and Cariveau 2004, Botrychium species can be extremely difficult to identify, due to their subtle diagnostic characters, the frequent co-occurrence of multiple *Botrychium* species at a location, and the high morphological variability within populations. Positive identification requires comparison with silhouette outlines of verified specimens (such as those presented in Wagner and Wagner 1986) and use of dichotomous keys (see Weber and Wittmann 2001).

ILLUSTRATIONS:

Photos and Herbarium Mounts:
http://swbiodiversity.org/seinet/taxa/index.php?taxon=Botrychium%20hesperium.
Photos and Fact Sheet:
http://www.public.iastate.edu/~herbarium/botrychium/B-hesperium.pdf.

TOTAL RANGE: As currently recognized, the species extends from the Yukon Territory south through the western Canadian Provinces, Washington and Oregon and the Rocky Mountain States to northern Arizona. It also occurs in Ontario, Minnesota and Michigan. Although not yet formally published, it has generally been accepted that the plants of the eastern distribution will be split off and named as a different species (see Taxonomic Uniqueness, above).

Even though *B. hesperium* has a large geographic range in North America, it is infrequent to rare and highly localized in its occurrence.

RANGE WITHIN ARIZONA: The Inner Basin of the San Francisco Mountain near Flagstaff in Coconino County, and just east of Mount Ord in Apache County.

SPECIES BIOLOGY AND POPULATION TRENDS

GROWTH FORM: A perennial fern.

PHENOLOGY: Leaves appearing in midspring, dying in early fall. Spores are produced in July. NatureServe 2016.

BIOLOGY: *Botrychium* species have high reproductive outputs and possibly produce more spores per sporangium than any other vascular plant. Like all Pteridophytes and unlike

angiosperms and gymnosperms, *Botrychium* spores develop into gametophytes that live independently of the sporophyte. The gametophyte produces male and female sex cells, and the male sex cells must move through a fluid environment to fertilize a female egg cell. Because of its subterranean environment, self-fertilization is usually the rule. Due to their apparent predisposal to selfing, *B. hesperium* and other *Botrychium* species may not be particularly sensitive to the effects of inbreeding depression.

The spores are small and light and are likely carried by the wind. Researchers have hypothesized that average dispersal distances might range up to three meters. The flow of rainwater downslope is likely another dispersal mechanism (Anderson and Cariveau 2004).

There have been many observations of herbivory on *Botrychium* species including *B. hesperium*. are often found to have been browsed, probably by deer or rabbits. In some cases, as many as 80 percent of the plants have been completely browsed. The spores of *Botrychium* species also have relatively thick walls, which may enhance their ability to survive a trip through the gut of an animal (Wagner et al. 1985). These observations have led to the hypothesis Sporophytes that animals may disperse the spores of *Botrychium* species.

The importance of spore banks is unknown for *B. hesperium*, but recent studies suggest that they play a vital role in the survival strategies of some ferns (Dyer and Lindsay 1992). The longevity of the spores of *B. hesperium* is unknown, but spores of other fern genera have been germinated from 50-year old herbarium specimens. No spores are currently in storage for *Botrychium hesperium* at the National Center for Genetic Resource Preservation.

B. hesperium has the highest ratio of belowground to aboveground structures (1950:1). The number of aboveground sporophytes observed in a given year may be a poor indicator of population size and viability, since much of the population is not visible and sporophytes can remain dormant for one or more years (Anderson and Cariveau 2004).

Mycorrhizae may be the most important factor for establishment, distribution, and abundance of *Botrychium* species, for both the sporophytic and gametophytic stages. Although germination can occur without mycorrhizal infection, the gametophyte will not mature without an arbuscular mycorrhizal symbiont. Arbuscular (also referred to in the literature as vesicular-arbuscular) mycorrhizae are the known fungal symbiont with *Botrychium* species. Mycorrhizal fungi are low in species diversity, ubiquitous in disturbed and undisturbed sites, and generalist in whom they infect. Recent studies have measured surprisingly high species diversity of arbuscular mycorrhizal (AM) fungi in a single hectare. A single plant root has been observed to host up to 49 species of AM fungi simultaneously. These observations, coupled with the ubiquity and low host specificity of AM fungi, suggest that mycorrhizae may not be a limiting factor in the distribution of *B. hesperium* (Anderson and Cariveau 2004).

It is extremely difficult to grow *Botrychium* species in the greenhouse or lab (Whittier 1972).

There are no reports of parasitism or disease in the literature for any *Botrychium* species.

HABITAT: Grassy mountain slopes, snow fields, road ditches with willows (Flora of North America 2016). In the western portion of its range (i.e. excluding "*michiganense*" material), occurs in the forested montane zone, where the forest is relatively open-canopied and/or within open habitat types, which tend to be subject to periodic disturbance and include subalpine meadows, snow fields, mesic grassy slopes, prairie pothole meadows, edges of lakes, gravel bars, and roadsides. Soils are dry to moist and tend to be coarse and gravelly.

B. herperium favors earlier successional habitats that result from periodic disturbance. The presence of coarse gravelly soil with little or no tree cover is often mentioned in collection records. Sites such as disturbed trail sides through meadows, decomposing granite soil, gneiss outcrops, organic soil slopes and open subalpine meadows have all been noted as well. Areas where catastrophic fires have occurred, avalanche chutes and open areas in the krummholz zone also provide suitable habitat.

In the Conservation Assessment prepared by Anderson and Cariveau 2004, they identified several habitat attributes that were commonly associated with sites containing *Botrychium* species, including *B. hesperium*. Sites were typically open, with much direct sunlight; well-drained; with 10 to 40 percent bare soil; with rock cover frequently 5 to 15 percent; on 20 to 30 percent non-southern slopes; historically disturbed; previously forested areas with a coniferous forest potential; often on calcareous substrates; usually at 3,210 to 3,510 meters elevation; and on compacted and eroded soils.

ELEVATION: Range-wide: 655 – 9185 feet (200-2800m), including the eastern distribution (Flora of North America 2016). 3280 – 11480 feet (1000-3500m) NatureServe. Colorado EOs 9847 – 11267 feet (3002-3435m), Anderson and Cariveau 2004. Arizona collections range from 9600 – 10600 feet (2927-3232m).

EXPOSURE: Generally open, with much direct sunlight, and not favoring southern exposures (in Colorado).

SUBSTRATE: Often on calcareous substrates, but decomposing granite and gneiss also noted in Colorado. Soils compacted and eroded. Soils are dry to moist and tend to be coarse and gravelly.

PLANT COMMUNITY: Forest - Conifer, Forest - Mixed, Forest/Woodland, Grassland/herbaceous, Sand/dune (eastern distributions), Woodland - Conifer, Woodland – Mixed, Herbaceous wetland.

In the Rocky Mountains (and Arizona) *Botrychium hesperium* often grows with *B. echo* (Flora of North America 2016) as well as *B. paradoxum, B. lunaria* and *B. lanceolatum*. Sterile hybrids between *B. hesperium* and *B. echo* have been observed in sites where these species occur together.

POPULATION HISTORY AND TRENDS:

For the species, no data is really available to analyze population trends. Population estimates are further confounded because there can be a wide variation in the number of stalks that actually emerge each year. Drought may be the controlling factor for the variability of stalk emergence.

Because large numbers of gametophytes and non-emergent sporophytes may occur in the soil undetected, a single emergent sporophyte may either indicate the presence of a viable population, or a recent colonist. The number of emergent sporophytes in a given year is highly variable and is an incomplete indicator of total population numbers in moonworts, including *B. hesperium*.

It has been hypothesized that *Botrychium* populations have been increased due to the anthropogenic disturbance associated with ski runs, roads, clear cut logging, trails and similar actions. On the other hand, the suppression of fire and grazing may have also decreased populations. Both of these are only theories, with little supportive data (Anderson and Cariveau 2004).

In Forest Service Region 2, there are 33 known populations (with 29 being on FS lands). These range in size from 1 to 100 individuals, with a total population estimated at 300-400 plants. This is not very substantial. It is suspected that there are more populations, but additional surveys are required to verify this. The very fact that this species prefers early successional habitats, suggests that habitats with currently established populations are destined to become unsuitable as the succession progresses, and therefore the populations are in jeopardy (Anderson and Cariveau 2004).

In Arizona, there are two element occurrences that were documented in the early 1970s to mid- 1980s, but have not been reconfirmed since. The San Francisco Mountain EO stated the species was common; the Apache County EO claimed the plant was very rare, "only plant found." NatureServe considers the species to be critically imperiled in Arizona.

Globally, *B. hesperium* is ranked as apparently secure with over 120 extant occurrences. However, only 15 of these are considered to have good to excellent viability. Nationally, the species is considered vulnerable. The population trend is essentially unknown for a variety of reasons. There is high variability in the appearance of the population year-to-year, and although some populations seem to be increasing, their long-term viability is not known and they face a number of possible threats. NatureServe's (2016) best estimates of both long-term and short-term trends is between a decline of <30% to an increase of 25%.

SPECIES PROTECTION AND CONSERVATION

ENDANGERED SPECIES ACT STATUS: None.

STATE STATUS: None.
OTHER STATUS: None.

MANAGEMENT FACTORS: *B. hesperium* requires at least somewhat open habitat, in the past most likely created by natural disturbance events such as fire. Anthropogenically-disturbed areas such as ski runs have been observed to harbor reasonably large numbers of individuals, but habitat created by anthropogenic disturbance has not yet been proven to support viable populations in the long-term (Anderson and Cariveau 2004). Mycorrhizal interactions are also of paramount importance to *Botrychium* species, and better understanding of this species' mycorrhizal relationships and requirements will lead to better understanding of management techniques that support those relationships (Anderson and Cariveau 2004).

Conservation efforts focused on protecting the known populations of *Botrychium hesperium* are more likely to be effective than restoration efforts. Restoration is probably precluded by the great difficulties in propagating the species (Anderson and Cariveau 2004).

Threats to the *Botrychium*s are not well understood. Because this species occurs in both naturally and artificially (human-caused) disturbed sites, threats include natural plant succession as well as the same human activities (recreation, road and trail maintenance activities, grazing) that also apparently resulted in creating the initial suitable habitat. Because of its assumed rarity and small number of individuals in known occurrences, any land use activity within an occurrence of *Botrychium hesperium* may potentially threaten, or even extirpate, it.

Although logging, ski trail development and maintenance, road and trail building and other human disturbances have created substantial potential habitat, it is not known if maintaining habitats in a state of arrested succession through the continuance of an imposed disturbance regime provides persistent habitat for *B. hesperium*.

Given these unknowns, one recommended management practice is that surveys to detect the presence/absence of *Botrychium* should be undertaken before any management actions occur within potential habitat.

Off-road vehicle use (both motorized and non-motorized) represents a significant threat to *B. hesperium* from recreation.

Construction of facilities to support recreational skiing present threats to specific moonwort populations.

Numerous management practices such as pulling stumps, creating and maintaining roads, using summer snowcats, controlling weeds mechanically or chemically, grooming the earth on ski runs, installing and maintaining waterlines and electrical lines, and maintaining lift corridors all have the potential to create new habitat, or destroy existing populations.

Fire is not detrimental to *Botrychium.* Even after their aerial portions have been burned, these plants, including *B. hesperium*, seem to suffer no negative consequences. This is likely due to the importance of the subterranean parts of the plant to its overall life cycle. Fires that occur during phenologically sensitive times (July and August, when forest fires are most frequent) would preclude any reproductive output for that year and might kill spores lying near the surface.

Grazing from both livestock and wild ungulate animals is known to occur, but does not seem to have significant deleterious effects. Some loss of individual plants by sheep grazing has been observed in Norway. The removal of above ground portions of the plant by grazing can eliminate a season's contribution to the spore bank.

There has been no research on the effects of weeds on *Botrychium* species, but it is known that disturbed areas are often colonized by weeds which may compete for resources.

Collection of plants could be a negative factor in small populations. It is recommended that no collections be made in populations having less than 20 individuals. Pictures should be taken instead. Roots should not be collected, because there are no diagnostic characteristics associated with the roots and collecting them kills the plant. Furthermore, to minimize the risk of infection or of removing the apical bud, it is recommended to cut the leaf with a knife near ground level rather than pinching or pulling with the fingers.

Given that the species does not prefer the more xeric southern exposures, it might be expected that climate change, currently projected to result in warmer temperatures with less precipitation in the region, will not be beneficial for *Botrychium*.

PROTECTIVE MEASURES TAKEN: None specified. However, the apparently best populations found in Arizona in the San Francisco Mountain are within a U.S. Forest Service Wilderness Area.

SUGGESTED PROJECTS: Surveys to identify new populations are needed. This work is complicated by the year-to-year fluctuations in the presence of above ground sporophytes. Searching for *B. hesperium* requires one's full attention. There are a number of researchers who are well experienced with this work, and it is recommended that they are involved. Further targeted inventory work would allow land managers and NatureServe to accurately assess the rarity and conservation priority of this species.

Annual monitoring of selected populations is recommended and will help to understand the ecology and population trends of this species. It is again noted that given the variable nature of the emergent sporophyte year-to-year, this alone can be a potentially misleading indicator of actual population numbers.

Metapopulation dynamics are not understood. Migration, extinction and colonization rates are unknown for all species of *Botrychium*.

Although the species is extremely difficult to propagate, efforts to develop successful restoration methods may prove to have future benefits. At this time, given the importance of the mycorrhizal symbionts, it is recommended to use a fungal inoculum in areas that have had historic soil disturbance to accelerate recolonization.

All of the above suggestions were taken from Anderson and Cariveau 2004.

LAND MANAGEMENT/OWNERSHIP: USDA Forest Service, Coconino National Forest, and USDI Bureau of Indian Affairs, White Mountain Apache Indian Reservation.

SOURCES OF FURTHER INFORMATION

REFERENCES:

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ADDITIONAL INFORMATION:

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