Conservation Assessment

For

Appalachian Vittaria (Vittaria appalachiana Farrar & Mickel)

Photo credit: Donald R. Farrar

USDA Forest Service, Eastern Region

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This document is undergoing peer review, comments welcome

This Conservation Assessment was prepared to compile the published and unpublished information on the subject taxon or community; or this document was prepared by another organization and provides information to serve as a Conservation Assessment for the Eastern Region of the Forest Service. It does not represent a management decision by the U.S. Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if you have information that will assist in conserving the subject taxon, please contact the Eastern Region of the Forest Service - Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203.

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EXECUTIVE SUMMARY

Vittaria appalachiana is a fern that exists only in the gametophyte phase of the fern life cycle. Long known as the "Appalachian gametophyte" it was identified as genus *Vittaria* in 1963 and subsequently determined genetically to be distinct from all other known New World Vittariaceae. It was described as a new species endemic to the eastern US in 1991.

Because it does not complete a sexual life cycle, *Vittaria appalachiana* reproduces exclusively by vegetative means. In addition to clonal expansion it produces detachable gemmae that may be dispersed locally by small animals but are too large to be effectively transported by wind. Consequently many apparently suitable habitats are unoccupied, especially man-made habitats (e.g., tunnel entrances and road cuts in bedrock near existing populations), geographically isolated habitats and habitats more than a few miles beyond the southern limits of Pleistocene glaciation.

Because of its limited dispersal capacity, once extirpated from isolated sites, *Vittaria appalachiana* is unlikely to recolonize those sites. Fortunately, the cliff and rockhouse habitats of *V. appalachiana* are exceptionally stable and additionally are often protected in parks and other special use areas for their scenic beauty and for the biological communities they support. The greatest threat to *V. appalachiana* populations is permanent desiccation of their habitats due to activities such as deforestation that opens the habitats to greater sunlight and wind penetration and most importantly to greater precipitation runoff resulting in insufficient recharge of the area bedrock. Most *V. appalachiana* populations do not receive any direct moisture and are dependent on permanent moisture held in interstitial spaces in the porous bedrock on which they grow.

Although genetically uniform within populations, *Vittaria appalachiana* is genetically variable among populations. Because it reproduces vegetatively, inbreeding depression associated with small genetically homozygous populations is not a problem. Its range-wide genetic variability, along with fixed heterozygosity derived from allopolyploidy, may mitigate vulnerability to regional climate change.

Vittaria appalachiana is listed globally as G4 (apparently secure). It is abundant in the heart of its range in the Appalachian Mountains and Appalachian Plateau from North Carolina to Alabama and north to Pennsylvania and Ohio. In Forest Service Region 9 it is listed as S1 in New York and West Virginia, S2 in Indiana and Pennsylvania and SNR in Ohio.

Vittaria appalachiana grows in deeply recessed crevices, grottos and rockhouses in bedrock cliffs of sandstone, schist, and other porous, non-calcareous rock. Most populations cannot be easily detected without the aid of a flashlight, consequently it is likely that more populations exist than are currently known. Additional surveys for *V. appalachiana* in Indiana and West Virginia are likely to be productive.

ACKNOWLEDGEMENTS

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NOMENCLATURE AND TAXONOMY

Vittaria appalachiana Farrar & Mickel

Synonyms: None

Common Names: Appalachian Vittaria, Appalachian Shoestring Fern

Long known as the Appalachian gametophyte, these plants were first recognized as the gametophyte generation of a fern by bryologist A. J. Sharp in 1930. It was formally assigned to the genus *Vittaria* by Wagner and Sharp in 1963. Morphological and molecular genetic studies by D. R. Farrar (1971, 1978, 1985) determined that the Appalachian plants were not conspecific with any other New World Vittariacea. Farrar and Mickel published *Vittaria* appalachiana as a new species in 1991. The common name of "Appalachian gametophyte" is not appropriate since several other species of sporophyte-less fern gametophytes are now recognized in the Appalachian Mountains (Farrar 1967, 1992, Raine et al. 1991).

Gastony (1977) reported the chromosome number of *Vittaria appalachiana* to be 120, twice the number expected of a haploid gametophyte in the *Vittaria* genus. Farrar (1978) reported fixed heterozygosity at several gene loci, indicating that *Vittaria appalachiana* probably originated as a hybrid between two diploid *Vittaria* species which doubled its chromosomes to yield an allotetraploid species. Assuming spore production by meiosis, gametophytes of such a species would possess a diploid chromosome number as observed by Gastony and fixed heterozygosity as observed by Farrar. Subsequent elimination of the sporophyte phase of the life cycle resulted in *Vittaria appalachiana* as it currently exists.

DESCRIPTION OF SPECIES

Sporophyte lacking. Gametophyte green, epipetric or occasionally epiphytic, perennial and clone-forming by vegetative reproduction. Meristem of individual plants discontinuous, marginal on rounded branch apices; mature form consisting of a branched, ribbon-like thallus one cell in thickness, usually differentiated into basal and upright branches; basal branches

attached to the substrate by numerous short brown rhizoids emanating from marginal and interior cells; upright branches terminating in the production of gemmae. Gemmae highly variable, composed of uniseriate filaments of 2 to 12 cells, with rhizoid primordia absent from medial cells and often lacking on one or both end cells and with end cells often swollen; gemmae subtended by specialized round or flask-shaped gemmifer cells which usually remain attached to the thallus after gemmae are shed; abrupt transition between thallus, gemmifers, and gemmae frequently lacking. Archegonia produced on small lobes of the basal branches, often buried in the substrate; antheridia produced on small plants and especially on germinating gemmae. Chromosome number = 120. (Farrar and Mickel 1991).

LIFE HISTORY

Reproduction

Sexual reproduction. Sexual reproduction is unknown in *Vittaria appalachiana*. Plants of this species in nature are entirely of the gametophyte phase of the ferns life cycle with only a single exception. Farrar (1978) recovered three tiny sporophyte plants, each with leaves less than one centimeter long from a collection in Jackson Co., Ohio. These appeared to have been produced asexually by apogamy as were several small sporophytes obtained in culture by A. G. Stokey (unpublished notes) and J. Caponetti (personal communication). Although male and female gametangia are produced, the plants appear to be genetically or physiologically incapable of producing viable gametes and/or sexually formed sporophytes (Farrar 1978).

Asexual reproduction. Gametophyte plants of *Vittaria appalachiana*, like other species of *Vittaria*, produce vegetative propagules called gemmae. These are short filaments of cells produced on margins of thallus lobes, subtended by marginal cells called gemmifers. An abscission zone forming between gemmifers and their attached gemmae allow the gemmae to be easily detached and dispersed. Upon arrival in a suitable habitat, dispersed gemmae can grow into new gametophytes (Farrar 1978).

As well as producing dozens of gemmae, each gametophyte is perennial, indefinitely extending its own growth along the substrate. As a colony multiplies by gemmae dispersal and vegetative growth, it can become a source of hundreds of gemmae per square centimeter or more than a million gemmae per square meter. In prime habitats, gametophytes of *Vittaria appalachiana* can occupy 10 square meters or more of rockwall habitat in a dense, bryophyte-like covering.

Though plentiful, gemmae are not a means of long-distance dispersal because at 0.2 to 0.5 mm long they are too large to be efficiently carried by wind currents (Ingold 1971), and furthermore could not easily, by wind, be extracted from or deposited into the deep rock crevices, grottos and rockhouses in which they grow. More likely they are transported locally by invertebrates, salamanders, small mammals and birds that frequent these same habitats.

Ecology

Vittaria appalachiana plants are evergreen perennials. Although capable of withstanding both desiccation and freezing, they thrive in habitats that are nearly continuously moist (but not wet) and maintain moderate temperatures that are seldom below freezing (Farrar 1978, 1983, 1998). Habitats maintaining these conditions are deep crevices, grottos and rockhouses in porous bedrock cliffs. Moisture in these habitats is provided by groundwater held within the porous bedrock. Bedrock types supporting *Vittaria appalachiana* are sandstones cemented by iron oxides, schists and acid shales. Plants are seldom found on non-porous bedrock such as granites, limestones or dolomites, and not on sandstones in which the quartz grains are cemented together by calcium carbonate. Plants have been found on calcareous bedrock on only two occasions, one on marble in western North Carolina, the other on continuously moist seepstone on the roof of a cave entrance in Alabama. Other uncommon substrates are cavities between flaring roots of large beech trees (*Fagus grandifolia*) in the southernmost portions of the range of *Vittaria appalachiana* and on a coal seam under overhanging sandstone in northern Georgia (Farrar 1978).

A condition common to all of these habitats is a very low light level, often on the order of 1% of full sunlight (100 foot candles or 1000 lux). Many populations cannot be seen without the aid of a flashlight. Low light is a consequence of the need for maintenance of moisture and temperature at levels suitable for photosynthesis, especially in winter when light levels are highest due to the absence of a deciduous tree canopy. Measuring the year-round microclimate and photosynthetic capabilities of *Trichomanes boschianum*, a common associate of *Vittaria appalachiana*, Farrar (1998) concluded that net photosynthesis in these habitats may be approximately equal in summer and winter with peaks in spring and fall when temperatures are moderate and light levels, in the absence of a deciduous canopy, are highest.

A good rule-of-thumb for assessing the microclimate suitability of a habitat is the amount of open sky to which the plants would be exposed in winter, 1/10 to 1/4 full exposure being suitable. Greater exposure allows too much radiative cooling, less exposure allows insufficient light for photosynthesis (Farrar 1998).

Vittaria appalachiana plants generally grow at light levels too low for most bryophyte species. A solid mat of mosses or liverworts usually indicates light exposures to high for *Vittaria appalachiana*. Growth of *Vittaria appalachiana* at light exposures too low for bryophytes is likely mode possible by its higher ratio of photosynthetic to non-photosynthetic tissue (Farrar 1998). In *Vittaria appalachiana* plants, all cells except the hair-like rhizoids are photosynthetic whereas bryophytes must maintain non-photosynthetic stem tissues as well as rhizoids. [Bryophytes, in turn, have a higher photosynthetic to non-photosynthetic tissue ratio than do seed plants and thus can grow in darker habitats than can seed plants. A few bryophytes species have light focusing cells that allow them to grow in darker habitats than most species. One of these, *Hookeria acutifolia*, often grows with *Vittaria appalachiana* and is a good indicator of appropriate habitat. (Farrar 1978)] This adaptation for growth at low light levels is not a specific adaptation in *Vittaria appalachiana*, but rather a characteristic common to the gametophyte generation of most ferns species.

Dispersal/Migration

Several observations indicate that *Vittaria appalachiana* is not a strong disperser (Farrar 1978, 1983).

1. *Vittaria appalachiana* is absent from man-made "rockhouse" structures such as tunnels, mine entrances and road cuts, even when these are adjacent to natural populations in the same rock formations.

2. *Vittaria appalachiana* is often absent from natural habitats that appear to be entirely suitable and near natural populations in the same rock substrate.

3. *Vittaria appalachiana* is not found in apparently suitable habitat more than a few miles within the boundaries of Pleistocene glaciation despite the presence of several of its common bryophyte and pteridophyte associates, most notably the independent gametophytes of *Trichomanes intricatum* which share the same life history characteristics.

4. *Vittaria appalachiana* is not present in southern Illinois in identical and more extensive Pennsylvanian sandstone canyon formations that support it in Indiana and western Kentucky. Illinois is isolated from these sources by broad river bottoms of the Ohio and Wabash Rivers.

5. Although *Vittaria appalachiana* displays site to site genetic variability, individual populations and series of populations within individual canyons are almost always composed of a single genotype (Farrar 1990). This pattern of intrapopulation uniformity within interpopulation variability is characteristic of asexually reproducing organisms with no gene flow between populations (Hamrick and Godt 1990; Pleasants and Wendel 1989).

Absence of *Vittaria appalachiana* from apparently suitable habitats can best be explained by assuming that these have not been continuously suitable in the past, and once eliminated from an area, *Vittaria appalachiana* is unable to migrate back into that area. Thus, if the canyons of southern Illinois became too dry to support *Vittaria appalachiana* during the hypsithermal interval from about 5,500 to 3000 years ago (Baker et al. 1992) *Vittaria appalachiana* may have been unable to re-enter the state across broad river bottoms of the Ohio and Wabash Rivers that would have been barriers to its dispersal agents. Unoccupied habitats within canyon systems housing *Vittaria appalachiana* may likewise be too recent in origin to have received propagules. "Too recent" may be on the order of hundreds of years judging from the absence of *Vittaria appalachiana* from very old tunnels and road cuts.

These considerations raise the issue of the stability of all *Vittaria appalachiana* habitats. While there is obviously some continuous creation and loss of grottos and rockhouses due to erosion, the long stability of these formations is also attested to by records of human occupation dating from 10,000 to 14,000 years in some rockhouses (Adovasio and Carlisle 1988). Well

documented sites, including many state parks, seldom record any change in their sandstone formations.

The limited dispersal/migration capacity is due to absence of an efficient, long-range dispersal mechanism. Because *Vittaria appalachiana* has lost the spore-producing sporophyte phase of a typical fern life cycle it can no longer disperse by spores as it presumably did in initially establishing its current range. Gemmae produced by fern gametophytes are too large for wind dispersal (Ingold 1971). Rather they are adaptations for local spread and perenniation and for promotion of cross fertilization with populations (Dassler and Farrar 2001).

Gemmae are not "sticky", nor do they possess hooks or barbs that might aid dispersal via animal vectors. To the extent that they are dispersed, the most likely vectors would seem to be invertebrates such as camel crickets and millipedes, small mammals such as salamanders and mice and birds such as phoebes and wrens that nest or forage in *Vittaria appalachiana* habitats.

Examination of the range-wide distribution of multilocus genotypes reveals a non-random pattern. A concentration of variability exists along an Ohio to Alabama axis within the network of sandstone canyons of the eastern portions of the Appalachian Plateau with a subset of genotypes (the most common genotypes) in the Appalachian Mountains and western portions of the Appalachian Plateau (Farrar 1990). This pattern would not be expected if *Vittaria appalachiana* was founded by long-distance transport of spores from a tropical ancestor. More likely *Vittaria appalachiana* originated in the Appalachian Plateau in a pre-Pleistocene time when the climate was warmer and *Vittaria appalachiana* possessed a complete life cycle and regional dispersal by spores was possible. Subsequent climate cooling in the Pleistocene Epoch eliminated the frost-sensitive and high-light demanding sporophyte phase from the life cycle.

Obligate Associations

Vittaria appalachiana has no known obligate associations.

HABITAT

Range-wide

Vittaria appalachiana, throughout its range, grows almost exclusively on exposed surfaces of non-calcareous bedrock that is porous and holds a permanent reservoir of groundwater. *Vittaria appalachiana* grows in sheltered crevices, grottos and rockhouses where it is not exposed to direct sunlight or precipitation and little wind. It grows on all surfaces of these protected chambers including the ceilings. Occasionally it grows on thin accumulations of soil on the chamber floor. Rarely, in the southern part of its range, it grows in chambers formed by flaring root buttresses of large beech trees (*Fagus grandifolia*) where these grow near canyon walls that also support populations of *Vittaria appalachiana*. All habitats have in common a more or less continuous supply of moisture and protection from extremes of temperature. See **Ecology** for a more detailed discussion of habitat microclimates.

Most supportive habitats are in narrow, steep-sided canyons with mature forest canopies. Elevation ranges from 500 to 6000 feet. The type habitat for *Vittaria appalachiana* is in crevices and grottos of sandstone cliffs in Hocking County, Ohio.

National Forests

In Indiana, Ohio and New York, *Vittaria appalachiana* grows exclusively in crevices, grottos and rockhouses in sandstone cliffs. In Pennsylvania and West Virginia *Vittaria appalachiana* grows in these sandstone habitats and in similarly protected habitats in schist and shale, often along fast-flowing streams and near waterfalls.

Site Specific

Known occurrences of *Vittaria appalachiana* in Indiana, West Virginia and New York are listed in Tables 1,2 & 3. Occurrences in Ohio and Pennsylvania are numerous (see discussion under state distributions).

Table 1. Recorded Indiana sites for *Vittaria appalachiana*

Site Name	County	EO#	Location	Owner	Collector	Date*	Habitat
Forest Service Records							
Shooting Star Cliffs	Perry	001		Forest Service		1988	cave-like recess in sandstone cliff
Morgan Ridge	Perry	002		Forest Service		1989	vertical sandstone cliff
Middle Deer Creek	Perry	003	east tributary off Middle Deer Cr.	Forest Service		1989	sandstone bluff
Morgan Ridge**	Perry	004	Head of Rock-house Hollow	Forest Service		1989	sandstone canyon
Hemlock Cliffs	Crawford	005	section 4	Forest Service		1989	sandstone rockhouse
Hemlock Cliffs	Crawford	006	section 4	Forest Service		1989	sandstone rockhouse
Other Records							
US Highway 62/37	Crawford		east of Perry County line	private	Farrar	1669	sandstone cliffs along highway
US Highway 62/37	Crawford		west of West Fork	private	Wagner	1971	sandstone cliffs along highway
Yellow Birch Ravine	Crawford		southeast of Tazwell	private	Yatskievych & McCrary	1983	sandstone bluffs
Mifflin	Crawford		southeast of Mifflin	private	Gastony	1976	sandstone bluffs
Hemlock Cliffs	Crawford		sec. 8, west of Grantsburg	Forest Service	Farrar	1981	sandstone rockhouse
East Fork of White River	Martin		north of Shoals	private	Farrar	1981	grottos in sand-stone bluffs
East Fork of White River	Martin		south of Shoals	private	Yatskievych & McCrary	1983	sandstone bluffs
Plaster Creek	Martin		southwest of Shoals	Forest Service?1	Yatskievych & McCrary	1984	sandstone bluffs
Plaster Creek	Martin		Plaster Creek Special Area	Forest Service	Larson	2005	sandstone bluffs
Penitentiary Rocks	Perry		near Mount Pleasant	private	Farrar	1981	sandstone rockhouse
Abbot's Hollow	Perry	near 001	west of Branchville	private	Yatskievych & McCrary	1982	sandstone cliffs
Rich Cave Hollow	Perry	near 001	north of Branchville	private	Yatskievych & McCrary	1982	sandstone cliffs
Rockhouse Hollow	Perry	004	northwest of Derby	Forest Service	Homoya et al.	1986	sandstone cliffs
Peter Cave Hollow	Perry		Oil Creek Special Area	Forest Service	Farrar & Larson	2003	sandstone cliffs

*Only the date of first observation is recorded. Many of the sites have been revisited one or more times by Farrar and others. All are presumed to be extant.
**Township and range data place this site at the head of Rockhouse Hollow. It may be the same site as the Rockhouse Hollow site recorded by Homoya.

Table 2. Recorded West Virginia sites for *Vittaria appalachiana*

Site Name	County	EO#	Location	Owner	Collector	Date*	Habitat
Forest Service Records							
Falls of Hills Creek	Pocahontas	001		Forest Service		1970	under deep rocky overhangs
Blackwater Falls	Tucker	002		WV DNR		1972	under rock overhang
Audra State Park	Barbour	003		WV DNR		1990	north facing sandstone
Other Records							
Hills Creek	Pocahontas	001	upper falls	Forest Service	Wagner	1970	under deep rock overhangs
Blackwater Falls	Tucker	002		WV DNR	McAlpin		in crevices near falls

*Only the date of initial discovery is listed. All sites are presumed to be extant.

Table 3. Recorded New York sites for *Vittaria appalachiana*

Site Name	County	EO#	Location	Owner	Collector	Date*	Habitat
Rock City Park	Cattaraugus		Route 646/16	private	Parks	1983	north-facing sand-stone rockhouses
Nichols Run Road	Cattaraugus		west of Route 646/16	private	Parks	1983	shaded crevices of sandstone
Panama Rocks Park	Chautauqua		Panama	private	Parks	1983	se-facing sand-stone rockhouses

*Only the date of initial discovery is listed. All sites are presumed to be extant.

DISTRIBUTION AND ABUNDANCE

Range-wide Distribution

Vittaria appalachiana ranges in the south from the gorges of the southern Blue Ridge escarpment in South Carolina westward across the Appalachian Mountains of northern Georgia and northeastern Alabama to the sandstone canyons of the Appalachian Plateau in northwestern Alabama and northeastern Mississippi (a single locality). It extends northward in the sandstones of the Appalachian Plateau to western Kentucky, southern Indiana, southern and northeastern Ohio, western Pennsylvania and southwestern New York. It extends eastward across the Appalachian Mountains of Pennsylvania and southward along the Blue Ridge Mountains with occasional occurrences where sandstones outcrop along the piedmont of North Carolina. In elevation *Vittaria appalachiana* ranges from 500 feet in canyons of the Appalachian Plateau to over 6000 feet in the Great Smoky Mountains (Farrar 1978).

State and National Forest Distribution

Indiana

Fifteen site occurrences of *Vittaria appalachiana* have been recorded in Indiana, at least seven of these in the Hoosier National Forest (Table 1). It has been recorded in Crawford, Martin and Perry counties. Yatskievych et al. (1987) reported 12 occurrences, only two of which, Hemlock Cliffs and Rockhouse Hollow, are currently listed in the Indiana Natural Heritage Database of element occurrences.

Ohio

Vittaria appalachiana is present in high abundance in the Hocking Hills and surrounding areas of sandstone canyons of southern Ohio. It has also been recorded from Lake and/or Geauga counties in northeastern Ohio where it occurs on Little Mountain "on dark moist faces of Sharon Conglomerate (sandstone)" (Cusick 1983). The type locality for *Vittaria appalachiana* is Cedar Falls in Hocking Co. The Hocking Hills of southern Ohio and similar sandstone canyons of northwestern Alabama are where *Vittaria appalachiana* reaches its greatest abundance and greatest genetic diversity.

New York

Vittaria appalachiana occurs in rockhouses in Pennsylvanian sandstones at Rock City and Nichols Run in Cattaraugus County and at panama Rocks in Chautauqua counties in southwestern New York. The Cattaraugus County sites are in the only area of New York not overridden by Wisconsinan glaciation. The Chautauqua County site is about 12 miles within glaciated terrain (Parks and Farrar 1984).

Pennsylvania

Vittaria appalachiana is abundant in Pennsylvania, having been recorded in 24 sites in 21 counties (Parks 1989). It grows in two types of habitats in Pennsylvania—under overhanging schist outcrops along fast-flowing tributaries to the Susquehanna River in the southeastern part of the state, and in rockhouses in Pennsylvanian age sandstones in western and northeastern Pennsylvania. It is notably absence from the many sandstone and shale habitats in the Pocono Mountains in the northeastern corner of the state that are more than about 20 miles within glaciated territory although many of its bryophyte and pteridophyte associates elsewhere are present in this part of the state (Parks 1989).

West Virginia

Vittaria appalachiana is known from thee sites in West Virginia—a National Forest site in Pocahontas County, a WVDNR site in Tucker County and a state park site in Barbour County, all under overhanging rock, identified as sandstone in the Barbour Co. site.

RANGE WIDE STATUS

Vittaria appalachiana is common throughout most of its range, occurring in abundance throughout the Appalachian Mountains and Appalachian Plateau south of the southern limits of Pleistocene glaciation wherever streams have carved steep-walled canyons and gorges lined with outcroppings of porous, non-calcareous bedrock. *Vittaria appalachiana* becomes less common where suitable bedrock habitats are isolated, probably due to its limited dispersal ability. *Vittaria appalachiana* is curiously absent from the extensive canyon systems in Pennsylvanian age sandstones in southern Illinois and Arkansas. These western areas appear to provide suitable habitats today, but perhaps they became too dry during the hypsithermal interval (5,500 to 3000 years ago) and *Vittaria appalachiana* has been unable to recolonize these areas due to its inefficient dispersal system.

In National Forest Region 9, *Vittaria appalachiana* is listed as Regional Forester Sensitive in the Hoosier National Forest in Indiana.

The USDA Natural Resources Conservation Service lists *Vittaria appalachiana* as Rare in Indiana, Endangered in New York and Threatened in Pennsylvania

A summary of the range-wide Heritage Status of *Vittaria appalachiana* as compiled by Nature Serve is presented below (NatureServe 2006).

NatureServe Status

Global Status: G4 (27Apr1995)
Rounded Global Status: G4 - Apparently Secure
Global Status Reasons:

Vittaria appalachiana is abundant within its range. Much of its rock-shelter habitat is currently protected. This species is extremely vulnerable, however, to any changes in its specialized habitat.

Nation: United States

National Status: N4

U.S. & Canada State/Province Status	
United States	Alabama (SNR), Georgia (S3?), Indiana (S2), Kentucky (S3?), Maryland (SNR), New York (S1), North Carolina (S2S3), Ohio (SNR), Pennsylvania (S2), South Carolina (SNR), Tennessee (SNR), Virginia (SU), West Virginia (S1)

Overall Degree of Threat: The primary threat to *Vittaria appalachiana* is logging above the rock shelters in which it occurs. Deforestation opens the canyons and causes them to dry out, which in turn destroys the moist, climate-controlled habitat. Because many habitats for this species are on protected lands, *V. appalachiana* is not currently threatened.

POPULATION BIOLOGY AND VIABILITY

Much evidence suggests that *Vittaria appalachiana* has extremely limited potential for dispersal (see discussion under **Dispersal/Migration**). Its absence from man-made as well as natural habitats of apparent suitability that are adjacent to (i.e., within 10 meters) of occupied habitat indicate high improbability of recolonization of isolated habitats. Reinforcing these observations are the size of its propagules (gemmae) that are too large for efficient wind dispersal and the observed fact that most populations are composed of a single genotype even where multiple genotypes are present in the region (e.g., Hocking Hills of southern Ohio). For these reasons, currently occupied sites are best considered as relict populations (Farrar 1998).

The most likely dispersal agents for *Vittaria appalachiana* gemmae are invertebrate and small vertebrate animals that inhabit the same crevices, grottos and rockhouses. As vectors, these agents probably accomplish some dispersal within canyon areas of relatively continuous habitat, but it is difficult to envision dispersal of these animals across unsupportive habitat from canyon to canyon.

With such limited dispersal capacity, *Vittaria appalachiana* would seem to be vulnerable to extinction, yet it remains, range-wide, one of the most abundant fern species in North America. This is probably due to 1) an original widespread abundance achieved by spore dispersal before it lost the sporophyte phase of its life cycle, 2) the extreme durability of the rock formations and microhabitats in which it lives, and 3) the lack of competition from other plants in its microhabitats that are too dark even to support most bryophyte species. Consequently, so long as the physical habitat and its microclimate remain stable, there is little likelihood of loss of *Vittaria appalachiana* from a given site. This is particularly true for an individual rockhouse or stretch of canyon wall where microhabitats are more or less continuous and dispersal via invertebrate and small vertebrate animals becomes more likely.

Because reproduction is entirely vegetative, lack of genetic variability within populations is not a problem from the standpoint of inbreeding depression.
Obviously current genotypes, although fixed within populations, are well adapted to their current niches. Adaptability to regional climate change may be of greater concern, however limited adaptability at the level of individual populations is tempered by interpopulational variability and the large latitudinal range occupied by the species. Susceptability is further tempered by the stability of the microclimates within the cave-like recesses that *Vittaria appalachiana* occupies (see discussion under **Dispersal/Migration**).

Possibly *Vittaria appalachiana* has also achieved some greater environmental tolerance, relative to that of most fern gametophytes, through its diploid genome that possesses fixed heterozygosity at many gene loci.

POTENTIAL THREATS

Present or Threatened Risks to Habitat

As discussed above, loss of *Vittaria appalachiana* from a given isolated site is likely irreversible due to the poor dispersal ability of the species. Thus preservation of known sites is imperative to maintain the species' presence in a given region. This becomes especially crucial in regions where known sites are few and isolated. Preservation of all current sites is of less concern in areas such as the Hocking Hills of southeastern Ohio where populations are numerous. Region 9 states with greatest susceptibility to loss of *Vittaria appalachiana* are Indiana, New York and West Virginia.

Because of the aesthetic attraction of the rockhouses and other rock formations of the canyons in which *Vittaria appalachiana* occurs, many of its sites are in state and private parks and preserves. Many of these sites receive large numbers of visitors annually, however, microhabitats of *Vittaria appalachiana* are so recessed and dark that few people venture to within arm's length of the plants and do not cause alteration of their habitat. A possible exception is the building of bonfires, a frequent activity in large rockhouses. However, I have not documented damage to *Vittaria appalachiana* populations in any of the many instances of this activity that I have observed.

The greatest threat to *Vittaria appalachiana* populations is desiccation of their microhabitats. Being deeply recessed in crevices, grottos and rockhouses, they receive moisture only through the rock substrate itself which acts like a porous sponge. The source of water held in these near-surface bedrocks is precipitation in the near vicinity that percolates into the groundwater and bedrock. Alteration of this water supply can occur through forest clearing, agricultural practices and development in the recharge areas that increases runoff and diminishes percolation into the soil and bedrock.

Alteration of forest cover in the valley adjacent to *Vittaria appalachiana* habitats can also negatively impact microhabits through increased light levels that allow growth of competing vegetation (especially bryophytes) and increased wind penetration that affects temperature stability and moisture retention in *Vittaria appalachiana* habitats.

I witnessed a dramatic affect of forest clearcutting on a *Vittaria appalachiana* population at Penitentiary Rock in Perry County Indiana when I visited the site in 1981 shortly after a near clearcut of the surrounding forest both above and in the valley below this large rockhouse. The site had held extensive robust mats of *Vittaria appalachiana* on the rockhouse ceiling, but all were dead or dying and falling from the rockhouse ceiling which had become too dry to support their continued growth.

Physical distruction of rock formations can destroy *Vittaria appalachiana* populations, but this is not a common practice. Neither the massively bedded sandstones nor the schists and shales supporting *Vittaria appalachiana* are heavily used in construction or for gravel or

minerals. An exception could be extraction of coal from seams above or below Pennsylvanian sandstones.

Over utilization

Vittaria appalachiana is not known to be used for any purpose.

Disease or Predation

No instances of disease or predation have been reported.

Inadequacy of Existing Regulatory Mechanisms
Other Natural or Human Factors

Vittaria appalachiana populations are afforded natural protection from disturbance by the nature of their microhabitats as discussed above. They are vulnerable to forest and land use practices that could alter the hydrology of their habitats. Specifically, these would be practices, including forest clear-cutting, that would cause more rapid runoff of precipitation and thereby prevent adequate water recharge of the porous rock formations on which *Vittaria appalachiana* is dependent for its source of moisture. Existing populations of *Vittaria appalachiana* could be safeguarded from this problem through banning of forest clear-cutting and other land use changes in land cover in an area surrounding the site (e.g., one square mile or more as determined necessary by a regional hydrologist). To achieve such regulation, sufficiently large tracts surrounding *Vittaria appalachiana* sites should be brought into ownership by cooperative public or private entities.

SUMMARY OF LAND OWNERSHIP & EXISTING HABITAT PROTECTION

Site records of *Vittaria appalachiana* on National Forest land are maintained by the Forest Service and all records for states are maintained in state Natural Heritage databases. Critical sites are revisited by state and Forest Service personnel as time permits but systematic monitoring is not performed.

In its Forest and Resource Management Plan the Hoosier National Forest in Indiana requires a protection buffer zone around cliffs of the type that support populations of *Vittaria appalachiana*. The 1991 Plan recommends that the Forest "prohibit vegetation management within a distance of 100 feet from the top and base of large cliffs or overhangs (distances measured horizontally).....For the purposes of this recommendation, large cliffs or overhangs are defined as rock outcrop areas which are 15 feet or more in height and 100 feet or more in length. These rock outcrop habitats are not limited to solid cliffs, and may include discontinuous rock faces." The 2006 Plan continues these recommendations with an exception for “possible salvage of dead and dying trees, or sanitation harvest provided it can be done without harming the plants or their viability.”

In addition, 8 of 11 known occurrences of *Vittaria appalachiana* on the Hoosier National Forest are within Forest Designated Special Areas that require management to emphasize the protection, perpetuation, or restoration of their special features and values (including sensitive species and their habitat).

SUMMARY OF EXISTING MANAGEMENT ACTIVITIES

See above.

PAST AND CURRENT CONSERVATION ACTIVITIES

See above.

RESEARCH AND MONITORING

Existing Surveys, Monitoring, and Research

Brief surveys for *Vittaria appalachiana* have been conducted by D. R. Farrar on several occasions over the past 40 years in each of the R9 States (Farrar 1971, 1978, 1991). Farrar and Parks (1983) spent two weeks surveying *Vittaria appalachiana* in Pennsylvania, recording six sites in five counties. Parks (1989) continued surveying annually in Pennsylvania and reported an additional 18 sites in 16 new counties, thus indicating the probable success of systematic surveys in other states. Yatskievych, Homoya and Farrar (1987) reported 12 sites for *Vittaria appalachiana* in 3 Indiana Counties. In the present study D. Farrar and K. Larson recorded additional sites for *Vittaria appalachiana* in Indiana.

Survey Protocol

Surveys should be conducted in areas of potential habitat as predicted by a combination of topography and bedrock geology. Appropriate habitats most often occur where streams have cut canyons into hard acidic sandstones of Pennsylvanian age (Pottsville formations or equivalent) or through outcrops of mica schists forming deep moist grottos and rock houses. Locations of such features can often be obtained from local residents familiar with the countryside.

Surveys can be conducted at any time of year. Potentially suitable cliff habitats as well as plant occurrences can be spotted more easily when the deciduous leaf canopy is absent.

It is imperative that a bright flashlight be used when searching for *Vittaria appalachiana*. Many sites are in the deepest recesses of crevices and grottos—reaching them may necessitate crawling. Identification usually requires collecting a small amount of the plants. A pair of forceps is useful for plucking the small plants from crevices and of bedrock. They can best be viewed in the field when placed on the lens of the flashlight using a 10X hand lens.

Vittaria appalachiana can be distinguished from liverworts and other fern gametophytes by the following combination of chacracteristis:

- thallus one cell thick
- midrib absent
- gemmae present on thallus branch tips
- gemmae in the form of short filaments 2 – 12 cells long

When the procedure above is used, gemmae can often be seen lying on the flashlight lens, having been shed from the parent thallus. If confirmation of identification is needed, plants can be sent to: D. R. Farrar, Department of EEOB, Iowa State University, Ames, Iowa 50011.

Research Priorities

Morphological description, analysis of life history, population genetics and discussion of probable origins of *Vittaria appalachiana* have been completed by Farrar (1978, 1990, 1998). The most important issues still to be resolved are the extent and mode of dispersal and migration. There appear to be many appropriate but unoccupied habitats, even within canyons where *Vittaria appalachiana* is common. Either those sites are unsuitable for reasons not apparent to us, or, they have not been suitable in the past and *Vittaria appalachiana* has not been able to colonize/recolonize them since they have become suitable. This could be tested by transplanting plants from nearby colonies (e.g., within 100 meters), growth of the transplants indicating that dispersal is limiting. A problem with this experiment is the difficulty of eliminating the possibility that undetected plants were already in the transplant habitat. This problem might be circumvented by heat sterilizing the transplant habitat. Creation of artificial grottos within and beyond occupied habitats might also be used to determine colonizing ability.

Any transplant experiments should be conducted only where plants are already abundant. Transplants should not be made to areas never having been documented as containing *Vittaria appalachiana*. Doing so negates the possibility of ever knowing whether the plants might have arrived on their own or have been there already but undetected.

The vector of dispersal of *Vittaria appalachiana* is not known, though invertebrates and small vertebrates frequenting these habitats are suspected. Collection of animals within *Vittaria appalachiana* habitats and examination of their bodies for presence of *Vittaria appalachiana* gemmae would be informative. It would also be useful to know how these animals disperse from site to site and how frequently they do so. A genetic analysis of the population structure of animal associates of *Vittaria appalachiana* could also be enlightening.

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