ARIZONA GAME AND FISH DEPARTMENT
HERITAGE DATA MANAGEMENT SYSTEM

Plant Abstract **Element Code:** PPOPH01080
Data Sensitivity: No

CLASSIFICATION, NOMENCLATURE, DESCRIPTION, RANGE

NAME: *Botrychium lunaria*
COMMON NAME: Moonwort Grape-fern, Common Moonwort
SYNONYMS: *Osmunda lunaria, Botrypus lunaria, Botrychium onondagense*
FAMILY: Ophioglossaceae

AUTHOR, PLACE OF PUBLICATION: Swartz, Olof (Peter). Journal für die Botanik 1800(2): 110. 1801.

TYPE LOCALITY:

TYPE SPECIMEN:

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.

DESCRIPTION: Moonwort is a very small, perennial fern with a single aboveground frond. The dark-green frond is usually about 4 inches long and can be seen through mid-summer. It is divided into two leaves above a common stalk. The sterile leaf is usually dark green, thick, and fleshy. It has up to 9 usually overlapping pairs of broadly fan-shaped leaflets (pinnae). The top edges are rounded and smooth or wavy or rarely have teeth. The fertile leaf is longer than the sterile leaf with branches that bear grape-like sporangia. Roots are few, erect, short, and spread horizontally. (NatureServe 2016).

Technical: Trophophore stalk 0--1 mm; blade dark green, oblong, 1-pinnate, to 10 × 4 cm, thick, fleshy. Pinnae to 9 pairs, spreading, mostly overlapping except in shaded forest forms, distance between 1st and 2d pinnae not or slightly more than between 2d and 3d pairs, basal pinna pair approximately equal in size and cutting to adjacent pair, broadly fan-shaped, undivided to tip, margins mainly entire or undulate, rarely dentate, apical lobe usually cuneate to spatulate, notched, approximate to adjacent lobes, apex rounded, venation like ribs of fan, midribs absent. Sporophores 1--2-pinnate, 0.8--2 times length of trophophore. 2 n =90. Flora of North America 2016.

AIDS TO IDENTIFICATION: *Botrychium lunaria* is most easily differentiated from other moonworts by the breadth of its pinnae. Typically the basal pinnae span an arc of nearly 180 degrees and the third pinna pair has a span of approximately 90 degrees. The upper pinnae

angle upward—the lower side margin creates a large angle (nearly 90°) with the rachis, the upper side margin is nearly parallel to the rachis. Although it is occasionally short stalked, the trophophore of *B. lunaria* is typically sessile, the stalk length seldom equaling or exceeding the distance between the first pinna pair as it usually does in *B. minganense*. Plants are green to dark green with a surface that is lustrous to dull, but never glaucous. The sporophore is long stalked, the stalk, at spore release, exceeding the length of the trophophore (Iowa State 2016).

The following characteristics from the dichotomous key provided by Clausen (1938) can also be used to identify *B. lunaria*:

Buds and leaves always glabrous,
Sterile blade oblong or ovate in outline, very rarely deltoid, sessile or stalked; the fertile and sterile segments in the bud either erect or with their tips variously declined, but never both completely reflexcd.
Both segments of the leaf erect in vernation or the fertile segment erect and the extreme tip of the sterile just slightly inclined over it; the blade simple or once pinnate, sometimes with basal divisions again divided, thus appearing ternate.
Sterile blade sessile or short stalked, with the divisions either imbricate or somewhat remote, usually decidedly flabellate, but sometimes obovate or oblong, generally all similar; the basal lobes rarely again divided; the spores 25-40µ in diameter……. *B. lunaria*

ILLUSTRATIONS:
Photos: http://swbiodiversity.org/seinet/taxa/index.php?taxon=Botrychium%20lunaria.
Photos and Line Drawings: http://eol.org/pages/597544/media.
Photos and Fact Sheet: http://www.public.iastate.edu/~herbarium/botrychium/B-lunaria.pdf.

TOTAL RANGE: In North America, from Newfoundland and Labrador west to Alaska, south to Massachusetts, New York and Pennsylvania, Michigan, Minnesota, South Dakota, Wyoming, New Mexico (not Colorado), Arizona and California. Also, extreme southern South America, Eurasia, Australia and New Zealand. *B. lunaria* has the largest range of all the moonworts.

RANGE WITHIN ARIZONA: Collected from two locations: San Francisco Mountain north of Flagstaff in Coconino County, and Mount Baldy, Apache County.

SPECIES BIOLOGY AND POPULATION TRENDS

GROWTH FORM: Small perennial fern.

PHENOLOGY: Leaves appearing in spring, dying in latter half of summer.

BIOLOGY: The spore cases of *Botrychium* are among the largest of all known ferns and appear like clusters of tiny grapes (creating the name Botrychium, from botrus, Greek for grapes). The number of spores per case is probably the highest known for vascular plants,

numbering in the thousands. Spores germinate underground and develop into tiny, non-photosynthetic gametophytes which depend on a fungus for nourishment. Essentially, the *Botrychium* gametophyte becomes a parasite of the mycorrhizal fungus. *Botrychium* mycorrhizae have been described as the vesicular-arbuscular (VAM) type. *Botrychium* may depend little on photosynthesis, and mycorrhizae alone may supply a significant amount of the plant's nutrients and energy. After the spores are released, in May or June for *B. lunaria*, they infiltrate into the soil and may germinate. Infiltration and subsequent germination may take up to 5 years, although some germinate immediately. *B. lunaria* has a relatively small cotyledon, and may take as much as seven years to produce an emergent frond (Chadde and Kudray 2001).

HABITAT: Open fields, occasionally forests in southern occurrences (Flora of North America 2016). *Botrychium lunaria* generally occurs on calcareous soils in the sunlight of open fields, wood edges, and occasionally forests in the southern parts of its range. It may also occur on rocky banks or gravelly ledges (NatureServe 2016). *Botrychium lunaria* is cosmopolitan in its habitats. At high latitudes and high altitudes it is often a plant of open to lightly wooded meadows as well as sparsely vegetated scree slopes. At lower elevations and southern latitudes it occurs in mesic woodlands as well as meadows and sparsely vegetated sand dunes. It most commonly occurs on moist but well-drained soils with a neutral pH (Iowa State 2016).

The National Plant Data Center (USDA, NRCS 1999) listed a number of habitat characteristics for *B. lunaria* including soil tolerances (no fine-textured soils), soil pH range (5.8 to 7.2), and minimum and maximum precipitation range (14 to 55 inches). A Forest Service database (USDA Forest Service 2000) reported the habitat as cool/moist conditions, along forest roads and trails, in open areas, lakeshores (sand dunes), and occasionally in forests; plants were also reported from sandy soils of old log landings in jack and red pine woods.

ELEVATION: Range-wide: 0 – 12135 feet (0-3700m), Flora of North America 2016. In Arizona, collections have been made from 9500 – 11550 feet (2900-3520m).

EXPOSURE: Open, seems to prefer sunlight.

SUBSTRATE: Well drained soils, calcareous soils sometimes noted, somewhat neutral pH (5.8-7.2).

PLANT COMMUNITY: Meadows surrounded by Spruce-Aspen forest (Inner Basin, San Francisco Mountain). Associated species include: *Juniperus communis, Lonicera involucrata* and *Ribes*; herbaceous plants include *Anemone globose, Arenaria fendleri, Carex, Castilleja linariifolia, Fragaria ovalis, Lathyrus arizonicus, Poa fendleriana, Potentilla pulcherrima, Pseudocymopteris montanus, Solidago decumbens, S. multiradiata, Swertia radiata* and *Zigadenus elegans*. *Cystopteris* is the only other fern present. Other plants associated with higher elevation collection sites (3292 and 3550m) on San Francisco Mountain include:

Androsace septentrionalis, Arenaria lanuginose, Lupinus argenteus, Penstemon whippleanus, Arenaria rubella, Festuca ovina, Mertensia franciscana, Polemonium viscosum, Saxifraga rhomboidea, Sedum rhodanthum, sebbaldia procumbens, Silene acaulis and *Solidago multiradiata*. On Baldy Mountain, plants associated on the grassy subalpine bald include *Achillea lanulosa, Arenaria fendleri, Draba helleriana, Festuca ovina, Heuchera parvifolia, Pedicularis parryi, Potentilla diversifolia, Pseudocymopteris montanus, Sedum rhodanthum, Solidago parryi* and *Zygadenus virescens*.

POPULATION HISTORY AND TRENDS: Unknown for Arizona. There are four occurrences within the State, collected between 1912 and 1978, but not since. Some of the collections from San Francisco Mountain noted the species was common. Because of the very limited occurrences, NatureServe considers the plant to be critically imperiled in Arizona.

Overall however, this is the most widely distributed species of *Botrychium*. It is considered secure globally. NatureServe assesses the short-term trend to be relatively stable (<=10% change). Despite this wide distribution, occurrences still tend to be rare and local.

A conservation assessment for the USDA Forest Service, Eastern Region, by Chadde and Kudray (2001) offers the following information regarding *B. lunaria* population dynamics:

Little information is available about the population biology of *B. lunaria*. Population studies on other species of moonworts have shown that there can be considerable annual variation in the number of aboveground plants at a given site. Since there is considerable variation in the numbers of aboveground sporophytes, a measurement of only sporophytes does not completely indicate population numbers, and findings suggest that a single emergent sporophyte may indicate a self-sustaining population at that site.

The spore bank that consists of all un-germinated spores, including unopened sporangia, is present within the litter, duff, and soil. Spores persist in the soil for several years and, along with underground gametophytes and developing sporophytes, form a highly buffered moonwort population that can rebound from unfavorable years. However, events that destroy the sporophytes, like an herbicide application, fires or excessive grazing, may have an effect several years later.

A species like *B. lunaria* that is often found in open areas with a regular disturbance regime may have a metapopulation structure where local populations are founded then go extinct as succession proceeds toward a closed climax community.

SPECIES PROTECTION AND CONSERVATION

ENDANGERED SPECIES ACT STATUS: None.

STATE STATUS: None.
OTHER STATUS: None.

MANAGEMENT FACTORS: Threats mentioned in a *Botrychium lunaria* conservation assessment for the USDA Forest Service, Eastern Region (Chadde and Kudray 2001) include drought, fire, timber harvesting, collecting, herbicide application, herbivory, exotic earthworms, and forest succession.

Mycorrhizae are probably the most limiting factor for *Botrychium* establishment, distribution, and abundance.

Given the general preference of the species for open sites, some kind of opening management may be a feasible management tool, although no information is available on the response of *B. lunaria* populations to management of any kind. Since *B. lunaria* often exists in a habitat that is early successional due to disturbance, it may be prone to local extinctions, thus population viability may rely on a shifting mosaic of suitable habitats opening up for colonization. Land protection should take into account the immediate area surrounding the *B. lunaria* populations to ensure that an adequate buffer to fully protect the population from potential threats and to allow for expansion is available (NatureServe 2001).

PROTECTIVE MEASURES TAKEN: None, but Arizona occurrences are all within Forest Service Wilderness Areas.

SUGGESTED PROJECTS: Field surveys at known locations should be conducted to verify if species is still extant.

Almost no information is available on *B. lunaria* life history in relation to disturbance and colonization of new sites. While its habitat is generally considered to be open areas, it also occurs in forested habitats. Succession has been considered a threat (USDA Forest Service 2000), but it is unclear how *B. lunaria* reacts to site changes over time.

Life history information for moonworts is mostly generalized from studies on various species within the group. Specific information on *B. lunaria* life history is needed including its important relationship with mycorrhizal fungi and its belowground ecology in general. Data on spore dispersal is also lacking.

Habitat monitoring is also a need for the species. Correlations between changes in habitat and reproductive success can give strong recommendations toward future management activities. Such monitoring will also indicate the appropriate time to initiate management activities. Perhaps the easiest and most effective way of monitoring habitat would be through permanent photo-points (Chadde and Kudray 2001).

LAND MANAGEMENT/OWNERSHIP: USDA Forest Service: Coconino (Kachina Peaks Wilderness) and Apache-Sitgreaves (Mount Baldy Wilderness) National Forests.

SOURCES OF FURTHER INFORMATION

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ADDITIONAL INFORMATION: *Botrychium lunaria* grows with many other species of *Botrychium*, occasionally hybridizing with them. This species, geographically the most widespread of the moonworts, has notably uniform morphology (Flora of North America 2016).

Botrychium lunaria is the original moonwort (Botrychium subgenus Botrychium) described by Linnaeus.

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