Plant Species Evaluation Form

Moneses uniflora A.Gray

WOOD NYMPH

Family: Ericaceae (CNPS 2018) | **PLANTS Symbol:** MOUN2 (USDA 2018) | **Calif. Endemic:** No (CNPS 2018)

Synonyms/Other Names: Originally described from European material by Linnaeus in *Species Plantarum* (1753) as *Pyrola uniflora*. S.F. Gray described the genus *Moneses* (1821), attributing the name to R.A. Salisbury, and therein placing one species, *M. grandiflora*. Thomas Nuttall described *Moneses reticulata* from Oregon material (1843), distinguishing it from the European and eastern North American species by its more strongly toothed leaves, with elevated (as opposed to depressed) venation. *Moneses grandiflora* shortly thereafter underwent a name change to *M. uniflora* (Gray 1848). S.F. Blake (1915) asserted Nuttall's distinguishing traits were actually population variants occasionally present in all regions, and reduced the taxon to *M. uniflora* var. *reticulata* (Nuttall) S. F. Blake. Calder and Taylor (1965) restored subspecies status to the western plants, but without explanation, and their concept did not become widely recognized, although Nevada Natural Heritage Program currently lists both *M. uniflora* and *M. uniflora* subsp. *uniflora* as rare (NNHP 2018). Modern authors treat *Moneses uniflora* as one species worldwide, and treatments currently do not recognize subspecies for that species. Additional synonyms (not discussed here) that formerly applied in Eurasia come under this name as well (Tropicos 2018; ITIS 2017).

Identification Issues: This small forest floor plant is superficially similar to its relatives *Pyrola* and *Orthilia*, with which it may co-occur. These three genera all have leaves clustered on the lower part of one or more short stems, a portion of which terminate in a delicate, short, flowering scape. Although *M. uniflora* most closely resembles *Pyrola* and *Orthilia*, it is most closely related to the more prominently cauline-leaved, multiply pink-flowered *Chimaphila*. *Moneses uniflora*, true to its name, is easily distinguished from all of its sympatric relatives from the scape bearing a single, large (relative to the size of the plant), fragrant, white (sometimes pink-veined) flower. In addition, *M. uniflora*, unlike its look-alikes in North America, has a prominently 5-lobed stigma.

Taxonomy:

The following description is from the Flora of North America North of Mexico (Freeman 2009).

Etymology: Greek monos, one, single, and hesis, delight, alluding to its attractive, solitary flower Notes: Most chromosome counts are 2n = 26; there are reports of 2n = 22, 24, and 32 (Á. Löve and D. Löve 1975b). The veracity of the latter reports has not been confirmed. Moneses uniflora has been used by different Native American tribes as a dermatological aid, cold remedy, throat aid, and analgesic (D. E. Moerman 1998). Species in Genus; 1. Herbs, chlorophyllous, autotrophic. Stems erect, glabrous or papillose distally. Leaves cauline, sometimes appearing basal, alternate or pseudoverticillate in 1-4 whorls; petiole present; blade not maculate, broadly

elliptic to orbiculate, subcoriaceous, margins crenate-serrate to serrate, plane, surfaces glabrous. Inflorescences solitary flowers, not lax in bud or flower, erect in fruit; peduncular bracts present or absent. Pedicels absent. Flowers radially symmetric, spreading or nodding; sepals 5, connate proximally, often obscurely so, calyx lobes ovate to narrowly ovate; petals 5, distinct, creamy white, without basal tubercles, corolla rotate to broadly campanulate; intrastaminal nectary disc absent; stamens 10, included; filaments broad proximally, gradually narrowed medially, slender distally, glabrous; anthers oblong, without awns, with tubules, dehiscent by 2 round pores; pistil 5-carpellate; ovary imperfectly 5-locular; placentation intruded-parietal; style (exserted), straight, expanded distally; stigma 5-lobed, without subtending ring of hairs. Fruits capsular, erect, dehiscence loculicidal, no cobwebby tissue exposed by splitting valves at dehiscence. Seeds ca. 1000, fusiform, winged. x = 11, 12, 13, 16.

Species description: Plants arising from horizontal roots, 0.3-3 dm. Leaves: petiole 5-20(-30) mm, channeled adaxially, glabrous; blade dull and light green abaxially, shiny and green adaxially, 6-22 × 5-20 mm, base rounded to obtuse, apex obtuse to rounded. Inflorescences: peduncle 3-15 cm; peduncular bracts absent or 1(-2), oblanceolate to elliptic or orbiculate, (2.5-)4-4.5 × (2-)2.7-3.4 mm, membranous, margins entire or obscurely erose-denticulate. Flowers: calyx lobes spreading or reflexed in fruit, green or green with margins whitish green, 2-2.5 × 1.5-2 mm, margins erose-denticulate, apex rounded to obtuse; petals ovate to broadly ovate, 8-12 × 4-8 mm, margins minutely denticulate; stamens 4-8 mm; filament base 0.4-0.8 mm wide; anthers 2.2-2.5 mm, thecae whitish yellow to tan or light brown, tubules golden brown to brown, 0.4-0.8 mm, abruptly narrowed from thecae, lateral walls not touching, pores 0.2-0.4 × 0.2-0.4 mm; ovary smooth; style 2-5 mm; stigma 1.4-3.5 mm wide, lobes erect. Capsules subglobose, 4-8 × 5-9 mm. 2n = 22, 24, 26, 32

Status:

Note: Federally recognized Endangered, Threatened, Proposed, or Candidate species under the Endangered Species Act are omitted as they do not meet the definition of a Species of Conservation Concern (FSH 1909.12 § 12.52).

State Listing	G-rank	S-rank	CRPR	R5 FSS	NFP SM	CA BLM
CA: Not listed NV: Not listed OR: Not listed	G5	CA: S2 NV: SNR OR: Not listed	2B.2	Not listed	Not listed	Not listed

SWAP:	NNHP:	NNPS:	ORBIC:	OCS:	IUCN:
Not listed	Not listed	Not listed	Not listed	Not listed	Not listed

Expanded abbreviations and citations: State Listing=California Endangered Species Act Listing (CDFW 2018b), Nevada Division of Forestry Fully Protected Plant Species (NAC 527) (NDF 2012), Oregon Department of Agriculture Listed Plants (ODA 2014); G-rank=Global Conservation Status (CDFW 2018a; NatureServe 2018); S-rank=Subnational (state or province-level) Conservation Status (CDFW 2018a; NatureServe 2018; NNHP 2017; ORBIC 2016); CRPR=California Rare Plant Rank (CNPS 2018); R5 FSS=USDA Forest Service Region 5 Regional Forester Sensitive Plant Species List (USDA 2013); NFP SM=Forest Service and Bureau of Land Management Northwest Forest Plan Survey and Manage Species (USDA 2001); CA BLM=California Bureau of Land Management Designated Sensitive Species (BLM 2010); SWAP=California State Wildlife Action Plan Status (CDFW 2015); NNHP=Nevada Natural Heritage Program Status (NNHP 2017); NNPS=Nevada Native Plant Society Status (NNHP 2017); ORBIC=Oregon Biological Information Center Status (ORBIC 2016); OCS=Oregon Conservation Strategy Species (ODFW 2016); IUCN=International Union for Conservation of Nature Red List Status (IUCN 2017).

Moneses uniflora has been included in the CNPS *Inventory* since the 6th Edition (RPSAC and Tibor 2001). It was originally given California Rare Plant Rank (CRPR) of 4.3 (Watch list; threat

rank low), based on limited occurrence information and limited communications with botanists. In the following decade, since few additional locations had been reported, and two locations of previous collections were surveyed in 2011-12 (EO 4 & 6) with no plants found, it was considered for re-ranking in 2013. Based on new information gathered, CNPS and CNDDB re-ranked *Moneses uniflora* from CRPR 4.3 to 2B.2 (rare, threatened or endangered in California, common elsewhere; threat rank moderate) in February of 2013 (CNPS 2018; CNDDB 2017; Slakey et al. 2013).

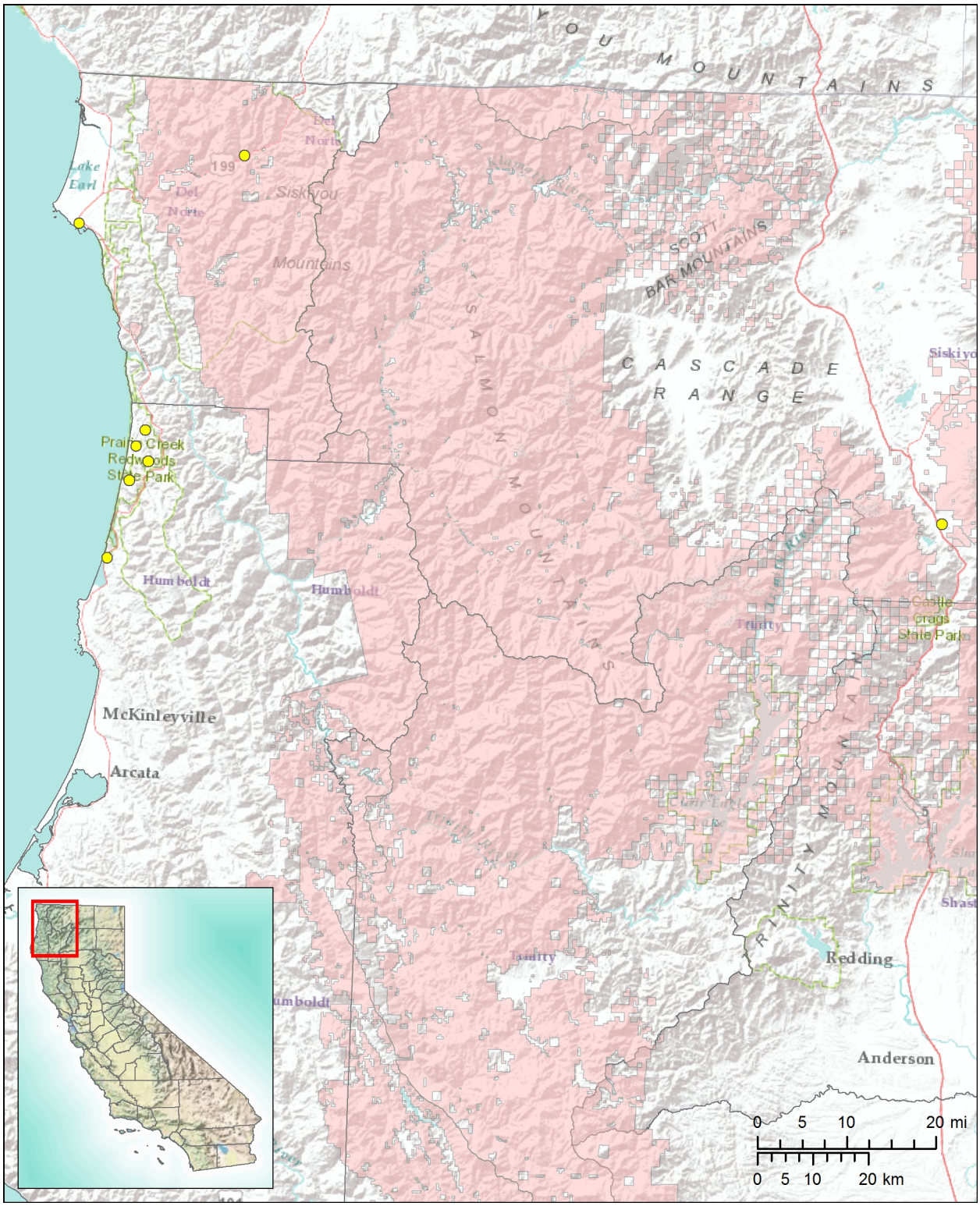
Distribution: Globally, *Moneses uniflora* is circumpolar in boreal montane habitats, with its main center in north-central Europe and Scandinavia. In Asia, it extends southward into India and Japan, and in Europe into Spain. In the UK it occurs in a few sites in Scotland (BRC 2018).

Records from herbaria (CNH 2018; CPNWH 2018) indicate a robustly populated distribution from the Brooks Range in central Alaska southward along the Canadian Rockies, with its presence becoming sparser in Wyoming and Colorado. The southernmost record is on the north side of Wheeler Peak in northern New Mexico. *Moneses* ranges eastward across Canada to Hudsons Bay, including the states and provinces north and south of the Great Lakes and into to the Maritime provinces of Canada and New England, where it has been more frequently collected. Along its southern border, in Ohio, Rhode Island, and Connecticut, it is listed as critically imperiled and in Massachusetts as imperiled (NatureServ 2017). *Moneses* also has a coastal (Pacific Rim) distribution, on the west side of Cascade Ranges, appearing frequently as specimen records from southeast Alaska and Kodiak Island, southward through the coastal ranges and islands of southeast Alaska, British Columbia, Puget Sound, and Oregon, reaching its southernmost distribution in the northwest corner of California where the coastal rainforest reaches its current southernmost extent.

In summary, *Moneses uniflora* is widely but intermittently distributed. It is abundant in some locations, sparse in others, and this distribution may reflect a limitation imposed by host fungus and the distribution of tree species associated with that fungus, these hosts varying over its circumboreal range (Hynson 2015). For instance, the distribution of *Moneses* within California, in the coastal rainforests from the Oregon border southward to Eureka, appears to be entirely within the distribution of the associated host tree species confirmed in Puget Sound (Hynson 2015), *Picea sitchensis*, although *P. sitchensis* also has an outlying population south of the southernmost known population of *Moneses* in the Fort Bragg area.

There are two specimen records for *Moneses* in California that lie outside of *P. sitchensis* range, and which are in need of verification. Element Occurrence one (EO 1) is derived from an unsubstantiated J.G. Lemmon collection titled “City of Mt. Shasta”, which has no date or corroborating information. Element Occurrence two (EO 2) is based on a 1969 collection by Ruby VanDeventer “near Patrick’s Creek Inn”, which is still in business on Route 199 east of Gasquet, but no other observations have been documented in the vicinity, and no *Picea* spp. occur on the Smith River east of Hiouchi (Michael Kaufmann pers. comm. 2018). The VanDeventer specimen (JEPS60166) is distinct from the coastal California collections in that it has the round, blunt-toothed leaves of the inland/eastern U.S. form (= S.F. Gray’s *M. grandiflora*). Lastly, a report of a *Moneses* occurrence in Fresno County listed in *The Jepson*

Manual (TJM 1993; TJM2 2012), was discounted after extensive information gathering from local botanists during the CNPS rank cange review (Slakey et al. 2013).



Sources: *Distribution*: Calflora 2017, CCH 2017, CNDDB 2017. *Layers*: USDA Forest Service, Pacific Southwest National Forests: CPAD 2016. California counties: CDF 2009. *Basemaps*: California inset map: © 2013 National Geographic Society, i-cubed (Esri 2017a). Main map: Esri, DeLorme, USGS, NPS (Esri 2012) and Esri, USGS, NOAA (Esri 2017b).

Locations within California:

Record numbers indicate sites that contain an individual, population, or groups of populations located within ¼ mile of each other, per the California Natural Diversity Database (CNDDB 2017) definition of Element Occurrences (EOs) in California. Official EO numbers for plants in California are determined solely by the CNDDB and are included within the Reference (Source) column for CNDDB data. Duplicate records from the same site are given the same record number and included in red. The Population Info column includes total number of individuals and total number and size of populations/sub-populations when provided. Elevations provided in meters from source have been converted to feet. If not provided in original source, Land Manager information was obtained using the California Protected Areas Database (CPAD 2016) and Quad information was obtained using 24K Quads, SDE Feature Class (CDFG 2013). All other information is directly from the Reference (Source) unless additional citation is given.

Rec. #	Locality	County	Quad	Reference (Source)	Date Last Observed	Population Info	Threats	Land Manager	Elev. (ft.)
1	SISSON, NEAR MT SHASTA.	Siskiyou	City of Mount Shasta (4112233)	CNDDB, May 2017 (EO 1)	Unknown	ONLY SOURCE OF INFORMATION FOR THIS OCCURRENCE IS AN UNDATED COLLECTION BY LEMMON. NEEDS FIELDWORK.		Unknown	
2	NEAR PATRICK'S CREEK INN.	Del Norte	Hurdygurdy Butte (4112377)	CNDDB, May 2017 (EO 2)	16-Jun-1969	ONLY SOURCE OF INFORMATION FOR THIS OCCURRENCE IS A 1969 COLLECTION BY VANDEVENTER. NEEDS FIELDWORK.		Six Rivers NF	850
2	near Patrick's Creek Inn	Del Norte	Shelly Creek Ridge (4112387)	CCH, Jan 2017 (JEPS60166)	16-Jun-1969			Six Rivers NF	850

Rec. #	Locality	County	Quad	Reference (Source)	Date Last Observed	Population Info	Threats	Land Manager	Elev. (ft.)
3	BETWEEN BIG LAGOON AND DRY LAGOON, APPROXIMATE-LY 1.7 AIR MILES S OF SHARP POINT, W OF MCDONALD CREEK.	Humboldt	Rodgers Peak (4112421)	CNDDB, May 2017 (EO 3)	29-May-2012	500-1000 PLANTS OBSERVED IN 2012.	FUTURE TRAIL MAINTEN-ANCE MAY IMPACT PLANTS GROWING RIGHT ALONG THE TRAIL.	DPR-Harry A Merlo SRA	500
3	Azalea Nature Tr -- Stagecoach Hill Azalea Res.	Humboldt	Rodgers Peak (4112421)	Calflora, May 2017 (wb1194-2293)	2-Jul-2013	1+ individuals		Humboldt Lagoons SP	499
4	JAMES IRVINE TRAIL, NEAR HEADQUARTER S OF PRAIRIE CREEK REDWOODS STATE PARK.	Humboldt	Orick (4112431)	CNDDB, May 2017 (EO 4)	15-Jul-2011	MAIN SOURCE OF INFO IS 1972 WALLACE COLLECTION. 1926 KILDALE COLLECTION FROM "TRAIL TO GOLD BLUFFS" AND 2011 COX PHOTO FROM FERN CYN ALSO ATTIB HERE. NO PLANTS FOUND BY BARRETT NEAR HQ IN 2011-2012, SO 2011 COX OBS MAY HAVE BEEN FURTHER NW.		DPR-Prairie Creek Redwood SP	180
4	Trail to Gold Bluffs	Humboldt	Orick (4112431)	CCH, Jan 2017 (DS160956)	6-Jun-1926			Prairie Creek Redwoods SP	

Rec. #	Locality	County	Quad	Reference (Source)	Date Last Observed	Population Info	Threats	Land Manager	Elev. (ft.)
4	Prairie Creek Redwoods St. Pk. near park Hq.	Humboldt	Fern Canyon (4112441)	CCH, Jan 2017 (RSA257008)	30-Jun-1972			Prairie Creek Redwoods SP	
5	S OF ROAD TO FERN CANYON.	Humboldt	Orick (4112431)	CNDDB, May 2017 (EO 5)	19-Jun-1973	ONLY SOURCE OF INFORMATION FOR THIS OCCURRENCE IS A 1973 COLLECTION BY IRWIN. NEEDS FIELDWORK.		NPS-Redwood NP	
5	S of road to Fern Canyon	Humboldt	Orick (4112431)	CCH, Jan 2017 (HSC26743)	19-Jun-1973			Redwood NP	
6	PRAIRIE CREEK, NORTHERN COAST RANGES.	Humboldt	Fern Canyon (4112441)	CNDDB, May 2017 (EO 6)	22-May-1926	ONLY SOURCE OF INFORMATION FOR THIS OCCURRENCE IS A 1926 COLLECTION BY TRACY. NO PLANTS FOUND DURING 2011-2012 SURVEYS BY BARRETT ALONG PRAIRIE CREEK NORTH OF ELK MEADOW.		DPR-Prairie Creek Redwood SP	500
6	Northern Coast Ranges, Prairie Creek Prairie Creek; Northern Coast Ranges, Prairie Creek	Humboldt	Orick (4112431)	CCH, Jan 2017 (JEPS13817)	22-May-1926				499

Rec. #	Locality	County	Quad	Reference (Source)	Date Last Observed	Population Info	Threats	Land Manager	Elev. (ft.)
6	Northern Coast Ranges, Prairie Creek Prairie Creek; Northern Coast Ranges, Prairie Creek	Humboldt	Orick (4112431)	CCH, Jan 2017 (UC314640)	22-May-1926				499
7	REDWOODS NEAR CRESCENT CITY.	Del Norte | Pacific Ocean	Crescent City (4112472)	CNDDB, May 2017 (EO 7)	11-Aug-1923	ONLY SOURCE OF INFORMATION FOR THIS OCCURRENCE IS A 1923 COLLECTION BY EASTWOOD. NEEDS FIELDWORK.		Unknown	
7	Redwood near Crescent City	Del Norte	Crescent City (4112472)	CCH, Jan 2017 (CAS43521)	11-Aug-1923				
8	Old growth redwood forest adjacent to trail. Visible along edges of trail in canyon. Observed upslope from trail in most cases.	Humboldt	Fern Canyon (4112441)	Calflora, May 2017 (oe5366)	19-Jun-2013	11 - 50 individuals		Prairie Creek Redwoods SP	180

Distribution on National Forest System (NFS) Lands:

(Please see Reference column of Locations table above for references pertaining to Record Numbers indicated on NFS lands.)

National Forest System (NFS) lands	Record #s (from Locations table above)	CNDDB EOs	Non-CNDDB Records	Recent (seen in past 20 yrs.)	Historic (not seen in past 20 yrs.)	Most Recent Obs.	EOs/ Recs. (5 mile buffer)	Total Records on NFS lands
Angeles:	-	-	-	-	-	-	-	0
Cleveland:	-	-	-	-	-	-	-	0
Eldorado:	-	-	-	-	-	-	-	0
Inyo:	-	-	-	-	-	-	-	0
Klamath:	-	-	-	-	-	-	-	0
Lake Tahoe Basin MU:	-	-	-	-	-	-	-	0
Lassen:	-	-	-	-	-	-	-	0
Los Padres:	-	-	-	-	-	-	-	0
Mendocino:	-	-	-	-	-	-	-	0
Modoc:	-	-	-	-	-	-	-	0
Plumas:	-	-	-	-	-	-	-	0
San Bernardino:	-	-	-	-	-	-	-	0
Sequoia:	-	-	-	-	-	-	-	0
Shasta-Trinity:	-	-	-	-	-	-	-	0
Sierra:	-	-	-	-	-	-	-	0
Six Rivers:	2	1	0	0	1	16-Jun-1969	0	1
Stanislaus:	-	-	-	-	-	-	-	0
Tahoe:	-	-	-	-	-	-	-	0
Totals:	N/A	1	0	0	1	N/A	0	1

Demographic and Population Trends: *Moneses uniflora* is a perennial species, is evergreen and propagates vegetatively, forming multi-stemmed clones (Klimesova 2007), so it is not expected to have notable fluctuations in population sizes or visibility across seasons or between years. It is an attractive plant, with relatively large flowers highly visible in its shaded, mossy forest floor habitat, so it is unlikely to have been significantly overlooked (BRC 2018). Therefore, that there are only potentially seven confirmed extant locations in California (CNDDB 2017), indicates that this species is both very rare and has a very small range in California.

Population sizes are not well understood in the California portion of *Moneses'* range. Population sizes may be overestimated if surveyors mistake each leafy stem for an individual, rather than each cluster of adjacent leafy stems potentially deriving from a clone. Population sizes will be underestimated by a certain amount because juveniles are undetectable underground for an unknown number of years. Only two of the approximately eight occurrences have any population size information: EO 3 (Harry A. Merlo State Recreaton Area) reports a large population of 500-1,000 plants in 2012, and EO 8 (Prairie Redwoods State Park) reports a small population of 11-50 individuals in 2013 (CNDDB 2017). Population trends are also not well known in California, as only two sites of older collections (EOs 4 and 5) had a targeted re-survey done in 2011-2012 (P. Barrett, pers. comm 2013, from Slakey et al. 2013). In the case of EO 4 (Prairie Creek Redwoods SP), collections in 1926, 1972, and a photo in 2011 indicate the presence of a stable population, but the population could not be located in 2011-2012; athough the cause could have been failed relocation or extirpation. That this charismatic little plant has only had two additional reported locations turn up in recent decades, despite awareness of its rarity by local botanists, prompted its re-ranking from CRPR 4 to 2B in 2013 (Slakey et al. 2013).

Trends in habitat quality are not well known for California populations. The occurrence rank (habitat quality and condition of population) for all seven CNDDB occurrences is listed as unknown. Six of the eight occurrences are on public lands, one in Redwoods National Park, three in Prairie Creek Redwoods State Park, and one in Harry A. Merlo State Recreation Area. The location of the sixth, presumed in Six Rivers NF, is unknown so its protection is less assured.

Life History: *Moneses* produces a single capsule per leafy shoot, but that capsule produces many seeds (Johannson et al. 2014 found samples from Sweden to average 7,324 seeds per capsule; Knudsen and Olesen (1993) found samples from Sweden to have a mean of 9,750 seeds per capsule). These seeds are characterized as 'dustlike' because they measure less than a millimeter in length and about 1/10th of a millimeter in diameter. This seed type is one of several features characteristic of a parasitic life strategy. The other characteristic traits found in this species are loss or redistribution of plastid genes (Braukmann and Stefanovic 2012) and extreme specificity for a particular species of mycorrhizal fungus (Bitartondo and Bruns 2005; Hynson et al. 2015). *Moneses* as an adult has green leaves, and produces most of its own carbon compounds through photosynthesis (Hynson et al. 2015), so is characterized as a partially mycoheterotrophic or myxotrophic species, as it relies on nutrients obtained through a fungal host for a part of its lifecycle: seed germination through emergence (Johansson et al. 2014). This plant is therefore highly dependent on a particular ectomycorrhizal fungus host and its mutualist plant partner. In western North America, *Tylophora fibrillosa*, and a related unidentified *Tylophora* species have been shown to be a fungal host and its mutualist partner has been shown to be *Picea sitchensis* (Hynson et al. 2015). According to specimen label data, *Moneses* also associates with *Picea engelmannii* throughout that species' range (CPNWH 2018), but the mycorrhizal fungus associate connecting the two has not been studied.

Moneses is a perennial herb, and may spend several years underground as a seedling parasite on its fungus (Johansson and Eriksson 2013). Once it emerges as an adult, it spreads vegetatively through adventitious shoots sprouting from its horizontal roots. This type of sprouting is unusual

and characteristic of mycoheterotrophic plants. The shoots are polycyclic, in that each may flower for multiple years (Klimesova 2007) and are green throughout the year (BRC 2018). No studies have come to light on the longevity of adult individuals of *Moneses*.

Knudsen and Tollsten (1991) found that *Moneses* has scented flowers, containing isoprenoids and benzenoids, dominated by citronellol, which function for attractant at a distance, but also may support foraging in buzz-pollinator species by facilitating orientation on the flower. The scent of *Moneses* differs chemically from co-occuring *Pyrola* species, likely enhancing species recognition and therefore foraging efficiency in pollinators. The nodding flowers and poricidal anther sacs (Knudsen and Olesen 1993) are classic anatomical adaptations to the buzz pollination syndrome. The flower of *Moneses* was observed to last an average of 16.4 +/- 3.5 days, and blooms June-July in northern Europe (Knudsen and Olesen 1993), and May to August in California (CNPS 2018).

Moneses, Orthilia, and *Pyrola* are also the alternate hosts of inland spruce cone rust fungus (*Chrysomyxa pyrolae*), one of the main diseases of western North American spruce, and which causes serious cone loss on several spruce species (white spruce, Engelmann spruce, Sitka spruce) in British Columbia (Peterson et al. 1997), and impacts *Picea* spp. seed germination (Tedersoo et al. 2007). *Moneses* is the sole telial host of coastal spruce cone rust (*Chrysomyxa monesis*). This rust fungus will cause cone rust when Sitka spruce occur in the presence of *Moneses*. According to Peterson et al. (1997), *Moneses* also carry the fungus where spruce do not occur. A recent analysis of four DNA sequence loci of *Chrysomyxa* and relatives, confirms the derived relationship of *Chrysomyxa monesis* from *Chrysomyxa pyrolae* (Feau et al. 2011). Through this fungal interaction and the myxotrophic on described above, *Moneses*, despite its low biomass, may be an important driver of forest dynamics, competition and biodiversity interactions (Tedersoo et al. 2007).

Diversity: *Moneses uniflora* has been included in several phylogenetic analyses of the Pyrolaceae, either as a single accession from Canada (Braukmann and Stefanovic 2012), or with two accessions, from Michigan and China (Liu et al. 2010). The results are consistent: *Moneses* accessions are very similar to each other, their closest relative is *Chimaphila*, and this pair nests in a clade with *Pyrola* and *Orthilia*, which is itself sister to the clade containing the nonphotosynthetic, fully mycotrophic species. Notably, relative to its sister *Chimaphila*, the plastid genome of *Moneses* has lost several ribosomal protein genes and several subunits of the ndh complex (electron transport in thylakoid membranes of the photosynthetic apparatus), thought to be a first step on the path to obligate heterotrophy (Braukmann and Stefanovic 2012).

Hynson et al. (2015) tested populations of *Moneses* from Olympic Peninsula, Washington (*Picea sitchensis*/*Tsuga heterophylla* rainforest), Scotland (*Pinus sylvestris, Betula, Fagus, Larix* forest) and Sweden (*Picea abies* forest) for host species fungus identity and for degree of enrichment for 13C and 15N (a measure of the degree of fungal host feeding). They found that the roots of all *Moneses* samples were associated only with members of the fungal family Atheliaceae, with a high degree of host specificity per region. Hynson et al. (2015) also found the *Moneses* tissue samples were somewhat enriched for 15N, revealing that *Moneses* utilizes nitrogen supplied by the fungal host. Interestingly, the European populations sampled parasitized only *Amphinema*

species and showed no enrichment for 13C and the Washington populations parasitized only *Tylospora* species and showed moderate enrichment for 13C, meaning that at least some of their carbon is also sourced from their fungal host. This suggests that the Washington populations of *Moneses* have a more strongly parasitic relationship on their fungal hosts, perhaps in response to localized selection pressure placed upon them by the wetter, darker environment they inhabit (Hynson et al. 2015). They also differ in their host fungus and host tree species, suggesting a distinct evolutionary trajectory. Unfortunately, despite these tantalizing differences in host preference and feeding dependence within *M. uniflora*, no intraspecific genetic studies over the circumboreal range of this species have been done to date (Stefanovic pers. comm. 2018).

Habitat: Hynson (2015) found that *Moneses* inhabits somewhat varied environments over its range. She describes three typical habitats used in her study thus: 1) In the Pacific Northwest, *Moneses* occupies temperate rainforest vegetation dominated by dense *Tsuga heterophylla* and *Picea sitchensis* canopies with 343 cm of average precipitation annually, one of the wettest regions on earth. All sampling sites were old growth forests (>100 yr old) with dark shaded understories. 2) *Moneses* in study sites in Scotland receive 98.5 cm average annual precipitation in open, 100-yr-old Scots pine forests (*Pinus sylvestris*) mixed with silver birch (*Betula pendula*), beech (*Fagus sylvatica*) and larch (*Larix decidua*). 3) The study site in northern Sweden is a forest and bog region dominated by spruce (*Picea abies)* with a diversity of mosses and herbs in the understory. This area has an average of 49.87 cm of precipitation a year. BRC (2018) provides additional habitat information for Scotland: in ericaceous dwarf shrub communities under remnant native stands *Pinus sylvestris* native forest and in old pine plantations, among leaf litter and bryophytes.

In western North America, *Moneses uniflora* is frequently reported to co-occur with *Picea sitchensis* and *P. engelmannii* on herbarium specimens. In Alaska and northern Canada, the frequently mentioned associate shifts to *Picea glauca* (CCH 2018; CPNWH 2018). *Picea sitchensis* occurs in the Pacific Rim rainforests west of the Cascade Ranges, from Kodiak Island through Alaska, British Columbia, Puget Sound south to Capetown in California, with an outlying population near Fort Bragg. In contrast, *P. engelmannii* occurs in drier inland forests in the Rocky Mountains from British Columbia south to Utah and Colorado, but only east of the Cascade Mountains, with two outlying populations in the Klamath Mountains of California (CCH 2018; CPNWH 2018).

Goldsworthy (2017, 2018) reports that, in the single occurrence on Green Diamond Resource Company land (submitted to the CNDDB database in 2017) and in reference plots on public land in Del Norte County, *Moneses* is associated only with *Picea sitchensis* forests and occurs in the understory of this species, or if in redwood forest, there are *Tsuga heterophylla* and *Picea sitchensis* present as canopy associates. She does not discount that it might also associate with *Tsuga heterophylla* via a fungal host.

In California, *Moneses* occurs from 100-1,100 meters elevation (CNPS 2018). Elsewhere in its range, herbarium records indicate that this species occupies coastal low elevation environments over a wide range of latitudes, although inland, it occurs in increasing elevation with decreasing latitude (CPNWH 2018; CNH 2018). *Moneses* appears consistent in its microhabitat

requirements throughout its circumboreal range: moist forests and bogs (Freeman 2007), with additional detail provided by herbarium specimens: seasonally wet meadows, forested meadow borders or moist microsites within a forest understory, such as adjacent to drainages, in riparian zones or among moss-covered boulders. It is frequently mentioned as occurring in leaf litter and among moss. The associates mentioned (besides *Picea* spp.) are also associated with wetlands: especially *Populus* spp., *Pinus contorta, Salix* spp., and *Carex* spp. Other Ericaceae such as *Vaccinium* spp., *Erica* spp., and *Orthilia secunda* are often mentioned as associates.

Habitat Status or Trend: Moola and Vasseur (2004) studied the recovery of late-seral plant species in forests with a series of times-since-clearcut. In their study, they found that *Moneses* was present only in late-seral stands (forests 100-165 years post-cut), even though it was present in low cover and frequency in adjacent uncut forest. They conclude that this species has an affinity for undisturbed habitat, and may have a limited dispersal ability (due to slow clonal expansion, limited seed dispersal, or a preference for old growth conditions in microhabitat). This study also suggests that this species is vulnerable to local extinction in forests managed for timber. Similarly, this species is known from old growth remnants and old pine plantations in Scotland (BRC 2018).

Moneses inhabits spruce forests throughout the boreal region, an ecological community of vast proportions, much of which is sparsely inhabited and/or lightly used by humans. However, *Picea* species, on which *Moneses* is dependent for part of its lifecycle, are vulnerable to outbreaks of predators, and climate change has exacerbated that threat. Spruce bark beetle (*Debdrioctonus rufipennis*) has caused areas of severe mortality in the western US and elsewhere. Temperli et al. (2015) reviewed the literature on these outbreaks and modeled the future of spruce populations under various climate change scenarios. Their results indicate that spruce component in forests will decline with continued higher pressure by bark beetles, but that long term spruce populations will reach a new stability as a less frequent component of the forest canopy. What impact this may have on *Moneses* survival worldwide has yet to be studied.

In California, *Moneses* occurs in the corner of the state occupied by the southernmost tip of the Pacific lowland rainforest. This community type is vulnerable to climate drying and warming in the form of decline in summer fog, a moderating influence on both temperature and moisture (Johnstone 2010).

Capacity for the Species to Disperse: This species, like the other members of the Pyroleae tribe of Ericaeae, produces many thousands of "dust" seeds per capsule, which are tiny in size and thought to enhance the possibility of encountering the host fungus by saturating the soil with large numbers of seed. The results of Johansson et al. (2014) on dispersal ability of Pyroleae dust seeds (including *Moneses*) showed that the vast majority of seeds (82.5% of the total number of seeds deposited) were deposited close to the seed source, i.e. with a dispersal distance less than 1 m, and 95.7% were deposited within approximately 5 m from the seed source. However, Johannsson et al. (2014) did not study what happens to seeds that exceed a distance of 5 m, and they conclude that the high seed production in Pyroleae provides for a large number of seed to potentially travel long distance by wind or other means. Recent studies on the related species *Monotropa uniflora* (Uehara and Sugiura 2017) open the door to the possibility of long-distance

dispersal occurring by forest floor insect herbivores attracted to the fleshy tissue of the ripening capsules.

This species is self-compatible but not selfing (established by pollinator exclusion experiments on plants in Denmark) and is pollinated mainly by bumblebees via buzz pollination (Knudsen and Olesen 1993). Its pollen falls in tetrads, is low in number relative to its ovules (Johannson et al. 2014), and the flowers are strongly scented (Knudsen and Tollsten 1991); all characteristic of a highly efficient bee-moderated pollination system.

This species reproduces vegetatively, spreading by fine horizontal roots, with stems sprouting adventitiously from the roots (Klimesova 2007). Approximately 32% of stems were flowering in a given year (Knudsen and Olesen 1993).

A significant impediment to dispersal would be *Moneses'* requirement for a specific host fungus for germination. Although one host fungus (*Tylospora fibrillosa*) is characterized as common (Hynson et al. 2015), its absence may be a limiting factor in *Moneses* dispersal. Johansson and Eriksson (2013) found that, for *Moneses*, both seed and microsite were limiting factors in recruitment of plants in experimental plots.

Threats: Johansson and Eriksson (2013) note that *Moneses uniflora* is presently declining in Sweden. They attribute this to one or several factors: the loss of natural disturbance regimes in forest ecosystems may have increased the competition from other plants and made it less likely that *Moneses* contacts suitable host fungi, or that increased inputs of nutrients, both from agricultural sources as well as atmospheric downfall, may deprive this and related myxotrophic species of their advantage of being adapted to low nutrient levels. BRE (2018) data show this species occupies plant communities with the lowest nitrogen availability.

Monesis uniflora in western North America relies on two other species, an ectomycorrhizal fungus and its spruce host (Hynson et al. 2015). It is thus reliant on a stable tree population within its preferred climate envelope. Its distribution appears secure in some regions where host species and habitat are abundant, but its dependence on hosts is a concern for working forests, since little is known about resilience of mycorrhizal fungi to the type of disturbance caused by timber harvest. For example, BRC (2018) assign *Moneses* a vulnerable status in Britain, ascribable to timber management practices that increase light levels and dryness of forest floor. In Scotland, BRC states past declines were driven by overcollecting, and current declines are ascribable to changes in land use and forest management. BRC points out that this species is very difficult to propagate, so ex situ conservation is not a viable option.

Few specific threats are listed for the occurrences of *M. uniflora* in California. In two cases, plants along current or future trails are potentially affected (EO 4 and 5). Although not stated in the occurrences, the scarcity and geographic isolation of all occurrences in California makes genetic isolation a significant hurdle for survival of this species in California.

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Formatting: Form is set up as 508 compliant. Please use the "styles" if further formatting is necessary.

Purpose: This is to maintain the best available science on a species that could be used by the Forest Service in a variety of functions. Specifically, there would be additional steps and evaluations to determine whether or not this species would be considered a Species of Conservation Concern under the 2012 Planning Rule or a Sensitive Species under the 1982 Planning Rule.

Additional Considerations at the Forest Level: Habitat amount and juxtaposition of both the species and habitat locations.