

**Conservation Assessment
for *Meesia triquetra* (L.) Aongstr. (three-ranked hump-moss) and
Meesia uliginosa Hedwig (broad-nerved hump-moss) in California
with a focus on the Sierra Nevada Bioregion**

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I. Executive Summary

Project Purpose: The primary objective of this investigation is to determine the status of the mosses *Meesia triquetra* and *Meesia uliginosa* throughout California with a primary focus on the Sierra Nevada bioregion within the context of the species' global range. A conservation assessment provides the founding information to guide management and monitoring plan development.

Range: *Meesia triquetra* is a circumboreal moss. The species is well distributed in the Northern Hemisphere with scattered southern hemisphere locations as well. The world distribution includes Europe, Asia, Australia, Papua New Guinea, and Venezuela (Montagnes 1990). North American collections have been made from Alaska to northern California in the west and Labrador and Newfoundland south to Pennsylvania and Wisconsin in the east. A large number of Central and Western European populations are now extinct due to human activities (Odgaard 1988). In California, there were 74 occurrences with the majority in the Sierra Nevada Mountains since 1980.

Meesia uliginosa has a continuous circumboreal distribution, with disjunct occurrences in Tierra del Fuego, the Himalayas (Vitt 1992) and Antarctica (Ochyra and Lewis-Smith 1999). It has been described as having an Arctic-Boreal-Montane distribution. In North America it has been found widely across the United States, Canada and Greenland. There were 16 occurrences in California with the majority in the Sierra Nevada Mountains since 1980.

Specific Habitat: Rich Fens, which are wetlands with at least 40 cm of peat (organic soils) supplied with water from springs with moderate to high pH. It is found uncommonly in the temperate-alpine zones but it achieves the highest frequency in boreal-low alpine areas (Montagnes 1990; Odgaard 1988).

Threats: Modification of habitat, specifically hydrologic changes to fens that may cause drying. Roadside ditches and cattle trails that channel water and drain surface waters from fens have particular negative impacts to fen vegetation such as *Meesia triquetra* and *Meesia uliginosa*.

Conservation Considerations:

- 1) Maintain habitat for these species by retaining occupied substrate, hydrological conditions and associated stand and microsite conditions near the population.
- 2) Restrict activities that have the potential to alter hydrological conditions (ditching, draining or groundwater extraction) or affect occupied substrate (direct disturbance, addition of sediment).
- 3) Avoid disturbance of soil substrate associated with the plants. Do not exceed greater than 20% bare ground in fens (cattle grazing, recreation impacts).

II. Taxonomy, Biology and Habitat Information

A. Nomenclature and taxonomic description

Family: Meesiaceae

The family is represented by the genera *Leptobryum* and *Meesia*. The presence of several (often 3) basal red cells on the axillary hairs on upper stem of these costate, acrocarpous mosses is diagnostic for the family.

Genus: *Meesia*

Meesia is a small genus characterized by acrocarpous plants; relatively small, rectangular upper leaf cells; no differentiated alar cells; strong, single costa with well differentiated internal structure; very long, erect seta; dark-colored capsules with a long, erect neck abruptly bent to the somewhat wider, horizontal urn; and reduced peristome. The four circumboreal species, *M. hexasticha*, *M. longisetata*, *M. triquetra* and *M. uliginosa*, are differentiated by leaf shape and costal anatomy.

Scientific name: *Meesia triquetra* (L.) Aongstr.

Common name: Three-ranked hump-moss

Citation: *Meesia triquetra* (L.) Aongstr. Nov. Act. R. Soc. Sci. Upsal. 12:257. 1844.

Synonyms: *Mnium triquetrum* L. in Richter, Codex Bot. Linn. 1045. 1840.

Meesia tristicha Bruch, Flora 9: 165. 1826.

Meesia trifaria Crum, Steere & Anderson, Bryologist 68: 434. 1965.

Taxonomic description: *Meesia triquetra* can be distinguished from the other two North American species of *Meesia* by a distinct three-ranked leaf arrangement, acute leaf apices, denticulate leaf margins, and dioicous sexual condition (Montagnes 1990).

Scientific name: *Meesia uliginosa* Hedwig

Common name: broad-nerved hump-moss

Citation: *Meesia uliginosa* Hedwig Spec. Musc. 173. 1801.

Synonyms: *Meesia minor* Brid., Musc. Rec. 2(3): 168. 1803.

Meesia uliginosa var. *minor* (Brid.) Web. & Mohr, Bot. Taschenb. 374. 1807.

Meesia alpina Funck ex Bruch, Flora 9: 164. 1826.

Meesia uliginosa var. *alpina* (Bruch) Hampe, flora 20: 278. 1837.

Meesia trichodes Spruce, Musci Pyren. N. 147. 1847.

Taxonomic description: Ligulate, obtuse leaves with strongly revolute margins. The wide costa has inner cells larger than those near the edges (Vitt 1992).

B. Species Range and Distribution

Distribution of *Meesia triquetra*

Meesia triquetra is a circumboreal moss. The species is well distributed in the Northern Hemisphere. The world distribution includes Europe, from Spain north through France, the British Isles, Sweden, northern Norway, and east to Romania and northern European and Asian Russia. Elsewhere in Asia, collections have been made in Mongolia, northeastern China, and northeastern India. A small number of specimens have come from the higher elevations of southeastern Australia, central Papua New Guinea, and western Venezuela (Montagnes 1990). North American collections have been made from Alaska to northern California in the west and Labrador and Newfoundland south to Pennsylvania and Wisconsin in the east. It is found uncommonly in the temperate-alpine zones but it achieves the highest frequency in boreal-low alpine areas (See Figure 1, from Montagnes 1990; Odgaard 1988; Slack et al. 1990). Slack et al. (1990) reported that *Meesia triquetra*, although often not abundant, could almost always be found in extremely rich fens in Alberta with careful searching. A large number of Central and Western European populations are now extinct due to human activities (Odgaard 1988).

In California, there were 74 occurrences with the majority in the Sierra Nevada Mountains. The two historical occurrences outside of the Sierra Nevada Mountains both appear to be extirpated. There is one extant record in the San Jacinto Mountains in the State Park wilderness. A large proportion of the occurrences are in the southern Sierra Nevada Mountains: 24 are on the Sierra NF in Fresno and Madera Counties. The species is well distributed to the north in the Sierra Nevada Mountains as well with 25 occurrences on the Lassen NF (Table 1). Where there is doubt on collection location, occurrences were not counted as being unique to prevent possible double counting of occurrences. For example, in Nevada County, the Weixelman, Mason and Toren collections were all thought to be from the same location so only one occurrence was counted. An occurrence discovered in 1974 on private land surrounded by the Six Rivers National Forest in Humboldt County was extirpated when the fen was mined for peat (Dan Norris, personal communication March 2003). One site listed as "Sisson" in Siskiyou County may have been on the Shasta Trinity NF, but none of the three 1890's collections have adequate label information to relocate the site. Jim Shevock (personal communication March 2003) said, "There is a train stop on the maps called Sisson so the labels probably refer to the nearest location on a map. This was a fairly common practice in the 1800's for label data to refer to the nearest town or railroad stop. Some think the collections were from a meadow that is now under a lake adjacent to Interstate 5 near Shasta City. One would have to consider the Sisson site as extirpated."

Figure 1. The distribution of *Meesia triquetra* in North America based on Montagnes (1990) and modified by Dillingham.

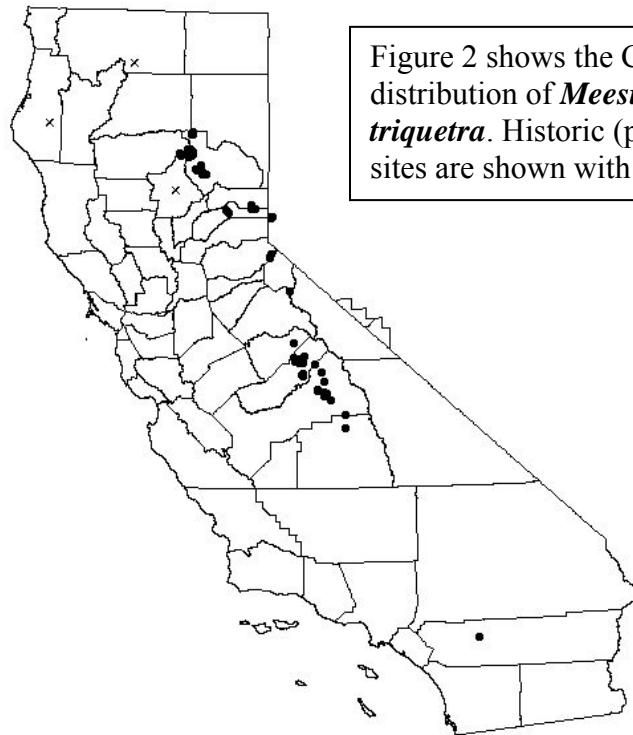
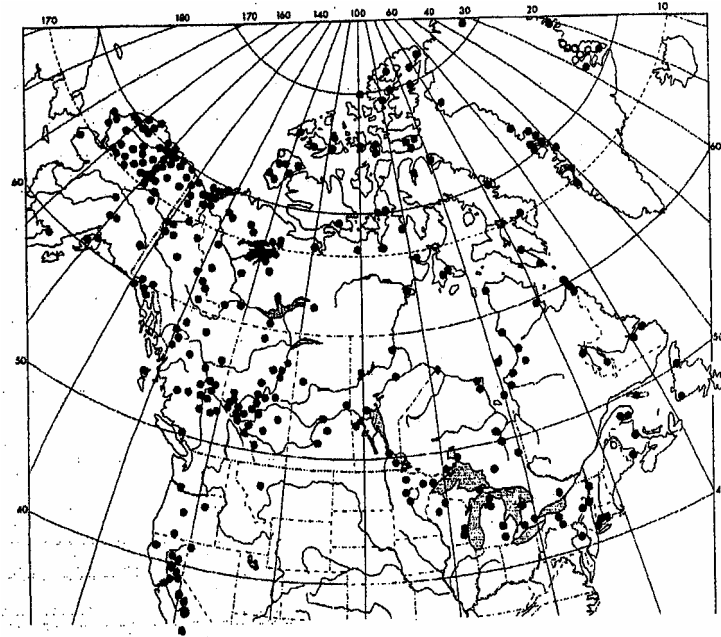


Figure 2 shows the California distribution of *Meesia triquetra*. Historic (pre-1980) sites are shown with "x".

Distribution of *Meesia uliginosa*

The worldwide distribution of this species is a continuous circumboreal distribution, with disjunct occurrences in Tierra del Fuego, the Himalayas (Vitt 1992) and Antarctica (Ochyra and Lewis-Smith 1999). In Europe, it is known as far south as Spain and Bulgaria, while in Asia it extends southward to northern Mongolia. It has been described as having an Arctic-Boreal-Montane distribution. In North America it has been found widely across the United States (Alaska, California, Michigan, Montana, Nevada, Washington, Wyoming), Canada (Alberta, British Columbia, Labrador, Manitoba, Newfoundland, Ontario, Quebec, Saskatchewan, Yukon) and Greenland.

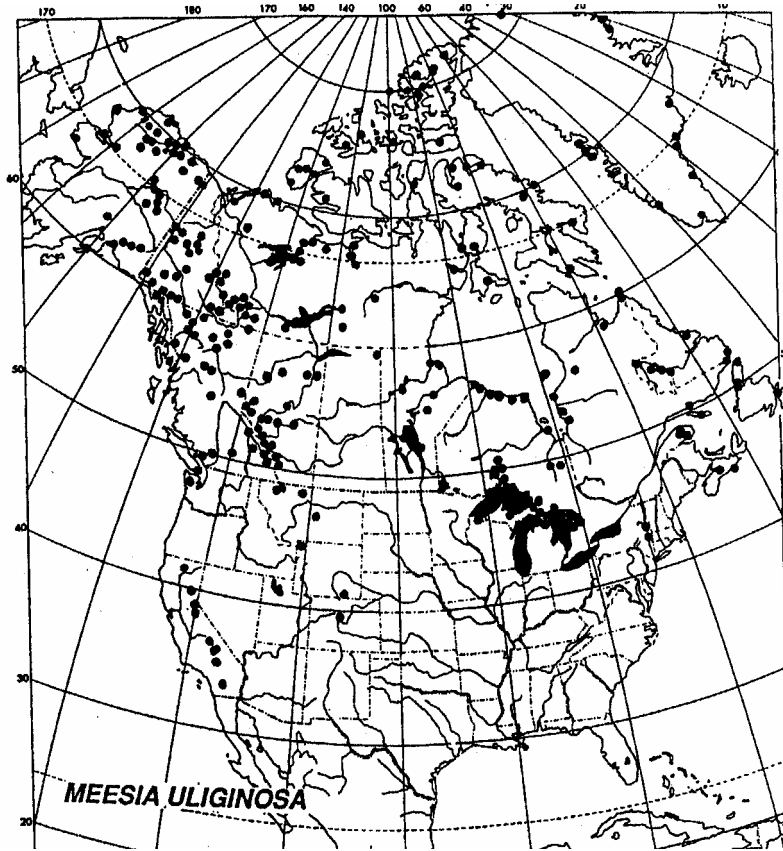
There were 16 occurrences in California with the majority in the Sierra Nevada Mountains since 1980. In addition there are additional occurrences not rediscovered since 1980. One of the historical occurrences outside of the Sierra Nevada Mountains appears to be extirpated. The species is sporadically distributed throughout the Sierra Nevada Mountains: 1 on the Sierra NF in Fresno County, 1 from the Kings River with inadequate site location data, 2 in Sequoia NF and 1 in Kings Canyon NP in Tulare County, 1 on the Plumas NF in Plumas county, and 9 in Nevada County and 1 in Sierra County on the Tahoe NF (Table 1). There is 1 collection from the San Jacinto Mountains in Riverside County from 1961 that has not been relocated, despite efforts by Jim Shevock in 2003. One site listed as “Sisson” in Siskiyou County may have been on the Shasta Trinity NF, but the 1890’s collections do not have adequate label information to relocate the site. See Jim Shevock’s comments from the *Meesia triquetra* results section regarding the likely extirpated Sisson site.

Figure 3. Shows the distribution of *Meesia uliginosa* in California. Historic locations (pre-1980) are shown with “x”.



Meesia uliginosa can be difficult to field determine if sterile and should be microscopically confirmed when possible. It can be confused with other genera of acrocarpous mosses (Ochyra and Lewis-Smith 1999). Collections should be made from all locations and be microscopically verified.

Figure 4. The distribution of *Meesia uliginosa* in North America based on Vitt (1992) and modified by Dillingham.



C. Population number, size and other relevant population information

Table 1. Number of *Meesia triquetra* and *M. uliginosa* occupied fens by National Forest, State Park and National Park in California and Region 5 portion of Nevada (only sites after 1980 to exclude historic, possibly extirpated sites). Unlisted forests have zero occurrences of each species. No extant populations known on other land ownership.

National Forest/Park	No. of <i>M. triquetra</i> occupied fens	No. of <i>M. uliginosa</i> occupied fens
Kings Canyon NP	0	1
Lake Tahoe Basin MU	4	0
Lassen NF	25	0
Plumas NF	6	1
San Jacinto Mountains SP	1	1961 record
Sequoia NF	1	2
Sequoia NP	2	1
Sierra NF	24	1
Stanislaus NF	1	0
Tahoe NF	8	10
Toiyabe NF	1	0
Yosemite NP	1	0
Total occupied fens	74	16

Table 2. *Meesia uliginosa* habitat parameters are presented. Little data was available regarding population size and threats.

Site #	Elev.	Habitat	Popn size	Threats
PNF_MEUL_001	5900 ft	wet marshy meadow		cattle grazing moderate
Sierra_MEUL_001	8500 ft	Wet Meadow		
San Jacinto_MEUL_001	9200 ft	Wet Meadow		trail nearby, threat from off trail hikers?
Tahoe_MEUL-001	6400 ft	fen		
Tahoe_MEUL_002	2100 m	boggy meadow		
Tahoe_MEUL_002	6721 ft	fen	occasional	cattle
Tahoe_MEUL-003	6500 ft	drainage		
Tahoe_MEUL-004	6200 ft	spring fed drainage		
Tahoe_MEUL-005	6200 ft	fen		
Tahoe_MEUL-006	6420 ft	fen		
Tahoe_MEUL-007	6389 ft	fen		
Tahoe_MEUL-008	7760 ft	fen near stream	several hundred	Pending fuels reduction in area.
Tahoe_MEUL-009	6800 ft	fen near stream	several hundred	Pending fuels reduction project in area.
Tahoe_MEUL-011	6360 ft	fen near stream	several hundred	Pending fuels reduction project in area.
Sequoia_NF_MEUL_001	9000 ft	Wet Meadow		
Sequoia_NF_MEUL_002	8000 ft	Streambank		
Sequoia_NP_MEUL_001	8000 ft	Wet Meadow		

Table 3. *Meesia triquetra* habitat parameters are presented below.

Site #	Elev.	Habitat Type	Popn Size	Threats
LTBMU_METR_001_A	7700 ft	saturated peat soils	4.84 acres, 17% cover, dominant moss over entire acreage with Sphagnum	Humans hiking in, vehicles driving off the road, and cattle sneaking in all of which do occur and have a potential to continue.
LTBMU_METR_001_B	7700 ft	saturated peat soils	3.51 acres, 24% cover, dominant moss over entire acreage with Sphagnum	Humans hiking in, vehicles driving off the road, and cattle sneaking in all of which do occur and have a potential to continue.
LTBMU_METR_002	8300 ft	fen	25 sq ft	None visible, perhaps future problems from beavers?
LTBMU_METR_003_A	9350 ft	wet meadow	0.01 acres, 20% cover	Possibly humans hiking off of trails
LTBMU_METR_003_B	9350 ft	wet meadow	0.07 acres, 25% cover	Possibly humans hiking off of trails
LTBMU_METR_004_A	8700 ft	areas with low vegetation	0.02 acres, 30% cover	No current threats, possibly adjacent private land development or beavers
LTBMU_METR_004_B	8700 ft		100 sq ft, 10% cover	No current threats, possibly adjacent private land development or beavers
LTBMU_METR_004_C	8700 ft	seepy wet meadow	0.01 acres, 28% cover	No current threats, possible future threats would be if the private land was developed it could alter the drainage and affect the populations or even destroy the population.
Toiyabe_METR_001	9200 ft	wet soils in meadow		
Ahart_METR_10609	5804 ft	bog	common	The meadow appears to be in relatively good shape, no signs of cattle. Immediately adjacent areas are logged, but this wetland appears to have been avoided with a buffer.
Tahoe_METR_001	6400 ft	drainage		
Tahoe_METR_002	6721 ft	fen	abundant	cattle damage to fen evident
Tahoe_METR_003	6500 ft	drainage		
NY_METR_382941	6500 ft	meadow		
Tahoe_METR_004	6420 ft	fen		
Tahoe_METR_005	1870 m	fen		
Tahoe_METR_006	2067 m	fen		
Sequoia_NP_METR_001	6800 ft	wet meadow		
Sequoia_NP_METR_002	6800 ft	wet meadow		
Sequoia_NF_METR_001	9300 ft	wet meadow		
Sierra_METR70-15-1	7200 ft	wet meadow		
Sierra_METR70-15-1	7100 ft	wet meadow		
Sierra_METR70-15-2	7100 ft	wet meadow		
Sierra_METR70-15-2	7080 ft	wet meadow		
Sierra_METR70-15-3	6800 ft	wet meadow		
Sierra_METR70-15-4	7515 ft	hillside fen	Found in small pockets, a few inches in diameter, scattered in about 1/100 of an acre	White Hazard Tree Sale
Sierra_METR70-15-5	6000 ft	wet meadow		
Sierra_METR70-15-5	6248 ft	wet meadow		cattle, heavy impacts, commercial thinning, road above fen
Sierra_METR70-15-5	6140 ft	wet meadow		cattle, heavy impacts, commercial thinning, road above fen
Sierra_METR70-15-6	5664 ft	fen in meadow	The small occurrence is found with scattered plants in a maze of cow prints. Another small occurrence is about 100 feet away near where first entered meadow, in wet muck	cattle, the meadow has heavy impact from grazing, and this has probably contributed to a shrinking of the population size and may eventually extirpate it. Bovine hooves have churned the fen into mud. The banks of the creek on the edge of the meadow have

Site #	Elev.	Habitat Type	Popn Size	Threats
Sierra_METR70-15-7	1900 m	wet meadow		
Sierra_METR70-15-7	6510 ft	wet meadow	5 X 100 feet, moss interspersed by many cattle hoof prints	cattle; Many stems totally black and assumed dead. Many other stems with dry brown tops, or stems dry. Most green stems small. Few green, twisted, fully hydrated stems. The road that crosses the meadow has impacted the occurrence, but some plants can still be found on the other side of the road
Sierra_METR70-15-7	6510 ft	wet meadow	plants small and occasional to rare	same as above
Sierra_METR70-15-7	6505 ft	wet meadow	badly chopped up by cattle hooves	same as above
Sierra_METR70-15-8	5600 ft	wet meadow		No perceived threats
Sierra_METR70-15-9	9240 ft	wet meadow		
Sierra_METR-15-10	6100 ft	fen in meadow		
Sierra_METR-15-11	7250 ft	wet meadow		
Sierra_METR-15-12	2000 m	moist meadow		cattle
Sierra_METR-15-13	6960 ft	fen in meadow	few patches	cattle grazing, forest service studies
Sierra_METR-15-14	6400 ft	fen in meadow	few patches	cattle grazing, moderate grazing disturbance was visible, hoof punching may be causing fragmentation of the occurrence.
Sierra_METR-15-15	6840 ft	moist, springy meadow	30 X 20 ft intermittent patches	cattle grazing, moss is fragmented, cattle hooves have punched through some of it.
Sierra_METR-15-16	6880 ft	fen in meadow	small and scattered patches	cattle grazing, some hoof punching from cattle is evident
Sierra_METR-15-17	6840 ft	fen in meadow	locally abundant in patches in 100 X 50 ft area	cattle grazing, visibly hoof punched by cattle
Sierra_METR-15-18	7200 ft	meadow associated with creek	patchy within a 6 X 6 ft area	cattle grazing
Sierra_METR-15-19	7280 ft	fen-like patch in meadow	few small patches in a 15 X 10 ft area	cattle grazing
Sierra_METR-15-20	7550 ft	wet meadow		
Sierra_METR-15-21	9240 ft	fen		
Sierra_METR-15-22	6100 ft	saturated soils of meadow		
Sierra_METR-15-23	6800 ft	saturated soils of meadow		
Sierra_METR-15-24	5380 ft	area of large meadow		Livestock, hoof punching within the METR population.
LNF_METR-001	1600 m	wet meadow		
LNF_METR-002	4300 ft	seep	150 ft X 150 ft	None area fenced
LNF_METR-003	6280 ft	wet meadow		
LNF_METR-004	5030 ft	fen area	80 individuals	no visible disturbances, excellent condition
LNF_METR-005	5360 ft	fen	millions of individuals	lodgepole pine encroachment, fair condition
LNF_METR-006	5360 ft	wet part of meadow	2 areas: 10 X 20 ft area and scattered patches in 10 X 50 ft area	Excellent condition
LNF_METR-007		fen area of meadow	thousands of individuals	Cattle grazing has affected the area fairly heavily, grasses are cropped and wet areas are punched by hooves, fair condition; timber harvest also a threat
LNF_METR-008	5760 ft	fen part of meadow	thousands of individuals	This meadow is heavily impacted by cattle grazing; also timber harvest is a threat; poor condition
LNF_METR-009	5760 ft	Hanson fen	multiple patches	Excellent condition, no threats

Site #	Elev.	Habitat Type	Popn Size	Threats
LNF_METR-010	5520 ft	wet meadow	many thousands of individuals	Excellent condition, no threats
LNF_METR-011A	4880 ft	fen	26,000 stems; 1 sq ft (A & B combined)	along trail; heavy ATV and foot traffic
LNF_METR-011B	4880 ft	fen	26,000 stems; 1 sq ft (A & B combined)	along trail; heavy ATV and foot traffic
LNF_METR-012	5120 ft	fen	millions of stems; 4500 sq ft	logging nearby
LNF_METR-013	5750 ft	fen	85000 stems; 30 sq ft	road 150 ft upslope; logging nearby
LNF_METR-014	5200 ft	fen	1000 stems; less than 5 sq ft	
LNF_METR-015	5420 ft	fen	millions of stems; 2500 sq ft	road immediately upslope; light wildlife use
LNF_METR-016	6120 ft	fen	40,000 stems; 15 sq ft	heavy cattle use
LNF_METR-017	5020 ft	fen	3000 stems; 1 sq ft	
LNF_METR-018A	5970 ft	fen	350,000 stems; 125 sq ft (A & B combined)	heavy cattle use
LNF_METR-018B	5970 ft	fen	350,000 stems; 125 sq ft (A & B combined)	heavy cattle use
LNF_METR-019	5950 ft	fen	millions of stems; 7500 sq ft	cattle; logging
LNF_METR-020A	5400 ft	fen	200,000 stems; 65 sq ft (A & B combined)	logging nearby
LNF_METR-020B	5400 ft	fen	200,000 stems; 65 sq ft (A & B combined)	logging nearby
LNF_METR-021A	4580 ft	fen	thousands of stems	firewood cutting; OHVs
LNF_METR-021B	4580 ft	fen	thousands of stems	firewood cutting; OHVs
LNF_METR-021C	4580 ft	fen	thousands of stems	firewood cutting; OHVs
LNF_METR-022	6140 ft	fen	130,000 stems; 45 sq ft	light cattle use
LNF_METR-023A	5980 ft	fen	millions of stems; one acre (A-E combined)	light cattle use; logging nearby
LNF_METR-023B	5980 ft	fen	millions of stems; one acre (A-E)	light cattle use; logging nearby
LNF_METR-023C	5980 ft	fen	millions of stems; one acre (A-E)	light cattle use; logging nearby
LNF_METR-023D	5980 ft	fen	millions of stems; one acre (A-E)	light cattle use; logging nearby
LNF_METR-023E	5980 ft	fen	millions of stems; one acre (A-E)	light cattle use; logging nearby
LNF_METR-024	6105 ft	fen	350 stems; 1 sq ft	heavy cattle use; logging nearby
LNF_METR-025	6760 ft	fen	40,000 stems; 15 sq ft	heavy cattle use; adjacent road
PNF_METR_001A	5400 ft	wet meadow		cattle are crushing plants with hoof action; fuel reduction project
PNF_METR_001B	5295 ft	wet meadow		cattle - heavily grazed, fuel reduction project
PNF_METR_002	1585 m	wet meadow		fuel reduction project
PNF_METR_003	5520 ft	fen	1/2 square meter	good condition, no perceived threats
PNF_METR_004-A	6400 ft	fen		low disturbance caused by cattle
PNF_METR_004-B	6400 ft	fen		low disturbance caused by cattle
PNF_METR_005-A	5800 ft	fen		moderate disturbance caused by cattle
PNF_METR_005-B	5800 ft	fen-like wetland, but with only 15 cm of peat.		moderate disturbance caused by cattle grazing
PNF_METR_006	5326 ft	fen	total area of Meesia 2 square feet	good condition, no perceived threats
Stanislaus_METR_001	9688 ft	fen		
San Jacinto_METR_01	9130 ft	saturated soil in meadow		

D. Reproductive Biology

Although no specific information has been located on the reproductive biology of *Meesia triquetra* and *Meesia uliginosa*, some generalizations may apply to these mosses. Asexual reproduction is common in most bryophytes (Wyatt and Anderson 1984) and dispersal distance may be limited even in those species that reproduce by means of spores (Stoneburner et al. 1992). While it was previously speculated that the small spores of bryophytes were widely dispersed, few spores may actually survive the atmospheric environment (Pocz and van Zanten 1991). Limited dispersal ability of bryophytes has important conservation implications. Populations may not recolonize areas readily and outcrossing opportunities may be limited. Even in continuously distributed bryophyte taxa, it appears that gene flow may be highly restricted (Wyatt 1992).

E. Habitat Description

Meesia triquetra is found in rich to extremely rich fens (Montagnes 1990; Slack et al. 1980). It is a rich fen (characterized by high pH from 5.5 to 7.5) indicator species of high fidelity (Montagnes 1990). It can be found as dense cushions and sometimes carpets open portions of rich fens. It usually occurs in fens with high species richness. Among the most abundant moss species found in these fens are *Aulacomnium palustre* (Hedwig) Schwaegrichen and *Bryum pseudotriquetrum* (Hedwig) G.M.S. (Montagnes 1990). Poor fens are often dominated by *Sphagnum* species, while *Meesia* species are not found in them (Slack et al. 1980), but individual strands of *M. triquetra* can be found intermingled with *Sphagnum* species in intermediate fens (Montagnes 1990).

Montagnes (1990) carefully examined surface water pH, calcium and magnesium concentrations and electrical conductivities of *M. triquetra* fens in west-central Alberta, subarctic Yukon Territory, and from the High Arctic on Ellesmere Island. She found surface waters in which *M. triquetra* grows are typical of moderate- and extreme-rich fens, characterized by high pH from 5.5 to 7.5 (although *M. triquetra* has been found growing in water with pH as low as 4.7), and high electrical conductivities from 50 – 300 μS (however conductivities have been recorded as high as 1,035 and as low as 12 μS). Calcium and magnesium concentrations in surface waters of fens in which *M. triquetra* occurs also are typical of rich fens; they range from about 30 to 60 mg l^{-1} and 6.0 to 20 mg l^{-1} respectively, although values as low as 0.8 mg l^{-1} for calcium and 0.3 mg l^{-1} for magnesium have been recorded.

Meesia uliginosa is an indicator of extremely rich fens (Slack et al. 1980; Sjors 1963). Thus far in California, it has only been found in fen or “wet meadow” habitats. The “wet meadow” habitats may have actually been fens, but were not carefully examined during moss collections. Outside of California Vitt (1992) found that *M. uliginosa* is a decided calciphile. It commonly occurs on small, soil covered ledges on calcareous rock outcrops. It is also found on small, organic mounds in arctic and alpine tundra. While *M. triquetra* often occurs in dense mats and cushions, *M. uliginosa* most often is found in small patches of only a few plants (Vitt 1992). Future surveys for *M. uliginosa* in California should continue to investigate calcareous rock outcrops, as well as drier organic mounds in alpine tundra for this species. This assessment recognizes rich fens as the only occupied habitat in California. A careful water chemistry study such as Montagnes (1990) completed for *M. triquetra* was not found for *M. uliginosa*.

F. Associated Species

Pinus contorta, *Vaccinium* species, *Drosera* species and mosses such as *Sphagnum* and *Aulacomnium palustre* appear to be the most common associated species (see Table 4). Forest botanists should start surveying in areas with these species in wetland meadows. Species of *Carex*, *Eleocharis* and *Scirpus* whose biomass formed the majority of peat in Sierra Nevada fens are dominant in healthy fens, but dominated by short-lived taprooted species such as *Phalacroseris bolanderi* in long-term cattle hoof punched meadows (Cooper et al. 2004).

Table 4. Lists associated species with *Meesia triquetra* (METR in site #) and *Meesia uliginosa* (MEUL in site #).

Site #	Associates
LTBMU_METR_001_A	Carex limosa, Carex sp., Drepanocladus sp., Sphagnum sp.
LTBMU_METR_002	Bryum sp., Carex vesicaria, Drepanocladus sp., Eleocharis sp, Juncus sp., Mimulus primuloides, Muhlenbergia sp
LTBMU_METR_003_A	Aster alpigenus, Carex nebrascensis, Circaea alpina, Deschampsia caespitosa, Dodecatheon sp., Drepanocladus sp., Eleocharis sp., Epilobium ciliatum, Juncus orthophyllus, Kalmia
LTBMU_METR_003_B	Aster alpigenus, Carex nebrascensis, Dodecatheon sp., Drepanocladus sp., Eleocharis sp., Epilobium ciliatum, Hypericum anagalloides, Juncus orthophyllus, Mimulus primuloides, Muhlenbergia sp., Philonotis sp., Salix orestera.
LTBMU_METR_004_A	Aster alpigenus, Carex sp., Carex utriculata, Eleocharis sp., Pedicularis groenlandica, Salix sp.
LTBMU_METR_004_B	Aulacomnium palustre, Aster alpigenus, Carex sp., Eleocharis sp., Hypericum anagalloides, Luzula sp., Mimulus primuloides, Muhlenbergia sp., Philonotis, Pedicularis groenlandica,
LTBMU_METR_004_C	Aulacomnium palustre, Aster alpigenus, Carex scoparia, Carex sp., Deschampsia caespitosa, Eleocharis sp., Gentianopsis simplex, Juncus dubius, Juncus orthophyllus, Luzula sp., Philonotis, Platanthera leucostachys, Polygonum bistortoides, Salix orestera, Spiranthes romanzoffiana, Vaccinium uliginosum
Ahart_METR_10609	Drosera, Darlingtonia
Tahoe_METR_002	Pinus contorta, Populus tremuloides, Pinus jeffreyi, Drosera rotundifolia
Tahoe_METR_003	Riparian species such as Saxifrage oregana, Phleum alpinum, Carex sp., Salix sp., Stellaria sp., Dedecatheon sp.
Tahoe_METR_004	Pinus contorta
Sequoia_NP_METR_001	Vaccinium, giant sequoia
Sequoia_NP_METR_002	Vaccinium, giant sequoia
Sequoia_NF_METR_001	Pinus contorta
Sierra_METR70-15-1	Pinus contorta, Salix, Vaccinium, Pedicularis, Abies magnifica
Sierra_METR70-15-2	Pinus contorta
Sierra_METR70-15-3	Pinus contorta
Sierra_METR70-15-4	Mimulus primuloides, Juncus oxymeris, Hypericum anagalloides, Salix, Carex, Philonotis fontana
Sierra_METR70-15-5	Drosera rotundifolia
Sierra_METR70-15-6	Mimulus primuloides, Juncus, Oxypolis, Hypericum anagalloides, Polygonum, Pedicularis
Sierra_METR70-15-7	Abies concolor, Pinus contorta
Sierra_METR70-15-9	Pinus contorta, western white pine, Vaccinium, Pedicularis, Polygonum, Carex species
Sierra_METR-15-11	Pinus contorta, Abies magnifica, Vaccinium occidentale, Philonotis fontana
Sierra_METR-15-12	Pinus contorta
Sierra_METR-15-13	Sphagnum sp., Vaccinium uliginosum ssp. occidentale, Drosera sp., Mimulus primuloides
Sierra_METR-15-14	Pedicularis groenlandica, Vaccinium uliginosum ssp. occidentale
Sierra_METR-15-16	Drosera sp., Pedicularis groenlandica, Vaccinium sp., Sphagnum sp.
Sierra_METR-15-17	Carex sp., Hypericum anagalloides, Mimulus primuloides, Oxypolis occidentalis
Sierra_METR-15-20	Pinus contorta, Vaccinium, Aulacomnium palustre, Philonotis fontana
LNF_METR-001	Pinus contorta, Vaccinium, Caltha, Drosera
LNF_METR-002	Associates include other mosses, Eriophorum gracile. Drosera anglica, Tofieldia occidentalis.
LNF_METR-004	Polygonum bistortoides, Mimulus primuloides, Spiranthes sp., Sisyrinchium
LNF_METR-005	Pinus contorta, Drepanocladus sp., Aulacomnium sp., Drosera rotundifolia, Aster alpigenus, Juncus balticus, Eleocharis macrostachya, Tofieldia occidentalis, Vaccinium uliginosum, Saxifraga sp., Eriophorum gracile, Pedicularis atollens, Drosera anglica
LNF_METR-006	Aster alpigenus, Perideridia sp., Juncus balticus, Deschampsia caespitosa, Mimulus primuloides, Gentiana newberryi var. tiogana
LNF_METR-007	Vaccinium uliginosum, Aster alpigenus, Caltha leptosepala, Juncus balticus, Tofieldia occidentalis, Pedicularis atollens, Gentianopsis simplex
LNF_METR-008	Vaccinium uliginosum, Eleocharis macrostachya, Aster alpigenus, moss, Carex nebrascensis, Pinus contorta
LNF_METR-009	Pinus contorta, Vaccinium uliginosum, Alnus incana ssp. tenuifolia, Eriophorum gracile, Juncus nevadensis, Aster alpigenus, Drosera rotundifolia, Pedicularis atollens, Hypericum anagalloides, Aulacomnium palustre, Drepanocladus sp.

Site #	Associates
LNF_METR-010	Mimulus primuloides, Mimulus guttatus, Spiranthes sp., Drepanocladus, Tritelia hyacinthina, Juncus spp., Eleocharis macrostachya
LNF_METR-011	Drosera rotundifolia, Saxifraga oregana, Mimulus primuloides, Hypericum anagalloides, Drepanocladus, Pedicularis groenlandica, Spiranthes romanzoffiana, Oxypolis occidentalis
LNF_METR-012	Saxifraga oregana, Drosera rotundifolia, Tofieldia occidentalis, Mimulus primuloides, Spiranthes porrifolia, Aster alpigenus
LNF_METR-013	Aster alpigenus, Drepanocladus, Philonotus, Eriophorum, Pedicularis, Tofieldia occidentalis, Parnassia californica, Oxypolis occidentalis, Hastingia alba, Platanthera sparsiflora, Carex echinata, Vaccinium uliginosum, Aulacomnium, Hypericum anagalloides, Mimulus primuloides, Saxifraga oregana
LNF_METR-014	Pinus contorta, Alnus incana, Vaccinium uliginosum, Spiraea douglasii, Drosera rotundifolia, Mimulus primuloides, Mimulus guttatus, Aster alpigenus, Saxifraga oregana, Tofieldia occidentalis, Perideridia, Platanthera leucostachys, Lupinus polyphyllus, Camassia quamash, Hypericum anagalloides, Spiranthes, Juncus nevadensis, Glyceria borealis, Philonotus fontana, Aulacomnium palustre, Drepanocladus
LNF_METR-015	Lophozia, Stachys ajugoides, Drosera rotundifolia, Calocedrus decurrens, Abies concolor, Pinus contorta, Madia bolanderi, Oxypolis occidentalis, Philinotus, Marchantia, Hypericum anagalloides, Aster alpigenus, Saxifraga oregana, Veratrum californicum, Vaccinium uliginosum, Cammassia quamash, Platanthera leucostachys, Mimulus primuloides, Drepanocladus, Aulacomnium, Carex echinata
LNF_METR-016	Pinus contorta, Aster alpigenus, Spiranthes porrifolia, Drosera rotundifolia, Tofieldia occidentalis, Carex aquatilis, Juncus nevadensis, Gentiana newberryi, Aulacomnium, Philonotus, Drepanocladus, Mimulus primuloides, Carex echinata, Vaccinium uliginosum
LNF_METR-017	Drepanocladus, Philonotus, Eleocharis acicularis, Aster alpigenus, Hypericum anagalloides, Mimulus primuloides
LNF_METR-018	Vaccinium uliginosum, Lonicera conjugialis, Mimulus primuloides, Hypericum anagalloides, Caltha leptosepala, Saxifraga oregana, Aster alpigenus, Spiranthes porrifolia, Polygonum bistortoides, Juncus balticus
LNF_METR-019	Pinus contorta, Abies concolor, Vaccinium uliginosum, Tofieldia occidentalis, Perideridia, Sphenosciadium capitellatum, Mimulus primuloides, Aster alpigenus, Saxifraga oregana, Spiranthes, Caltha leptosepala, Lonicera conjugialis, Pedicularis groenlandica, Oxypolis occidentalis, Drosera rotundifolia, Orobanche californica, Potentilla drummondii, Platanthera leucostachys, Hypericum anagalloides, Juncus nevadensis, Carex echinata, Deschampsia caespitosa, Muhlenbergia, Philonotus, Aulacomnium palustre, Drepanocladus, Bryum
LNF_METR-020	Drosera rotundifolia, Spiranthes romanzoffiana, Tofieldia occidentalis, Aster alpigenus, Vaccinium uliginosum, Pedicularis, Carex echinata, Parnassia californica, Eriophorum, Saxifraga oregana, Hypericum anagalloides, Oxypolis occidentalis, Caltha leptosepala, Drepanocladus, Philonotus, Aulacomnium, Marchantia polymorpha
LNF_METR-021	Drosera anglica, Mimulus primuloides, Tofieldia occidentalis, Hypericum anagalloides, Drepanocladus, Drosera rotundifolia
LNF_METR-022	Pinus contorta, Vaccinium uliginosum, Salix lemmoni?, Mimulus primuloides, Pedicularis, Tofieldia occidentalis, Saxifraga oregana, Hypericum anagalloides, Aster alpigenus, Juncus nevadensis
LNF_METR-023	Vaccinium uliginosum, Aster alpigenus, Juncus nevadensis, Hypericum anagalloides, Gentiana newberryi, Drosera rotundifolia, Pinus contorta, Abies concolor, Alnus incana, Platanthera leucostachys, Drepanocladus, Philonotus, Mimulus primuloides, Tofieldia occidentalis
LNF_METR-024	Pinus contorta, Abies concolor, Alnus incana, Vaccinium uliginosum, Tofieldia occidentalis, Aster alpigenus, Oxypolis occidentalis, Perideridia, Mimulus primuloides, Hypericum anagalloides, Gentiana newberryi, Gentianopsis simplex, Juncus nevadensis, Carex aquatilis, Agrostis, Bryum, Philonotus,
LNF_METR-025	Carex angustata, Scirpus microcarpus, Aulacomnium, Aster alpigenus, Pedicularis, Eriophorum gracile, Veratrum californicum, Caltha leptosepala, Tofieldia occidentalis, Salix lemmonii, Salix lucida
PNF_METR_001A	Pinus contorta, Sphagnum, Philonotus americana, Drosera rotundifolia, Vaccinium
PNF_METR_001B	Drosera rotundifolia, Alnus incana, Philonotus americana, Drepanocladus aduncus
PNF_METR_002	Pinus ponderosa, Calocedrus decurrens, Alnus incana, Spirea douglasii, Drosera rotundifolia, Darlingtonia californica
PNF_METR_003	Alnus incana, Salix sp, Spiraea douglasii, Rubus parviflora, Vaccinium uliginosum, Drosera rotundifolia, Aulacomnium palustre, Bryum turbinatum, Philonotus tomentella
PNF_METR_004	Alnus incana, Carex, Sphagnum mendocinum
PNF_METR_005	Alnus incana, Pinus contorta, Abies concolor, Kalmia polifolia, Spiraea douglasii, Vaccinium uliginosum, Drosera rotundifolia, Epilobium ciliatum, Hypericum anagalloides, Madia bolanderi, Oreostemma alpigenum, Pedicularis attollens, Carex echinata, Glyceria elata, Juncus nevadensis
PNF_METR_006	Alnus incana, Aulacomnium palustre, Abies magnifica
San Jacinto_METR_01	Carex nebrascensis, Veratrum californicum

Site #	Associates
PNF_MEUL_001	Pinus contorta, Salix, Mimulus primuloides, Aulacomnium palustre, Drepanocladus aduncus, Leptobryum pyriforme
Sierra_MEUL_001	Pinus contorta
San Jacinto_MEUL_001	Bryum species
Tahoe_MEUL-001	Other mosses, Epilobium Spp. Hypericum anagelloides
Tahoe_MEUL_002	Pinus contorta
Tahoe_MEUL_002	Pinus contorta, Populus tremuloides, Pinus jeffreyi, Drosera rotundifolia
Tahoe_MEUL-003	Riparian species such as Saxifraga oregana, Phleum alpinum, Carex sp., Salix sp., Stellaria sp., Dedecatheon sp..
Tahoe_MEUL-004	Salix sp., Alnus sp., Mimulus guttatus, Veronica sp., Ribes nevadense,
Tahoe_MEUL-005	Other mosses, Epilobium Spp. Hypericum anagelloides
Tahoe_MEUL-006	Pinus contorta
Tahoe_MEUL-007	Pinus contorta
Tahoe_MEUL-008	Mimulus primuloides, Frageria sp., Vaccinium uliginosum ssp. Occidentalis, Platanthera leucostachys
Tahoe_MEUL-009	Drosera anglica, Drosera rotundifolia, Salix geyriana, Alnus incana, Vaccinium uliginosum ssp. occidentalis, Veratrum californicum, Platanthera leucostachys
Tahoe_MEUL-011	Mimulus primuloides, Veratrum californicum, Pinus contorta, Aster alpigenum, Frageria sp., Potentilla gracilis.
Sequoia_NF_MEUL_001	Pinus contorta
Sequoia_NF_MEUL_002	Abies magnifica
Sequoia_NP_MEUL_001	Pinus contorta

G. Ecological Relationships

Meesia triquetra and *Meesia uliginosa* are strongly tied to montane fens within the Sierran Nevada bioregion. Although there are one or two occurrences where *Meesia* has been found in a spring in a meadow without the required 40 cm of peat to qualify as a fen, the vast majority of the California occurrences are found in sites that meet the definition of a fen. It is important to understand and define fens in order to manage for these two species. Montane peatlands represent reservoirs of great ecological diversity yet are among the least studied peatlands in the world. This is especially true in montane regions of western North America including northern California, where most peatlands have yet to be identified and inventoried in entire mountain ranges such as the Sierra Nevada and Cascades. Peatlands are considered an uncommon meadow type in the Sierra Nevada (Bartolome et al. 1990).

Inconsistent classification and terminology of peatland ecosystems confounds identification and inventory of these wetland systems (Bridgham et al. 1996; Ratliff 1982; Sawyer and Keeler-Wolf 1995; Wheeler and Proctor 2000). There is a large diversity of peatland ecosystems, often with conflicting colloquial nomenclature of such systems and peatland terms are at times ambiguous (Wheeler and Proctor 2000). Despite this, more formal classifications of peatlands have identified a few common characteristics, the first of which is the presence of thick accumulations of preserved dead plant material (USDA, Soil Conservation Service 1999). Thick accumulations of organic matter can occur only when primary production exceeds decomposition (Chadde et al. 1998; Cooper et al. 1998; Chimner and Cooper 2003b). Decomposition can be hindered by a number of processes, the most important being an absence of oxygen resulting from waterlogged soils and, in some cases, low temperatures (Bridgham et al 1996; Chadde et al. 1998). The thickness of organic soil is the second characteristic used to identify the

presence of a peatland, although definition of a minimum depth remains unresolved (Charman 2002; cited by Patterson 2003).

American classification labels organic soils histosols, where organic soils comprise at least 40 cm of the upper 80 cm of soil, yet if the bulk density is very low, 60 cm or greater must be organic (USDA, Soil Conservation Service 1999). Chadde et al. (1998), who describe peatlands of the Northern Rocky Mountains, use the depth of 30 cm or more of peat because once peat has developed to this depth, peat forming vegetation becomes independent from the mineral soil and must therefore derive nutrients from water inputs and the peat body itself. These characteristics help distinguish peatlands from other areas with organic soils. However, when considering *Meesia* habitat, remember that plant community designations are to some degree a matter of human convenience, and fine distinctions and rigid boundaries among plant communities should be avoided (Bridgham et al 1996).

Due to the separation of peatland plants from the mineral soil because of the thickness of peat accumulation, the nutrient status of water inputs to the peat body is of utmost importance in controlling vegetation composition, peatland formation and therefore peatland classification. Although, peatland vegetation varies considerably on both regional and global scales, classification of peatland ecosystems has come to reflect the hydrochemical gradient of such systems. This gradient has been described as the poor to rich nutrient gradient, or the bog to fen gradient and can be used both in regards to peatland topographic origin (suffix –genous) and nourishment of minerals (suffix –trophic). At the poor end of the nutrient gradient are ombrotrophic peatlands, or bogs, which receive only atmospheric water inputs and therefore tend to be acidic and low in nutrients (Bridgham et al. 1996). Bogs are extremely acidic, nutrient-poor type of peatland and are unknown in the Sierra Nevada bioregion. Fens, or minerotrophic peatlands, are tightly linked to the local hydrological regime and receive additional non-atmospheric inputs, either ground or surface water and tend to be more nutrient rich and alkaline (Bartolome et al. 1990; Chadde et al. 1998). As fens depend on non-atmospheric water inputs, their mineral ion supply is a reflection of basin geochemistry (Moore and Bellamy 1973; cited by Patterson 2003).

Variability in basin geochemistry and the resulting mineral content of water inputs has resulted in further division of fens along the nutrient poor to rich gradient (Chadde et al. 1998; Slack et al. 1980). Poor fens are characterized by low pH and a paucity of mineral ions (e.g. pH range of 4.2 to 5.8 and a calcium concentration of 10 to 30 mg/l), while rich fens are characterized by high pH and an abundance of mineral ions. Rich fens are often further divided into rich fens (e.g. pH of 5.8 to 7 and a calcium concentration of 2 to 10 mg/l) and extremely rich fens (e.g. pH range of greater than 7 and a calcium concentration of over 30 mg/l). These designations have received considerable attention and many alternatives have been proposed (see Chadde et al. 1998; Slack et al. 1980; Wheeler and Proctor 2000 for examples), yet the nutrient gradient continues to be the most widely recognized and used classification system. When used appropriately and with adequate detail, the use of terms such as rich fen is extremely useful when describing a particular peatland, as it conveys both a hydrologic and geochemical understanding of the peatland. Plant indicators of water chemistry conditions are particularly evident among the mosses (Slack et al. 1980). *Meesia triquetra* populations are found in rich fens (Montagnes 1990; Slack et al. 1980).

Due to the reliance of bogs on atmospheric water inputs, bogs occur only in areas where precipitation exceeds evapotranspiration, runoff and loss to groundwater. Due to the dry summer climate found in the Sierra Nevada bioregion, bogs do not occur in this region. Conversely, due to their reliance on a high water table, fens may occur in a wider range of climates, including interior mountain landscapes that receive little summer precipitation and have a low relative humidity (Chadde et al. 1998; Cooper and Andrus 1994). Development of fens is not only contingent on an adequate water supply, but also on basin morphology and site topography. Basin morphology and site topography determine movement patterns and erosional potential of water, which must be minimal in order for vegetation to develop and peat to accumulate. Basin morphology results in further division of fens into limnogenous, topogenous and soligenous systems, with limnogenous fens developing along lakes and slow-flowing streams; topogenous fens described as those that develop within topographic depressions and are fed by upwelling groundwater or surface runoff; and soligenous fens, described as those that develop on lower slopes and valley floors and are fed by movement of water down valley and/or springs and seepage from the valley walls (Bridgham et al 1996).

Several types of wetlands are sometimes confused with peatlands. Marshes are wetlands on mineral soil with standing water for all or part of the year. In contrast to peatlands, marshes are well aerated and rich in minerals. Common plant species of marshes include *Typha latifolia* (common cattail) and various coarse sedges such as *Carex utriculata*. Sedge meadows occur in shallow basins on mineral soil and are drier for at least part of the year than peatlands. Seasonal drying of the soil encourages microbial decomposition of plant remains, limiting organic matter accumulations.

Much of the ecological relationship information above was borrowed from Patterson (2003).

III. Management

The two most critical factors affecting the abundance and distribution of peatland species appear to be water levels and the nutrient concentration of incoming water (Bartolome et al. 1990; Chadde et al. 1998; Montagnes 1990). Basin topography and hydrogeochemical regimes determine the biologic processes necessary for fen development, as different vegetation communities correspond to ranges in pH and calcium concentrations (Chadde et al. 1998). These biologic processes in turn influence the topography and hydrogeochemical regime within the fen, illuminating the intimate relationship and feedbacks between vegetation and both moisture and chemical gradients (Glaser et al. 1990). The intimate connection between hydrologic and biologic processes suggests that changes in the hydrochemical regime of fen ecosystems, especially those with dry summer climates, may have severe ecological impacts (Cooper et al. 1998; Chimner and Cooper 2003a).

There is a long history of hydrologic modifications to peatland ecosystems throughout the world, the most common goal being drainage for agriculture, peat harvest and grazing (Chimner and Cooper 2003a). Drainage of peatlands is most frequently achieved through ditching, the impacts of which are still being realized due to variability in both the placement and extent of ditching and variability in the peat landforms. Ditching can also occur incidentally through road construction, timber harvest or grazing practices, when roads, log yarding corridors or cattle trails cut through natural drainage

barriers. The most direct impact of ditching is an alteration of the hydrologic regime, which will, in turn, alter the fundamental biochemical processes necessary for fen maintenance. These fundamental processes include the carbon balance (Chimner and Cooper 2003a; Chimner and Cooper 2003b), soil structure and vegetation community of the fen (Chadde et al. 1998). Glaser et al. (1981) concluded that drainage ditches produce local changes in hydrology in peatlands of northern Minnesota, while Cooper et al. (1998) found that fens in the Rocky Mountains are extremely sensitive to even small ditches or water diversions. It is suspected that similar changes would occur in Sierra Nevada mountain fens.

Glaser et al. (1981) found that ditches in the Red Lake Peatland in Northern Minnesota most strongly impacted minerotrophic water tracks, with the peatland becoming progressively drier downslope from consecutive drainage ditches. Boelter (1972; cited by Patterson 2003) found that the presence of an open ditch greatly influenced the drainage of surface or near surface horizons of fibric peat. The ditch had little influence on the water table beyond 5 meters from the ditch when the water table was in deeper horizons of moderately decomposed peat, yet in an organic soil with less decomposed peat, the ditch influenced the water table as far as 50 meters from the ditch. A ditched fen in Rocky Mountain National Park, Colorado successfully removed a major water source from much of the fen, sufficiently lowering the water table to create aerobic conditions in the upper part of the soil. The water table of sites located in the ditched water track dropped to 40-70 cm below the soil surface during late summer of three consecutive years, while un-impacted reference areas never dropped below 10 cm below the soil surface during the same three years (Cooper et al. 1998).

Many studies also consider the impact of hydrologic modifications on vegetation (Allen-Diaz 2003; Glaser et al. 1990) and peat landforms (Glaser et al. 1981). In the Red Lake Peatland in Northern Minnesota, *Carex lasiocarpa* became progressively more dominant in drier areas, while species more susceptible to drying (*Drosera* species, *Utricularia* species, *Equisetum fluviatile* and *Scheuchzeria palustris*) were eliminated. A number of exotic plant species also invaded hydrologically modified areas of this peatland (Glaser et al. 1981). Cooper et al. (1998) found similar results in a ditched mountain fen in Rocky Mountain National Park, noting that the reduction in soil saturation allowed the invasion of *Deschampsia cespitosa*, a native grass common in seasonally dry mineral soils.

Current management direction from the Sierra Nevada Forest Plan Amendment FSEIS (2004, Appendix A Standards and Guidelines) indicate that default riparian conservation area buffer widths would be established around special aquatic features such as fens. These buffers would extend 300 feet from the edge of fens or include all riparian vegetation whichever is greater. Another critical standard and guideline is to maintain and restore the hydrologic connectivity of streams, meadows, wetlands and other species aquatic features such as fens.

Land allocations and Standards and Guidelines for Management

Fens in the National Forests of the Sierra Nevada Mountains are in the Riparian Conservation Area land allocation (USDA Forest Service 2004). Fens are considered "Special Aquatic Features" and receive a default riparian conservation area buffer width of 300 feet from the edge of the fen (USDA Forest Service 2004, pg 339). There is a

listing of standards and guidelines for these “Special Aquatic Features listed on pages 340-349 of the Sierra Nevada Forest Plan Amendment (USDA Forest Service 2004). Districts within the HFQLG pilot project area have a different default conservation area buffer width. The HFQLG ROD prescribes a 150-foot buffer from non-fish bearing wetlands, which would include most fens. Although these Standards and Guidelines are intended to maintain or restore the geomorphic and biological characteristics of fens and other aquatic features, they do not prohibit other forest activities such as fuel reduction, logging and grazing activities.

Concerns/risks/threats

As stated previously, the two most critical factors affecting the abundance and distribution of fen species such as *M. triquetra* and *M. uliginosa* in the Sierra Nevada bioregion are hydrology and the nutrient concentration of incoming water. Wildfires and drought bring periodic changes in these two factors and consequent shifts in location and abundance of fen species (Bursik and Mosely 1995). Although most wildfires are unlikely to cause irreversible harm to fens during normal or wet years, other wildfires occurring during droughts have been known to burn Sierran fens for up to two months (Bartolome 1990; DeBenedetti and Parsons 1984). The abrupt, large-scale, and often irreversible nature of changes in hydrology and nutrient concentrations that result directly or indirectly from human activities, however, may be beyond the tolerance level of resident populations to relocate and persist. Although human activities often affect hydrology of fens, impacts to nutrient concentrations of incoming water are less common.

Ditching fens is a major threat to fens. Sierra Nevada fens have been ditched both purposefully for drainage and inadvertently by road construction or cattle trails (Patterson 2003, Cooper et al. 2004). Cooper et al. (1998) found that fens are extremely sensitive to even small ditches or water diversions. Chimner and Cooper (2003a) found that it is most critical to maintain high fen water tables during the months of July and August. The long-term consequences of hydrologic modification for fens and other montane wetlands will continue to be a concern in the western United States as the human population grows and demands for water increase (Chimner and Cooper 2003a).

Cooper et al. (2004) and Bursik and Mosely (1995) identified ground disturbance associated with grazing as a widespread threat to Southern Sierra Nevada and Idaho peatlands respectively. Ground disturbance associated with grazing was identified as a potential threat in 53% of *Meesia* occupied fens in California National Forests when threats were identified (Table 2, Table 5.). Allen-Diaz (2003) and Cooper et al. (2004) recognized that cattle and sheep grazing have caused erosion and lowering of the water table in Sierra Nevada wet meadows and fens. Chadde et al. (1998) report that livestock grazing directly impacts peatland vegetation through removal and trampling, and may result in soil compaction, and altered local hydrologic conditions. Cooper et al. (2004) determined that fens with bare ground greater than 20% have a negative carbon balance and likely are losing peat. Guardino et al. (2001) report anecdotal evidence that cattle trampling may have had severe hydrological modifications to a *Meesia* fen on the Plumas National Forest. Direct trampling by cattle has been shown anecdotally to be lethal to *Meesia triquetra* on the Sierra National Forest (Beyer 2000). Direct trampling by cattle is the most widespread threat identified on Sierra Nevada *Meesia* occurrence discovery forms (Table 2, Table 5). Indirect impacts associated with grazing may include altered

water chemistry (Chadde et al. 1998), altered plant composition, reduced plant production and negative carbon balance (Cooper et al. 2004).

Management activities on landscapes that have peatlands imbedded within them can potentially threaten system integrity, if they adversely alter hydrologic regimes and nutrient regimes. Hydrologic conditions of individual peatlands depend upon where they are located (i.e. topographic position) in the drainage basin. Since most fens in the Sierra Nevada bioregion are flow-through systems, water is obtained from the lands higher up in the drainage. Certain off-site management activities, such as timber harvest, road building, and livestock grazing that alter hydrologic and nutrient regimes may adversely impact fens (Bursik and Mosely 1995; Chadde 1998). The degree of impact of these activities on fens is the result of many factors including the extent and intensity of land management activity or disturbance, and the particular physiographic features of the drainage. Off-site management activities need to be planned so that hydrologic and nutrient conditions remain within the range of natural variability.

Allen-Diaz (2003) recognized that human recreational use has resulted in trampling damage to fens. Slack et al. (1980) identified snowmobile riding as a potential threat to rich fens through ground disturbance. Cooper et al. (2004) identified ground water pumping as a threat to one fen in Yosemite National Park because it created a deep water table and dry peat in mid-summer. Recreational use was identified as a potential threat to 16% of California *Meesia* sites (Table 2, Table 5.) when combining hikers and off highway vehicles.

Little peat mining has taken place in the Sierra Nevada bioregion, although the only known *M. triquetra* fen in Humboldt County was extirpated through mining (Dillingham 2003). No special use permits for peat mining should be considered in this rare habitat type.

Invasion by exotic plant species is apparent in some peatlands (Chadde et al. 1998). Canada thistle (*Cirsium arvense*) may invade peatlands following disturbances such as wheel ruts, cattle trampling or fire. Maintenance of proper hydrology in rich fens is likely to prevent the establishment of most exotic species. Cooper et al. (2004) noted that long-term hoof punching by cattle can disturb the native vegetation so severely, that the species of *Carex*, *Eleocharis* and *Scirpus* whose biomass formed the peat are largely absent from the vegetation. Instead, the vegetation in these fens is dominated by short-lived and taprooted species such as *Phalacroseris bolanderi*.

A commonly observed threat to fens is vegetation change by the invasion of *Pinus contorta* (Bartolome et al. 1990), although it was only noted as a threat to one fen on *Meesia* occurrence forms (Table 2). Wood (1975) however, found that episodes of invasion should be expected. His study of wet meadows showed that periods of meadow establishment and periods of tree invasion alternated over the last several thousand years. Bartolome et al. (1990) studied fen longevity and succession and suggested that fens are stable biological systems and only alteration of their physical environment, particularly hydrology, causes changes. The establishment of pines within the fen ecosystem should be considered a temporary, natural fluctuation, not an indication that manager must act to prevent their loss by plant succession.

Table 5. Perceived threats as listed on occurrence forms or data requests for *Meesia triquetra* and *M. uliginosa* occupied fens by National Forest, State Park and National

Park in California and Region 5 portion of Nevada (only sites after 1980 to exclude historic, possibly extirpated sites). Unlisted forests have zero occurrences of each species. Most data is *M. triquetra* data, as only 6 of 16 *M. uliginosa* sites had perceived threats; three from fuel reduction projects (Tahoe NF); two from cattle grazing (Plumas and Tahoe NF) and one from recreational hikers (San Jacinto S.P.). Data collected at sites from the Kings Canyon NP, Sequoia NF, Sequoia NP, Stanislaus NF, Toiyabe NF and Yosemite NP did not include disturbance or perceived threat data and are excluded from this table, except in the number of *Meesia* occupied fens column.

National Forest/Park	No. of <i>Meesia</i> occupied fens	No. of sites with threat data	Cattle Grazing	Timber Management	Off Trail Hiking	Off Highway Vehicle	Adjacent roads	No perceived threats
Lake Tahoe Basin MU	4	4	1		2	1		1
Lassen NF	25	21	8	8	2	3	3	5
Plumas NF	7	7	4	2				2
San Jacinto Mtns SP	2	1			1			
Sierra NF	25	15	14	2			1	1
Tahoe NF	18	6	2	4				1
Total (% of sites with identified threats)	90	55	29 (53%)	16 (29%)	5 (9%)	4 (7%)	4 (7%)	10 (18%)

IV. Conservation Consideration

The National Forest Management Act of 1976 and Forest Service policy require that Forest Service land be managed to maintain populations of all existing native animal and plant species at or above the minimum viable population level (USDA Forest Service 1991). In the past, this type of biodiversity conservation took place on a species by species basis. More recently, the values of other aspects of biodiversity have been recognized as important conservation elements (Marcot et al. 1994). Redirecting conservation efforts from the traditional single-species approach to an ecosystem or unique habitat-based system, such as has been done with coastal Pacific Northwest old-growth forests and associated rare and threatened plant and animal species, can greatly increase the efficiency and effectiveness of biodiversity conservation.

In the Sierra Nevada bioregion, peatlands have been recognized as important habitats characterized by a unique suite of environmental conditions and hosting a diversity of rare plant species. Peatlands are neither abundant, nor exceedingly rare in the Sierra Nevada Mountains of California, (Bartolome et al. 1990; Cooper and Wolf 2004) and are probably best considered uncommon to rare habitats with vast areas of uplands between each site. The study of the biota of California's peatlands is much like the discipline of island biogeography where long-distance dispersal and persistence of relict populations must account for their flora and fauna. A comprehensive conservation

strategy for peatlands is desired for the success of land management of these important physical and biotic features.

The sensitivity of *Meesia* fen habitat to environmental conditions requires conservation approaches that ensure protection for these important sites. Integrity of fen ecosystems is inherently tied to hydrologic conditions. Although fairly small in size, fens are sustained by water and nutrient resources derived from much larger portions of the surrounding landscapes. Under naturally occurring hydrologic regimes, fens are relatively stable ecosystems. However, the ability to recover from disturbance is low in fens. Land-use activities that have direct (such as ditching) and indirect impacts such as upslope timber harvest or road construction can cause changes to fen biodiversity because many species are sensitive to minor changes in water chemistry and hydrology (Bursik and Moseley 1992).

Fortunately many protection measures are already in place or are available for conserving fens, and therefore *Meesia*, on National Forests. The Sierra Nevada Forest Plan Amendment FEIS (USDA Forest Service 2004, pg 339), qualifies fens as “Special Aquatic Features” and provides a 300 ft default riparian conservation area buffer surrounding them. Management standards and guidelines set forth in forest plans collectively provide conservation mechanisms for many fens occupied by *Meesia* species, although some timber harvest, grazing, and road building may still be permitted.

Additional protection mechanisms could include application of special designations to the most significant sites, such as Special Interest Botanical Areas (Forest Service Manual 2072) or Research Natural Areas (Forest Service Manual 4063). These designations allow for recognition of significant biological features, such as areas of significant biological diversity with rare biota, or high quality examples of representative ecosystem types.

The ecological importance of mountain fen ecosystems has been increasingly recognized, with more and more attention focused on rare mountain fen systems in recent years. This attention has also prompted increased conservation efforts of these unique ecosystems (see Cooper et al. 2004).

V. Data Gaps and Needed Research

Inventory

Inventories for *Meesia* species on peatlands on National Forests in the Sierra Nevada bioregion have been implemented to a small degree (Bishop and Bishop 2003; Cooper and Wolf 2004, Cooper et al. 2004). However, much of the land base has not been surveyed for peatlands, and even a smaller percentage for *Meesia* presence on these peatlands. Continued surveys on National Forest lands are recommended, following the methodology suggested by Bishop and Bishop (2003), Cooper and Wolf (2004) and Cooper et al. (2004). Inventory of known fens, such as those identified by Weixelman (30 identified fens across the El Dorado, Inyo, Lassen, LTBMU, Plumas, Sierra and Tahoe National Forests, 2003, Appendix 1) for *Meesia* species would be valuable. This would lead to a better understanding of rare plant distribution within the region.

Peatland Classification

Classification is often considered the first step in understanding the nature and dynamics of habitats in order to properly manage them. Habitat classification could then be used as a basis of peatland ecosystem conservation efforts (Bursik and Moseley 1995). While peatland classifications based solely on vegetation dominance are of limited value, future efforts should be directed toward refining descriptions and classifications of entire peatlands in terms of a combination of physical features, hydrology, water chemistry, and floristics (Chadde et al. 1998). The widely accepted peatland classification that recognizes poor fen, rich fen, and extremely rich fen is sufficient for most purposes in the region and has the advantage of being relatively easy to apply in the field (Chadde et al. 1998).

Monitoring

The establishment of long-term studies, including monitoring programs, can lead to a better understanding of the magnitude and direction of change in dynamic landscapes. Human activities and management paradigms can be modified appropriately. Recent analysis of peatlands in northern Idaho have revealed a significant level of change in these systems that is likely attributed directly or indirectly to human activities (Bursik and Moseley 1992). Human impact on Sierra Nevada fens remains largely speculative (Bartolome et al. 1990). Durham (2002) has prepared a rigorous Fen Monitoring Study Plan for the Sierra Nevada Mountains that would be valuable if implemented.

Research

A standardized classification of peatlands based on landscape features, hydrology and water chemistry, and vegetation would be useful in describing peatlands. Such a multifaceted classification would provide a useful tool for predicting or modeling a site's potential as rare plant habitat. Hydrologic studies are needed to protect and maintain peatland integrity, and have direct bearing on how lands adjacent to peatlands may be best managed without degrading peatlands (Gorham 1994).

The inventory of *Meesia* species on peatlands in the Sierra Nevada bioregion would lead to a research program to examine the habitat requirements and autecology, including detailed studies of life history. We need to learn more about how these *Meesia* plant communities might respond to impacts from land disturbances caused by Forest Service activities such as grazing and logging. Are *Meesia* species particularly sensitive to disturbance; are they capable of sufficiently rapid migration to suitable habitats?

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Appendix 1. Weixelman locations data for fens in the Sierra Nevada Mtns (2003).

PLOT COD	PLOT NAM	FOREST	DOMINANT_SPECIES	LAT	MIN	SEC	LONG	MIN	SEC
ELD0101	Onion valley	EIDorado	Scirpus congdonii	38	33	53.2	120	11	15
INY0054	Mcgee park station	Inyo	Carex nebrascensis	37	33	20.8	118	47	35.5
INY0103	Sanger	Inyo	Carex nebrascensis	37	10	53.9	118	26	43.4
INY0120	Upper casa vieja	Inyo	Carex nebrascensis	36	11	55.4	118	15	31.5
LAS0005	Westwood junction	Lassen	Juncus balticus	40	26	11.8	120	56	36.2
LAS0009	Bond valley	Lassen	Eleocharis acicularis	40	26	21.9	121	8	17.8
LAS0014	Cooper swamp	Lassen	Eleocharis pauciflora	40	30	31.5	121	8	5.9
LAS0020	Barne's flat	Lassen	Carex vesicaria	40	27	49.9	121	5	55.7
LTB0004	Grass lake meadow	LTBMU	Juncus mexicanus	38	47	21.5	119	57	5.4
LTB0006	Hell hole meadow	LTBMU	Carex limosa - Carex uti	38	49	42.3	119	56	40.7
PLU0201	Tamarack flat	Plumas	Eleocharis machrostachy	121	2	38.7	39	52	3.3
PLU0202	Silver lake fen	Plumas	Carex echinata	121	7	50.8	39	57	30.1
PLU0203	Right hand crk wet mead	Plumas	Eleocharis machrostachy	121	10	22.1	39	56	32.2
SIE0003	Cold springs west mead	Sierra	Carex nebrascensis	37	24	59.1	119	29	59.5
SIE0004	Poison meadow	Sierra	Carex echinata	37	23	53	119	31	11.9
SIE0006	Hogan meadow	Sierra	Carex echinata	37	28	11.9	119	29	5.7
SIE0007	Polk salt log meadow	Sierra	Scirpus congdonii	37	28	44.9	119	30	41.3
SIE0009	Lower murray meadow	Sierra	Juncus oxymers	37	28	4.2	119	32	50.5
SIE0018	Willow meadow	Sierra	Phalacroseris bolanderi	37	9	1.3	119	7	1.9
SIE0020	Lorenzana meadow	Sierra	Eleocharis pauciflora	37	12	30.6	119	10	49.8
Sierrafen	Bull meadow	Sierra	Carex vesicaria	36	58	46	119	4	46
TAH0116	Cornish flat	Tahoe	Mimulus primuloides	39	30	22.5	120	47	0.1
TAH0117	Nebraska flat	Tahoe	Scirpus congdonii	39	30	6.7	120	46	20.5
TAH0118	Galino cow camp	Tahoe	Carex simulata	39	30	54.9	120	48	34.7
TAH0119	Harris meadow	Tahoe	Carex echinata	39	31	23.3	120	43	49.6
TAH0201	Sagehen creek	Tahoe	Carex capitata	39	26	15.1	120	16	48.9
TAH0202	Oakland pond	Tahoe	Carex utriculata	39	39	26.4	120	40	36.9
TAH0209	Pat yore flat	Tahoe	Eleocharis pauciflora	39	24	46.6	120	42	17.7
TAH0216	Pig canyon spring	Tahoe	Carex luzulina	39	36	13.2	120	43	4.4
TAH0217	Harris meadow north	Tahoe	Scirpus microcarpus	39	31	40.9	120	43	29.6