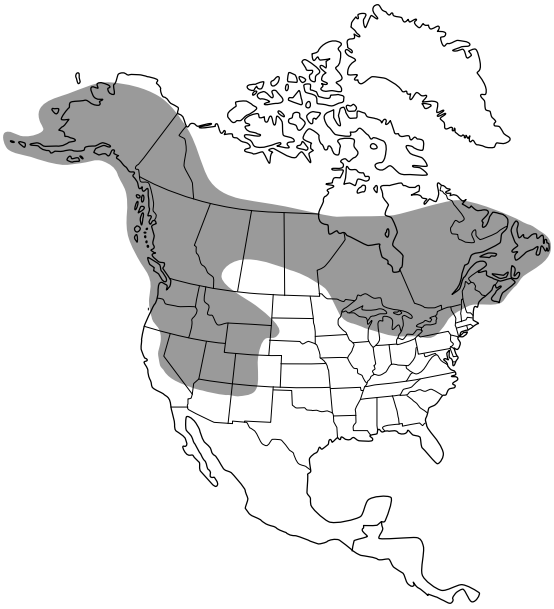
Botrychium neolunaria sp. nov. ined.

Family: Ophioglossaceae
Genus: *Botrychium*
Species: *Botrychium neolunaria sp. nov. ined*. Stensvold & Farrar
Common Name: Common Moonwort
Ploidy: Diploid



Technical description: Trophophore stalk 0-1 mm; blade dark green, oblong, 1-pinnate, to 10 x 4 cm, thick, fleshy. Pinnae to 9 pairs, spreading, mostly overlapping except in shaded forest forms, distance between 1st and 2nd pinnae not or slightly more than between 2nd and 3rd 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. 2n = 90. (Wagner and Wagner 1993 as *B. lunaria*)

Taxonomy

Linnaeus described *Osmunda Lunaria* in 1753 (Species Plantarum 2:1064), presumably based on European plants. It was transferred to *Botrychium lunaria* by Swartz in 1801 (Schrader's Journal fur die Botanik 2:110). Clausen (1938) and later workers considered similar plants in North America to be of this species.

In 2008, Stensvold completed dissertation research on *B. lunaria* world wide. Using genetic analysis as well as morphology, Stensvold discovered much greater genetic variability in this taxon than previously recognized. Among her discoveries was the fact that plants in the contiguous US, in much of southern Canada, and in the coastal and lowland interior of Alaska were greatly different genetically from European *B. lunaria*. These American plants possessed unique alleles at 18% of the gene loci tested, and an overall genetic difference generally indicative of distinct species. Stensvold proposed the name *B. neolunaria sp. nov. ined* for these North American plants. Official publication of this name is preparation, but until publication is completed, the qualifying term, *ined.* should accompany printed use of this name.

Identification

Botrychium neolunaria and other members of the *B. lunaria* complex (including *B. lunaria var. crenulatum, B. tunux* and *B. yaaxudakeit* in North America) of species are most easily differentiated from other moonworts by the breadth of their basal pinnae. Typically the basal pinnae of *B. neolunaria* have a span of nearly 180 degrees and the third pinna pair has a span of approximately 90 degrees. The upper pinnae angle upward—the basicopic inner margin creates a large angle (nearly 90°) with the rachis, the acroscopic inner margin is nearly parallel to the rachis. Although it is occasionally short stalked, the trophophore of *B. neolunaria* is typically sessile, the stalk length never equaling or exceeding the distance between the first two pinna pairs 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 usually long stalked, the stalk, at spore release, exceeding the length of the trophophore.

The only other species with basal pinnae as broad as *B. neolunaria* are B. *lunaria* var. *lunaria*, *B. lunaia* var. *crenulatum*, *B. tunux* and *B. yaaxudakeit*. *Botrychium lunaria* var. *crenulatum* is a much more delicate plant with thin textured pinnae with finely crenulate or toothed margins. Its trophophore is typically short stalked and all pinnae stand more or less at right angles to the rachis. *B. tunux* can be differentiated by its asymmetrical lower pinnae, stiffly spreading pinnae, and a sporophore stalk that is shorter or equal to the length of the trophophore. *B. yaaxudakeit* has stalked lower pinnae with spans exceeding 180^{o} and basiscopic inner margins that are distinctly recurved. Its upper pinnae also approach 180° in span, conspicuously overlapping one another and the rachis. In southern populations (in Montana, Oregon and California) *B. yaaxudakeit* attains a much

smaller size and cannot be reliably distinguished from *B. neolunaria* by pinna shape alone. However, *B. yaaxudakeit* is an allotetraploid with spores significantly larger (avg. 45 µm) than those of *B. neolunaria* (avg. 36 µm). *B. neolunaria* cannot be reliably distinguished from *B. lunaria* var. *lunaria* by morphology alone, but these species overlap in distribution only at high elevations in Alaska and Yukon and in eastern Canada.

Distribution and Abundance

Botrychium neolunaria is endemic to North America, but in North America it is one of the most abundant and widely distributed of moonwort species. Only *B. minganense* and *B. lanceolatum* (the two subspecies combined) copy its widespread occurrence in both eastern and western North America. *B. neolunaria* ranges from Pennsylvania north to Laborador and west across Minnesota and South Dakota to the high mountains of all southwestern states and across all Canadian provinces and coastal and lowland Alaska. Through much of this range it is the most common moonwort in its habitat which includes open fields, stabilized sand dunes, mountain meadows, roadsides and less frequently, mesic forests.

Plants of high mountain habitats in Alaska and northern Canada are most commonly of *B. lunaria* var. *lunaria* whereas plants of low elevations in Alaska, Canada and all of the lower US are, with few exceptions, are *B. neolunaria*

In California populations of *B. neolunaria* are genetically confirmed in Modoc, Mono and Inyo Counties. Historical collections presumed to be *B. neolunaria* have been made in Inyo and Tuolumne Counties. Morphological determinations in California are complicated by the presence of the similar plants of *B. yaaxudakeit* which differ from *B. neolunaria* only in their larger spore size (see discussion of *B. yaaxudakeit*).

Habitat

Botrychium neolunaria 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 latitudes it occurs in deep woods as well as meadows and sparsely vegetated sand dunes. It most commonly occurs on moist but well-drained soils with a neutral pH.

Population Genetics

The widespread North American *B. neolunaria* is remarkably uniform genetically. Plants from the Great Lakes, Colorado and Washington display only a single allele at 19 of 20 gene loci studied (Farrar 2001). In coastal Alaska the genetic

variability increases slightly with addition of a second allele at a second locus. Additionally, some plants in the Black Hills of South Dakota possess a unique allele at one locus.

This uniformity of genotype over most of North America stands in sharp contrast to a relatively high level of genetic variability in European *B. lunaria* var*. lunaria* and in the Alaska representatives of this European taxon. Probably *B. neolunaria* arrived in North America as a single colonizing genotype or was restricted by Pleistocene events to a single genotype that subsequently spread across North America following deglaciation. Presence of unique alleles in North American *B. neolunaria* indicates that this genotype has long been separated from the European *B. lunaria*. Eurasian genotypes in Alaska may represent recent migration from Siberia or possibly relicts of an earlier distribution that survived the Pleistocene in unglaciated portions of Alaska.

With over 60 sites surveyed in Alaska (over 400 plants analyzed), European genotypes of *B. lunaria* var*. lunaria* have not been found at low elevations in Alaska. The two genotypes have been found growing together only rarely. Because many of these sites are relatively close it seems unlikely that lack of spore dispersal is responsible for this differentiation. More likely the two taxa have differing habitat requirements that are seldom met for both in the same site. In Bic National Park in the St. Lawrence Seaway, large populations of *B. lunaria* var*. lunaria* and *B. neolunaria* occur side by side but delineated by tidal zonation. Genetic examination of the two populations disclosed no evidence of hybridization.

Phylogenetic Relationships

Among diploid moonworts, *Botrychium neolunaria* is most closely related to *B. lunaria* var*. lunaria*, *B. lunaria* var*. crenulatum, and B. tunux*. This relationship suggests a relatively early differentiation of western US *B. neolunaria* from the widespread *B. lunaria* var*. lunaria,* possibly during early events of Pleistocene glaciation. *B. neolunaria* is highly distinct from the other common moonworts with GI values ranging from 0.17 to 0.48.

The widespread *B. neolunaria* of North America possesses a number of alleles that, among the diploid species, are present only in this species. These unique alleles clearly indicate *Botrychium neolunaria* as one of the parents in a number of allopolyploid species. In combination with *B. lanceolatum* it has produced *B. pinnatum*; with *B.* “X” it has produced *B. minganense*; and with *B. lunaria* it has combined to produce *B. yaaxudakeit*. It may also be involved in the parentage of the rare allohexaploid species *B. pseudopinnatum*.

Additional images of *Botrychium neolunaria*: