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Rare Plant Status Review: *Botrychium paradoxum*
Proposed New Add to Rank 2.1, G3G4 / S1

Danny Slakey (CNPS), Aaron E. Sims (CNPS), and Roxanne Bittman (CNDDB)
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Changes to original document appear in blue text.

Three *Botrychium* species (*B. paradoxum, B. tunux,* and *B. yaaxudakeit*) are new to California and were recently discovered by Alison Colwell in the vicinity of Yosemite National Park. They are individually discussed in separate status review proposals; however, all of the proposals contain the same background information on the *Botrychium* genus, which is outlined in the first section below.

Background on the *Botrychium* genus

The genus *Botrychium* is a group of ferns in the Ophioglossaceae that are perennial rhizomatous herbs. Understanding the unique *Botrychium* morphology is important to differentiating species. The aboveground sporophyte, which only emerges some years, consists of a single leaf divided into a sporophore (spore-bearing segment) and trophophore (vegetative segment). The majority of *Botrychium* spp. are cryptic, owing to their paucity of morphological features, the plasticity of those features, and the fact that many morphologically similar species are separated by genetic isolating mechanisms (Hauk and Haufler 1999). Because of this, all but one of the known California occurrences of the three species have been confirmed through genetic testing by Dr. Don Farrar (D. Farrar pers. comm. 2011).

Some general threats and management considerations for these three species can be inferred from studies done on other *Botrychium* spp. The California occurrences are highly disjunct from neighboring populations (D. Farrar pers. comm. 2011). Many such plants would be considered at risk of inbreeding depression or genetic drift; *Botrychium* spp., however, reproduce almost exclusively by intragametophytic self-fertilization, eliminating these concerns (J. Clines ~~et al. 2009~~, D. Farrar, and C. Johnson 2011).

These plants are ~~highly~~ dependent on endomycorrhizal associations with fungi in the genus *Glomus* throughout their life cycle. The *Glomus* fungi are dependant on other green plants for photosynthetic nutrition, and they strongly prefer to associate with perennial herbs (as well as trees in the Cupressaceae and a few broadleaf tree species; D. Farrar pers. comm. 2012). Perennial herbaceous vegetation can be a short-lived successional stage following anthropogenic disturbances. There fore, s~~S~~ome individuals and populations of rare *Botrychium* spp. as a whole tend to be ephemeral, growing only after the herbaceous vegetation has had time to colonize and before other vegetation has taken over (generally 15 to 50 years post-disturbance). Three different *Botrychium* spp. (including *Botrychium paradoxum*) studied over 6 years had relatively short life spans of individuals after sporophyte emergence, with half-lives ranging from one to three years (Lesica and Ahlenslager 1995). However, *Botrychium* spp. also grow

in habitats with perennial herbaceous vegetation that is not maintained by anthropogenic disturbance, such as mountain meadows and prairies. Recent observations from naturally-formed habitats have shown that individuals can have significantly longer life spans, ranging from 20 to more than 44 years (D. Farrar pers. comm. 2012). The high-elevation populations of *B. yaaxudakeit, B. tunux,* and *B. paradoxum* are more likely to be longer-lived, given that they occur in more stable, natural habitats.

~~Also, many populations of *Botrychium* spp. undergo routine extirpations and colonizations of new areas, which could be attributed to their affinity for a moderate degree of disturbance (Clines et al. 2009). However, *Botrychium* spp. populations are usually highly buffered, with a "seed bank equivalent" consisting of spores, gametophytes, and underground sporophytes (Clines et al. 2009). While similar demographic data are not available for *Botrychium tunux* and *Botrychium yaaxudakeit,* the possibility of natural extirpation of the California occurrences of these 3 species over time should be considered. Because of these typical population dynamics, the California occurrences of these rare *Botrychium* spp. should be monitored frequently, and surrounding lands with potential habitat should be surveyed and managed for the potential colonization of spores to form new populations (Clines et al. 2009).~~

Background on *Botrychium paradoxum*

Botrychium paradoxum is known from British Columbia, Canada, to as far south as Utah and California, and as far east as Colorado. It is included in the *Flora of North America* (available online at http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=233500289) and *The Jepson Manual, Second Edition* (*TJM 2*; available online at http://ucjeps.berkeley.edu/cgi-bin/get_IJM.pl?tid=15939), but not *The Jepson Manual* (1993). It is a tetraploid species (n=90) derived from a hybridization event between two diploid parents, ~~both~~ one of which may be extinct (Clines ~~2009~~ et al. 2011, Hauk 1995). Although most *Botrychium* spp. are cryptic, *B. paradoxum* is one of the easiest species in the genus to recognize as its trophophore has been converted into an identical second sporophore, whereas all other members of the genus contain a trophophore and sporophore on the single leaf (Wagner and Wagner 1981). Occasionally, other *Botrychium* spp. will produce a spore-bearing trophophore, but the two leaf segments are generally not identical (Farrar 2011). Specimens resembling *B. paradoxum*, especially those occurring outside of its known range, should undergo genetic testing to confirm their identity. In part of its range in Canada, it hybridizes with *Botrychium hesperium* to produce a sterile (but possibly vegetatively-reproductive) hybrid *Botrychium x watertonense*, which is intermediate between the two parents in morphology (Wagner and Wagner 1984, Ahlenslager and Lesica 1996). Two distinct genotypes of morphologically-similar *Botrychium paradoxum* are currently known, and often co-occur. Although the genotypes may have different origins, it is more likely that one of the genotypes is a hybrid with another *Botrychium* sp. (Farrar 2011). More research is needed to understand this infraspecific variation. Aboveground sporophytes of *B. paradoxum* have been observed with sporangia in August in California.

Botrychium paradoxum occurs in upper montane coniferous forest and alpine boulder and rock fields. It is found on vegetated talus slopes below rare outcroppings of limestone and marble at the alpine site. At the upper montane site, it is found along a small ephemeral drainage, and is closely associated with *Calocedrus decurrens*, which can apparently favorably modify the habitat for rare *Botrychium* spp. (Clines et al. 2011~~2009~~). In California, *B. paradoxum* occurs between 1,740 and 4,200 meters.

Botrychium paradoxum is known from at least two ~~three~~ occurrences in California. The first California occurrences were found by Allison Colwell in Madera and Tuolumne Counties, in or near Yosemite National Park, and have been confirmed through genetic testing by D. Farrar (date unknown; Clines et al. 2011~~2009~~). ~~A voucher of *B. paradoxum* had been previously collected in 1939 (*Sharsmith 4132*; California Natural Diversity Database – CNDDB EO #4) but labeled as *Botrychium lunaria*.~~ A third occurrence, consisting of a single aboveground sporophyte, was found by CNPS Rare Plant Treasure Hunt volunteers in the El Dorado National Forest in August of 2011, and is awaiting genetic testing by D. Farrar (scheduled for either ~~January or~~ June 2012). Collection of the aboveground leaf after spore dispersal is not known to harm individuals or populations of *Botrychium* spp., so collecting the single specimen is unlikely to have damaged the population (Clines et al. 2011~~2009~~, D. Farrar pers. comm. 2011). More potential habitat exists near the upper montane population, and potentially near the alpine population, so more surveys should be conducted nearby.

Botrychium paradoxum is widely distributed, but uncommon throughout its range. It is Critically Imperiled (S1; generally < 5 occurrences) in Idaho, Oregon, Utah, Wyoming and three Canadian provinces (Alberta, British Columbia, Saskatchewan); it is Imperiled (S2; generally 5-20 occurrences) in Montana and Washington (NatureServe 2011), and is not yet ranked in Colorado (D. Farrar pers. comm. 2012). However, given its broad distribution, *Botrychium paradoxum* is not particularly threatened or rare overall (D. Farrar pers. comm. 2011).

No threats are currently known for the alpine population, but the upper montane population is potentially threatened by the alteration of the site's hydrology as a result of logging activities (S. Durham pers. comm. 2011). Based on the available information, CNPS and CNDDB recommend that *Botrychium paradoxum* be added to California Rare Plant Rank 2.1 of the CNPS Inventory.

Recommended Actions
CNPS: Add *Botrychium paradoxum* to CNPS 2.1
CNDDB: Add *Botrychium paradoxum* to G3G4 / S1

Draft CNPS Inventory Record
Botrychium paradoxum W.H. Wagner
paradox moonwort
Ophioglossaceae

Rank 2.1
El Dorado, Madera, Tuolumne
Colorado, Idaho, Montana, Oregon, Utah, Washington, Wyoming
Loon Lake (524A) 3812083
Alpine boulder and rock fields (limestone and marble), Upper montane coniferous forest (moist, ~~associated with *Calocedrus decurrens*~~); elevation 1740 – 4200 meters
Perennial rhizomatous herb. Fertile in August.
Discovered in California by Alison Colwell in the vicinity of Yosemite NP. Potentially threatened by hydrological alterations caused by logging activities. Easy to identify due to two nearly identical sporophores and no trophophore; other *Botrychium* spp. will occasionally produce a spore-bearing trophophore, but the two leaf segments are generally not identical. Not in *The Jepson Manual* (1993). See *American Fern Journal* 71(1):20-30 (1981) for original description, and 85(4):375-394 (1995) for taxonomic treatment.