Conservation Assessment
for
Heart-leaved Foam-flower (Tiarella cordifolia)

photo credit: John Kohout

USDA FOREST SERVICE, EASTERN REGION

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Prepared by
Douglas Fields
and
Marjory Brzeskiewicz
Chequamegon-Nicolet National Forest
1170 4th Av South
Park Falls, WI 54552
715-762-2461

This Conservation Assessment was prepared to compile the published and unpublished information on Tiarella cordifolia. 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, 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 this species, please contact the Eastern Region of the Forest Service – Threatened and Endangered Species Program at 310 Wisconsin Avenue Milwaukee, Wisconsin 53202.

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EXECUTIVE SUMMARY

Heart-leaved Foam-flower (*Tiarella cordifolia*) is designated as a Regional Forester Sensitive Species on the Chequamegon-Nicolet and Ottawa National Forests in the Forest Service's Eastern Region (R9). The species' occurrence is documented but not designated as sensitive on the Hiawatha and Green Mountain National Forests. The purpose of this document is to provide the background information needed to prepare Conservation Approaches and a Conservation Strategy that will include management actions to conserve the species.

Tiarella cordifolia is an herbaceous perennial woodland plant in the family Saxifragaceae. It is frequent to common through most of its wide distribution in the eastern U.S. and Canada but becomes rare at the edges of its range, in Wisconsin and the western Upper Peninsula of Michigan, Nova Scotia, New Jersey and Mississippi. *T. cordifolia* reproduces by means of seed and stolons. Pollination is probably by insects, though no specific pollinators are mentioned in the literature. Foamflower exhibits morphological variability in the wild and many cultivars have been developed by horticulturalists. It is typically found in deciduous, hemlock-hardwood, or white-cedar forest habitats, often near seeps or streams, usually in rich, moist, often circumneutral soil. *T. cordifolia* appears to be relatively sensitive to forest canopy removal (due to logging or natural processes) and/or disturbance of the soil surface, possibly because it is shallow-rooted and intolerant of high light conditions. It also seems more limited in its ability to re-colonize isolated forest stands after disturbance than most common ground layer species. Other potential threats include exotic earthworms, invasive exotic plants, and global warming. Foamflower is listed as endangered in Wisconsin and New Jersey. The species receives some protection on National Forest lands in Wisconsin and Upper Michigan, but other occurrences are on private land where protection may not be required by law. Several possible reasons for *Tiarella*'s scarcity in Wisconsin and the UP are discussed and a list of needed research topics is offered.

ACKNOWLEDGEMENTS

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INTRODUCTION

This Conservation Assessment provides a review of currently known information regarding the distribution, habitat, ecology, and population biology of Heart-leaved Foam-flower (*Tiarella cordifolia*) within its natural range. Special emphasis is given to the species in Wisconsin and the Upper Peninsula of Michigan and the National Forests on which it occurs. This document would also have applicability in other states on the periphery of foamflower's

range that currently list it or are contemplating listing. It is an administrative study only and does not include management direction or management commitment.

The National Forest Management Act and U. S. Forest Service policy require that Forest Service lands be managed to maintain viable populations of all native plant and animal species. A viable population is one that has the estimated numbers and distribution of reproductive individuals to ensure the continued existence of the species throughout its range within a given planning area (FSM 2670.5.22). In addition to those species listed as endangered or threatened under the Endangered Species Act, or Species of Concern by U. S. Fish and Wildlife Service, the Forest Service designates species that are sensitive within each region (Regional Forester Sensitive). *Tiarella cordifolia* is on the Regional Forester's Sensitive Species List for the Eastern Region (R9) for two national forests on which it occurs (Chequamegon-Nicolet and Ottawa). The objectives of management for such species are to ensure their continued viability throughout their range on National Forest lands, and to ensure that they do not become threatened or endangered because of Forest Service actions (FSM 2670.22).

NOMENCLATURE AND TAXONOMY

Scientific name: *Tiarella cordifolia* L.

Synonymy: *T. wherryi* Lakela (for *T. cordifolia* var. *collina* Wherry)

Common names: Heart-leaved Foam-flower, Heartleaf foamflower, Foamflower, False miterwort, Allegheny foamflower, Coolwort.

Family: Saxifragaceae

Taxon Codes: TICO (Natural Resource Conservation Service)
PDSAX10010 (Natural Heritage Program)

Linnaeus named *Tiarella cordifolia* in 1753 from cultivated material that was brought to Europe from North America much earlier. Later, two varieties, besides the typical var. *cordifolia*, became widely recognized: var. *collina* Wherry, without stolons, and var. *austrina* Lakela, with leaves and their terminal lobes longer than wide. Both are found in the southeastern U.S., coming as far north as Kentucky or Virginia (Gleason 1952). Various forms have also been recognized; for instance, Fernald (1950) lists three and Seymour (1969) another two. In her monograph of the genus, Lakela (1937) gave var. *collina* species status and named it *Tiarella wherryi* Lakela, a name by which it is sometimes still known, especially in the horticultural trade. Fernald (1950) followed Lakela in listing var. *collina* as a separate species. However, some more recent authors consider both var. *collina* and, especially, var. *austrina* to be of doubtful status (Soltis and Bohm 1984; Gleason and Cronquist 1991; Reveal 1991). But the fact that var. *collina* significantly departs from the typical *T. cordifolia* in lacking stolons and in some floral characters (Spongberg 1972) does

seem to argue for retaining it as a valid taxon. In 1991, Reveal designated one of Linnaeus' specimens as the lectotype for *Tiarella cordifolia* (Reveal 1991).

Fig. 1. *Tiarella cordifolia.*and capsular fruit (re-produced approximately 150% of original size).
(Illustration by Walter L. Graham. Reprinted with permission from The New York Botanical Garden Press. Originally published in H. A. Gleason, The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada, Vol. 2, p. 265, copyright 1952, The New York Botanical Garden.)

Species Description

Tiarella cordifolia is a delicate and beautiful colonial, stoloniferous (except for var. *collina*) herb with maple-shaped basal leaves and an airy raceme of fine, whitish flowers that give it a "foamy" appearance.

Leaves: Leaves are all basal (rarely with small cauline leaves). The leaf blade is broadly heart-shaped; 5-10 cm long by 3-8 cm wide with three to five lobes (rarely seven-lobed); sparsely hairy with unevenly toothed margins. Leaf petioles (4-9 cm) have long glandular hairs of different lengths (though on older petioles, most glands may have weathered off of the longer hairs). Semi-evergreen.

Scape: The scape, or flower stalk, is glandular, 4-10 cm, naked, or rarely with a small bract.

Flowers: The white to pinkish flowers are borne in a raceme 2-3 cm wide and 3-15 cm long on a glandular axis. The flowers bloom from the bottom to the top of the raceme, the top appearing more crowded before it elongates as blooms open (Fig. 2).

Petals: 5 petals, white to pinkish in color, lance- shaped 3-5 mm long, somewhat toothed on tip.

Sepals: 2 sepals subtending the petals, 3-5 mm, with gland-tipped hairs

Stamens: 10, slightly longer than the petals (2-7 mm) add to the foamy appearance of raceme

Carpels: 2, develop into capsules of unequal lengths (4-10 mm); ovary superior.

Seeds: numerous, ovoid, 1.5 mm, shiny and black; 2n=14. (Lakela 1937; Judziewicz 1983; Voss 1985; Chatfield 2001)

According to Rickett (1966) the name *Tiarella* "…means 'little tiara,' from the odd form of the fruit. A tiara was the headdress of the classical Persians – a kind of turban. ...The two halves of the pistil are curiously different in size, and the resulting fruit has a large lobe and a small one" (Fig. 1). The specific epithet *cordifolia* refers to the heart-shaped leaves.

The foliage of foamflower is similar in appearance to Bishop's cap (*Mitella diphylla*), which occurs in similar range and habitat. *Mitella* differs in having a pair of leaves located halfway up the flowering stalk and in having fringed flower petals. Characteristics of the hairs on the leaf petioles have been used to separate *Mitella* spp. and *Tiarella cordifolia* in Canada (Savile in Judziewicz 1983). Fernald (1906, 1917) cited sterile specimens that he felt were examples of rare inter-generic hybrids of *T. cordifolia* x *Mitella nuda* and *T. cordifolia* x *M. diphylla*.

Foamflower is a member of the Saxifrage family which includes commonly recognized wild and cultivated members such as *Astilbe*, *Chrysosplenium*, *Heuchera, Mitella,* and *Saxifraga.* Some authors also include Grossulariaceae (*Ribes*) and Hydrangeaceae (*Hydrangea*, *Philadelphus*) in Saxifragaceae. In its widest interpretation, the Saxifragaceae are a large, nearly cosmopolitan family, though best represented in the North Temperate Zone (Heywood 1993). The genus *Tiarella* includes two (or as many as five, depending on the author) North American and one Asian species (Reveal 1991; Gleason & Cronquist 1991).

Fig. 2. *Tiarella cordifolia* — inflorescence. (USDA, NRCS 2001- the PLANTS online database.)

LIFE HISTORY

Flowering, pollination, and propagation

T. cordifolia is a perennial, with the next year's plant arising from the root crown. Range-wide, flowering time of *Tiarella cordifolia* varies from early spring to summer. In the Midwestern states of Michigan and Wisconsin this means April to mid-July. Peak blooming time for known sites in northeastern Wisconsin is late May to mid-June. In Kentucky it flowers from March to May (Kentucky Native Plant Society 2002) and the median date for flowering in New York's Adirondacks is May 23 (Kudish 1992). The flowers open from the bottom to the top of the raceme (Fig. 2).

Detailed published information on pollination in *T. cordifolia* is lacking and it may be that a wide range of insects, including bees, butterflies, and syrphus flies, serve as pollinators (Palmer and Fowler 1975). However, Spongberg (1972) observed that even though the species appeared to have no adaptations for self-pollination, nectaries which might attract pollinating insects were not evident (though glandular hairs on the carpels might produce insect-attracting substances). The closely related western North American species *Tiarella trifoliata* is pollinated in part by a species of *Greya* moth that deposits eggs in floral pedicels, inadvertently carrying pollen from flower to flower (Pellmyr 1996). But *Greya* moths are apparently restricted to western North America and whether or not a similar plant-insect relationship exists for *T. cordifolia* is unknown. Western North American species of *Tiarella* were found to be self-compatible but not spontaneously self-pollinating (Kern 1966).

The first seeds of *T. cordifolia* ripen 5-7 days after the uppermost flowers have faded (Chatfield 2001). The small seed pods split, dropping the seed, presumably near the parent plant as the seeds are very small and have no mechanism for wind dispersal (Smith 2002, personal communication), though the species' habit of often growing along stream courses may aid in seed dispersal. The unequal wings (carpels) of the capsules in *Tiarella* (Fig. 1) may have adaptive value in seed dispersal in that water drops landing on the longer of the two wings have been observed to depress that carpel and open the valvate capsule (Spongberg 1972).

Foamflower (except for var. *collina*) also reproduces vegetatively by stolons, much as a strawberry plant, and can form fairly large colonies. In spring or summer the crown produces many pinkish stolons which are capable of developing roots at the nodes, each developing into a new plant. Sources differ as to whether stolons grow underground or on the surface; it might depend on soil conditions (Chatfield 2001; Sperka 1973; Fernald 1950).

Fig. 3. A garden cultivar of *T. cordifolia*. (Oregon State University 2002)

A grower in Crivitz, Wisconsin, reported that her plants of *T. cordifolia* rarely set seed (Sperka 1973). Whether due to climate or some other environmental condition, lack of suitable pollinators, or, possibly, seed predators, this could be a factor limiting the spread of wild populations in that state.

Many questions remain concerning the life history of this species. More information is needed on pollinators, seed dispersal mechanisms, and the rate of colony spread.

Cultivation

T. cordifolia was cultivated as early as the 1630's in Europe (long before the species was named by Linnaeus) from material of the typical variety collected in Virginia by John Tradescant the Younger (Reveal 1991). There is much variability in wild plants, a fact not lost on horticulturalists who have developed numerous garden forms (Liberty Hyde Bailey Hortorium, staff 1976; Brickell and Zuk, eds. 1996; Oliver 2002). Cultivars have been developed having deeply lobed leaves, pink flowers or patterned leaf colors (Fig. 3) (Oregon State University 2002).

As native wildflowers gain in popularity, foamflower is increasingly used as a garden plant. It is recommended for shade gardens for its attractive foliage and because it spreads to form weed-excluding mats (NHBirdsnest 2002). *Tiarella cordifolia* var. *cordifolia* is hardy in planting zone 3 (Rodda 2002), while var. *collina* may only be hardy to zone 5 (Brickell and Zuk 1996). Plants generally sell for between four and seven dollars each from garden centers and online nurseries.

Chatfield (2001) gives the following propagation advice: Clumps can be divided in early spring and replanted in soil high in organic matter with a pH of 5-6.5. The seeds are gathered after the uppermost flowers have faded. Cut the stalk carefully holding it over a paper bag so as not to lose the small seeds. Seed is best stored under refrigeration and should be sown in flats in late winter. They are ready to transplant to small pots in 6-8 weeks. Germination rate is usually high.

Phillips (1985) begins collecting seed approximately five to seven days after the uppermost flowers have faded. Mature seeds are shiny and black. The stalks are carefully cut and placed in a paper bag, then spread out on newspaper and allowed to dry for a day or two. Seed is separated from litter with a sieve, if necessary. Cleaned seeds are refrigerated in a sealed container and spring-sown into flats or pots which are then placed in a warm protected spot or coldframe. Thin seedlings to one-inch spacing and transplant to 2-3 inch pots in 6-8 weeks.

T. cordifolia can also be rapidly propagated by tissue culture. A protocol that allows economical direct field planting of microcuttings is set out in detail by Kitto and Hoopes (1992).

Medicinal uses

Leaves of *Tiarella* were used by Native Americans as a wash for mouth sores and eye ailments. The entire plant is rich in tannin, so has been used for its astringent properties in dressing wounds (Reed 2002). A tea made from leaves or roots is diuretic and has been used to help pass kidney stones and for other urinary problems, and for loosening phlegm in the chest (Krochmal and Krochmal 1973). Foamflower is reportedly useful in treating bladder and liver problems, as a tonic in indigestion and dyspepsia (Grieve 1971), and for the treatment of diarrhea (Plants For A Future 2000).

HABITAT AND ECOLOGY

Tiarella cordifolia is typically found in moist, rich, deciduous woods with fairly open understories and in partial to full shade. Older second-growth sugar maple (*Acer saccharum*) forest is the most common community. In Wisconsin, the northwestern edge of its range, foamflower occurs in mature, second-growth sugar maple-beech or hemlock-hardwood forest with sparse shrub layers. The soil is very moist due to a high water table in its usual stream-side habitat. The ground flora is rich with spring ephemerals and other herbaceous species, including *Dicentra, Dentaria, Viola* and *Mitella diphylla* (Wisconsin Natural Heritage Inventory data; Brynildson 1982). The relevant Wisconsin forest habitat types (based on Kotar et al. 1988) are Acer/Hydrophyllum (AH), Acer/Viola-Osmorhiza (AViO) (Wisconsin DNR 1993), and possibly Acer-Tsuga/Maianthemum (ATM) and Acer-Tsuga/Dryopteris (ATD). These habitat types are characterized by hardwood or hemlock-hardwood forest cover types and soils that are rich to medium in nutrients.

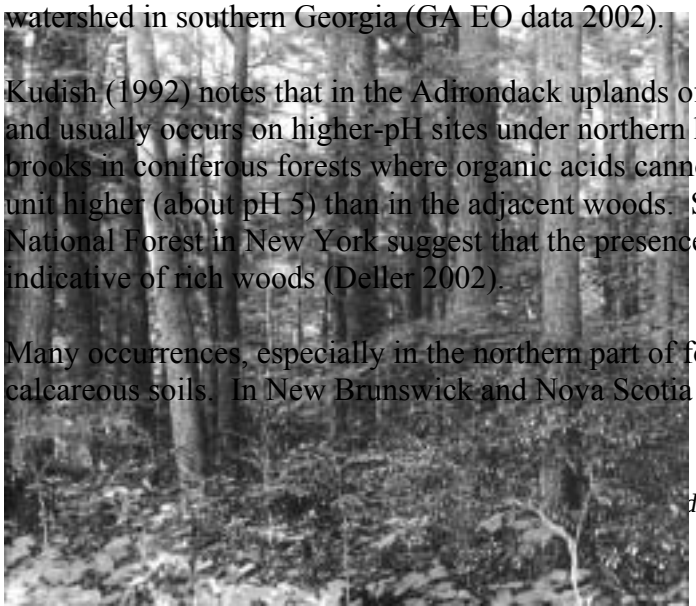
In Michigan *T. cordifolia* is found in deciduous and mixed woods, often in wet hollows or springy places (Voss 1985). A disjunct Michigan population in Berrien County, in the extreme southwestern part of the state, is on wet muck on an old forested glacial lake bottom with a diverse groundlayer and overstory of sugar maple, red maple, yellow birch, and slippery elm (Swink and Wilhelm 1994).

Besides sugar maple, trees often associated with foamflower in the northern part of its range include white ash (*Fraxinus americana*), yellow birch (*Betula allegheniensis*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*) and northern white-cedar (*Thuja occidentalis*). Appendix 1 lists other habitat associates from Natural Heritage element occurrence records.

Moisture appears to be a key micro-habitat component as most occurrences are along streams and in seepy places. On the White Mountain National Forest in New Hampshire foamflower is found in dense colonies at the edges of seeps and ephemeral streams, with soils composed of granitic parent material, some areas of calcareous bedrock, and a moderate buffering effect from limestone sedimentary rock material in the glacial drift. (Williams 2002). New Jersey Natural Heritage element data describes “boggy edge of streams” and damp to wet mossy seeps along the edge of a flooded swamp (NJ Natural Heritage Program EO data 2002). At the southern edge of its range it is restricted to stream courses in the Chattahoochee watershed in southern Georgia (GA EO data 2002).

Kudish (1992) notes that in the Adirondack uplands of New York foamflower is common and usually occurs on higher-pH sites under northern hardwoods, but it is also found along brooks in coniferous forests where organic acids cannot accumulate readily and pH is about a unit higher (about pH 5) than in the adjacent woods. Site surveys in the Finger Lakes National Forest in New York suggest that the presence of *Tiarella* is not necessarily indicative of rich woods (Deller 2002).

Many occurrences, especially in the northern part of foamflower’s range, are on relatively calcareous soils. In New Brunswick and Nova Scotia the species is found on fairly strong



d Foam Flower (Tiarella cordifolia)

calcareous soils where there is some seepage water flowing to the surface (from EO data). Blaney (2002) reports that in New Brunswick foamflower is most often found in *Thuja*-dominated habitats, especially valley slopes and creek valley floors, and in southern Ontario typically occurs in better-quality cedar seepage swamps and cedar-dominated riparian habitats.

T. cordifolia was probably an important element of the ground flora in at least parts of the original hemlock-white pine-northern hardwoods forest of New England. One of the last virgin climax forests in Connecticut, called the Colebrook tract (Fig. 4), was described in detail by G.E. Nichols shortly before it was cut in 1912 (Nichols 1913 in Braun 1950). "Immense" hemlock and beech, in about equal proportions, comprised 55 percent of the Colebrook tract, with smaller numbers of sugar maple, yellow birch, other hardwoods, and white pine. The ground layer was diverse but made a sparse cover, with *Oxalis montana* and *Tiarella cordifolia* being the two most "representative" species. Considering the composition of the Colebrook tract as described by Nichols, E. Lucy Braun (1950) felt that it was representative of the whole eastern part of the hemlock-hardwood forest.

In southern Ohio oak forests, *T. cordifolia* is fairly common on mesic sites (Hutchinson 2002). Ongoing studies there on the effectiveness of prescribed fire in maintaining oak dominance are also looking at its effects on understory vegetation, soils, animals, and other ecosystem components. Though no data specific to foamflower have yet been published, Hutchinson (2002) has observed that the fires have had no effect on the frequency of *T. cordifolia*.

T. cordifolia is semi-evergreen (at least in the colder parts of its range), defined here as a species whose leaves develop during deciduous forest canopy leaf-out and senesce after snow melt the following spring (Rothstein and Zak 2001a). Compared to spring ephemerals, which have very high rates of photosynthesis and biomass accumulation before canopy leaf-out in the spring, *T. cordifolia*'s capacity to utilize available sunlight varies within a relatively narrow range through the growing season. However, its ability to tolerate the long summer shade period and exploit the short periods of high irradiance in both spring and fall, as well as sunflecks in the summer, results in a net relative biomass gain exceeding that of *Allium tricoccum*, for example, a common spring ephemeral which shares the same habitat (Rothstein and Zak 2001a, 2001b).

Ecological Classification (Bailey 1997) for the major part of *T. cordifolia*'s range

Humid Temperate Domain

Warm Continental Division

Laurentian Mixed Forest Province
Northern Great Lakes Section
Southern Superior Uplands Section
New England – Adirondack Province
Hot Continental Division
Eastern Broadleaf Forest (Oceanic) Province
Central Appalachian Broadleaf-Coniferous Forest Meadow Province
Eastern Broadleaf Forest (Continental) Province

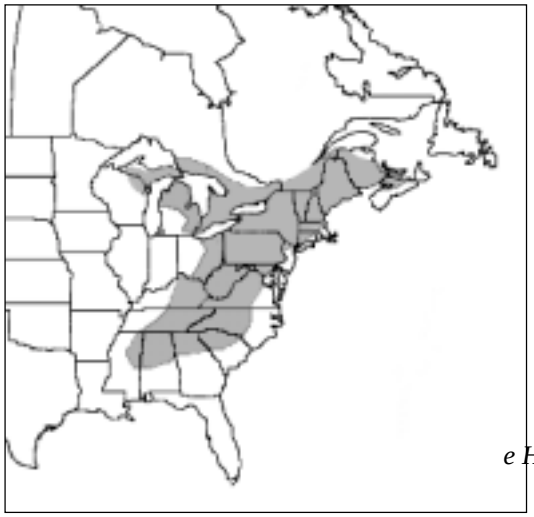
Wetland Indicator Status

Foamflower occurs in Regions 1, 2, and 3, according to the Natural Resource Conservation Service (NRCS) system for wetland classification (USDA NRCS 2001). In these regions it is a *Facultative (minus)* wetland indicator, meaning it is less likely to occur in wetlands than non-wetlands. The probability of it occurring in a wetland is between 34 and 66 percent; the *minus* putting it toward the 34 percent end of this range.

Geographical Distribution

Tiarella cordifolia ranges from northeastern Wisconsin to Nova Scotia and south through the Appalachians to Alabama and Mississippi (Fig. 5). The genus *Tiarella* also occurs in western North America and eastern Asia, indicating that this once was probably a widespread member of the Holarctic forest, a continuous mixed mesophytic forest community, which has since become divided into more restricted ranges by the gradual change of climatic conditions (Judziewicz 1983). This likely occurred during the late Miocene, about 10-12 million years B.P. Some 30 other genera of vascular plants also have closely related and highly disjunct species occurring in eastern North America, western North America, and eastern Asia (Soltis and Bohm 1984).

Foamflower is quite common in Michigan's Lower Peninsula, falling out in the southwest (except for an occurrence in Berrien County in the southwest corner of the state), but is rarer in the Upper Peninsula (Voss 1985). In Wisconsin, *Tiarella* is restricted to the northeastern counties of Door, Florence, and Oconto. The first verifiable collection in Wisconsin dates from 20 June 1950 (Maycock 1956). This represented a 200 mile northwesterly extension of the species' range as cited in Lakela (1937).



e Heart-leaved Foam Flower (Tiarella cordifolia)

Until 1978, the species was not known from Minnesota, but was collected in Stearns County that year (Judziewicz 1983). The Minnesota Natural Heritage Program lists it as "exotic" in the state (NatureServe 2002). Welby Smith (2002, personal conversation), state botanist

for Minnesota, acknowledged that this occurrence is most likely an escape. This patch of foamflower is in natural woods but close enough to human populations to explain its presence. Whether it represents an accidental or deliberately transplanted occurrence cannot be determined.

Other ecologists and botanists agree that *T. cordifolia* is not native to the state of Minnesota (for instance, Ownbey and Morley 1991).

The western edge of the species' range cuts through Ohio, Kentucky, and Tennessee and includes five counties in northeastern Mississippi (Szell 2002). In Georgia it occurs commonly in the north but is restricted to the counties along the Chattahoochee River in the south (Allison 2002). Deam (1940) made note of two undocumented reports of *T. cordifolia* from Indiana but concluded that they were probably cases of mistaken identification and hence excluded the species from that state's flora.

CONSERVATION STATUS

Listed below and in Table 1 is the official status of *Tiarella cordifolia* with respect to federal, state or province, and private agencies. (Rank given, followed by rank definition.)

U.S. Fish and Wildlife Service: none

The Nature Conservancy Global rank: **G5** (rank across its entire range)
Definition of G5: Secure – Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals. (NatureServe 2002)

The Nature Conservancy National rank: **N5** (17 Dec 1994)
Definition of N5: Secure – Common, widespread and abundant in the nation. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals. (NatureServe 2002)

The Nature Conservancy rank (Canada): N? (09 Aug 1993)
Definition of N?: Unranked – Nation or subnation rank not yet assessed.

U.S. Forest Service (Region 9): **Regional Forester Sensitive** for Chequamegon-Nicolet and Ottawa National Forests

Definition - The Regional Forester has identified it as a species for which viability is a concern as evidenced by: a) significant current or predicted downward trends in population numbers or density, and/or b) significant current or predicted downward trends in habitat capability that would reduce its existing distribution (FSM 2670.5.19).

Sub-national ranks (Table 1): (All sub-national [state/provincial] ranking definitions are from The Nature Conservancy - Natural Heritage Program 1996.)

Definitions:

S1 - Critically imperiled in the sub-nation because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation from the sub-nation.

S2 - Imperiled because of rarity (6-20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the sub-nation.

S3 - Vulnerable in the sub-nation either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences.

S4 – Uncommon but not rare, and usually widespread in the sub-nation. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals.

S5 – Common, widespread and abundant in the sub-nation. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.

SE – Exotic; an exotic established in the sub-nation; may be native in nearby regions.

S? - Rank not yet assessed.

SR - Reported to occur in sub-nation but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program hasn't yet received first-hand information: others are old, obscure reports.

Table 1. Conservation status of *T. cordifolia* in U.S. states and Canadian provinces.

Status	State	# of EOs	Province	# of EOs
S1	**New Jersey - END** **Wisconsin - END**	8 (var. *cordifolia*) 3 (1 on NF)		
S2	**Mississippi - SC**	13		
S2S3			**Nova Scotia**	10 +
S5	**North Carolina** **Pennsylvania**	common common	**Ontario**	common
SE	**Minnesota**	1 (introduced)		
S?	**Kentucky** **Michigan** **South Carolina** **West Virginia**	no report common common common		

SR	**Alabama** **Connecticut** **Georgia** **Maine** **Maryland** **Massachusetts** **New Hampshire** **New York** **Ohio** **Rhode Island** **Tennessee** **Vermont** **Virginia**	no report common common common common common occasional common common no report common common common	**New Brunswick** **Quebec**	common-west uncommon-east common

POTENTIAL THREATS

Threats to the viability of *Tiarella cordifolia* include habitat loss due to forest fragmentation and canopy alteration, mechanical damage, competition, collecting, and, perhaps, global warming. The forests that exist today within the range of this species are very different from those of the 1700's due to development, changes in forest composition, and climate change, leaving little undisturbed forest (Albert 1995). Activities that significantly alter the habitat can destroy present populations and remove options for future colonization.

Forest fragmentation

Foamflower may be particularly sensitive to habitat fragmentation. Studies by Ford et al. (2000) in secondary cove-hardwood stands in Georgia found that *Tiarella cordifolia* was among a very few groundlayer species that appeared to have been negatively affected by small stand size and surrounding land use. The researchers studied stands in four age classes, from 15 to ≥85 years old, and found that foamflower was present in most of them. However, it was apparently absent from stands in the 25-year-old age class, which tended to be more isolated than stands in the other age classes. The authors hypothesized that stands surrounded by drier habitats or roads may present an insurmountable barrier to colonization. Understory plant diversity has been shown to relate negatively to forest stand isolation (Grashof-Bokdan and Geertsma 1998 in Ford et al. 2000). Ford et al. (2000) suggested that forests be managed in a large context, providing for connectivity to other hardwood forest.

Canopy alteration and mechanical damage

Timber production activities and associated ground disturbance are major threats, as foamflower may be intolerant to increased sunlight. Clearcutting and heavy thinning open up the forest canopy, causing more sunlight to reach the ground and dry the soil. Element occurrence data from throughout its range indicate that foamflower requires at least partial canopy cover. (However, on the White Mountain National Forest in New Hampshire, Williams [2002] reports seeing it in a wide range of canopy conditions, from recent clear-cut to full canopy, and states that increased light seems to stimulate more robust flowering.) Plants can be mechanically damaged or up-rooted by machinery, placing additional stress on a colony (Judziewicz 1983).

In a fifty-three year study, researchers at the Harvard Forest in Massachusetts found that *T. cordifolia* was one of a small group of woodland herbs that disappeared following a large-scale disturbance—the complete loss of the forest canopy due to a hurricane—and subsequent salvage operations (Mabry and Korsgren 1998). The loss suggests that certain species are particularly sensitive to this type of disturbance. While many forest species are resilient to natural and human disturbance, some, like foamflower, are shallow-rooted and may not survive. The authors of the study further suggested that *T. cordifolia*'s failure to re-colonize the site was due to stand isolation.

Competition from invasive, non-native species

The threat of competition by invasive exotic plants is not well researched. Non-native species such as buckthorn (*Rhamnus cathartica* and *R. frangula*), Asian honeysuckle (*Lonicera morrowii* and others) and garlic mustard (*Alliaria petiolata*) are known to threaten the integrity of mesic hardwood forest habitats (Hoffman and Kearns 1997). These species are aggressive growers which leaf out early and tend to shade out native plant species. Natural systems invaded by non-native plants become less species-rich, threatening biodiversity and habitat quality (FICMNEW 1998).

Exotic earthworms which consume the detritus layer in hardwood forests may be cause for concern. The Great Lakes states are thought to have lost all their native earthworms following the last glacial period. European earthworms were introduced intentionally and accidentally and have spread rapidly. Eggs, cocoons, and adults are spread in soil on machinery and all-terrain and other vehicles, through river systems, and by the release of unwanted fishing bait (Conover 2000).

Following the introduction of earthworms, the upper organic soil layers in northern forest soils can disappear within a very short time (Langmaid 1963). According to Sauer (1998), earthworms consume the litter layer five times faster than the fungi which normally dominate in northern forest soils. They create an environment that stimulates the bacteria that convert ammonium to nitrate, as in grasslands. Nitrates are easily leached out of forest soils, leaving many native old-growth species starved for nutrients while allowing the rapid spread of early successional species and fast-growing exotics. In natural forests nitrogen is stored as ammonium and made available to plants much more slowly. Fungi also tend to promote the acid soil conditions that many woodland species favor.

Evidence suggests that colonization by several species of non-native earthworms may be incompatible with the survival of many North American hardwood forest understory species (Hale et al. 2002; Conover 2000). For instance, Gundale (2002) found that populations of the rare fern *Botrychium mormo* often disappeared after the loss of the upper organic soil horizons due to the introduction of the earthworm *Lumbricus rubellus*. He also suggested that roads, even small utility roads, are important sources of invasion by exotic earthworms. Remote forest areas still lack earthworms but their spread seems inevitable.

Collecting

Poaching as well as legal collection of wildflowers may be a threat. *Tiarella* has long been collected in the wild for home gardens and, as noted earlier, for medicinal use. Collecting results in a loss of mature individuals and wild genetic material. Some wild populations that were previously remote now can be accessed via new roads and the use of off road vehicles. Foamflower is available at garden centers and through catalogs and on-line nurseries, which may put less pressure on wild populations. Many lovely genetic hybrids have been developed which may reduce poaching of wild plants.

Predation and disease

Deer browse other members of the Saxifrage family (Brzeskiewicz, personal observation), so they might also take foamflower on occasion. However, one source asserts that the genus is rarely if ever browsed by deer (Plants For A future 2000). An on-line nursery listed black vine weevil, *Otiorhynchus sulcatus,* as a potential threat (Rodda 2002). This insect can kill the plant by tunneling into the crown. Slugs and snails are known pests of cultivated *Tiarella* plants (Birdseye and Birdseye 1951), as are earwigs (Blaney 2002) The species is reportedly prone to rust disease (Brickell and Zuk, eds. 1996) and mildew (Oregon State University 2002).

Global warming

Various models have tried to predict the effects of global warming and some hypothesize that "mid-latitude to high-latitude regions in the Northern Hemisphere—areas such as the Continental United States, Canada, and Siberia—will likely warm the most. These regions could exceed mean global warming by as much as 40 percent" (Weier 2002).

Higher average temperatures may or may not have significant effects on species like *Tiarella cordifolia* which have relatively large geographical ranges. However, changed precipitation patterns and other altered environmental conditions connected with global warming could be a different matter. For instance, parts of the southeastern and northeastern U.S., the center of *T. cordifolia*'s range, were recently in the midst of one of the worst droughts on record. Foamflower, being shallow-rooted, is reportedly extremely sensitive to drought (Carley 2002).

In past periods of climate change many species were able to migrate to newly-suitable habitat. However, this time around, the rapidity of change is likely to exceed the dispersal ability of most plants (Malcolm and Markham 2000). Greatly compounding the problem is habitat fragmentation and other human-caused barriers to migration. With global warming we are entering unknown territory and most of the effects it will have on species are not yet apparent.

Other threats

Participants in an expert panel (USDA FS 2000) recently convened by the Forest Service considered the population viability of a number of sensitive species, including *T. cordifolia*, in Michigan, Minnesota, and Wisconsin National Forests. In addition to many of those listed above, other possible threats mentioned by panel members were genetic isolation, buffer zones around existing populations that were too narrow (only 50 feet in some cases), flooding out of habitat by beaver activity, changes in hydrology, and vandalism.

LAND OWNERSHIP AND PROTECTION

Long-term viability of foamflower at the edge of its range may be dependent upon maintaining habitat on public lands. While private landowners may be sympathetic to sensitive species, in many cases they are under no obligation to protect even federally listed plants on their own land. Listed plants are protected, however, on federal land and indeed both the U.S. Forest Service and Bureau of Land Management have policies to maintain viable populations of all native plant species. Opportunity exists, therefore, to create and maintain havens for rare species on public land, including state and county land.

There is one known occurrence of foamflower on the Chequamegon-Nicolet National Forest in Wisconsin. The current management protocol is to protect occurrences of this plant by maintaining the existing forest canopy conditions and deferring the entire stand from any activity. The colony, in the Barney Creek area, has been proposed as a "Special

Management Area" due to its high natural quality and the presence of rare plant species (Janke 2002).

The Ottawa National Forest in the Upper Peninsula of Michigan has a single known occurrence within its proclamation boundary, but on private timber corporation land. Should additional colonies be discovered on Forest Service land, the area around the plants would be buffered by 2-3 tree lengths. Because *T. cordifolia* is often found along stream courses, there is a good chance that undiscovered colonies would fall within riparian protection zones typically used around streams and wetlands, and therefore be protected (Trull 2002). The Ottawa considers mitigation measures for rare species on a case by case basis depending on the species status, proximity to activity, the health of the population, and other factors.

Foamflower is more frequent in eastern Upper Michigan on the Hiawatha National Forest. It is common in the northern tier of the forest *within its restricted habitat* (Schultz 2002) and occurs in at least an equal number of sites in the southern part, including Round Island and Bois Blanc Island (Voss 2002).

Foamflower is reportedly common on the Huron-Manistee National Forest in Lower Michigan. It is not listed as rare in the state and apparently no special protection is allotted the species in management decisions.

RESEARCH AND MONITORING

Possible reasons for *Tiarella*'s scarcity in Wisconsin and the western Upper Peninsula of Michigan

Tiarella cordifolia is a rather common species through much of its large range, becoming rare at the periphery, as in northeastern Wisconsin and Michigan's western Upper Peninsula. Before developing a conservation management plan for foamflower in these areas, it might be useful to first ask the question: Why is it rare? Doing so may well suggest directions for research that will lead to informed management decisions. Certainly there are other possibilities, but the "hypotheses" discussed below are meant to suggest starting points for research and monitoring. All are speculation, since no hard data exist.

1*) Tiarella* is simply at the edge of its natural range in Wisconsin and is limited by climate and marginal habitat. Climatic, edaphic, and/or biological factors are the most likely reasons for its scarcity. Other species reach their range limits in Wisconsin; American beech (*Fagus grandifolia*) for instance, is limited to the eastern part of the state, presumably because it is unable to tolerate cold dry winters (Snyder 1980). Though *Tiarella* seems to do well enough in cultivation in Wisconsin, this does not necessarily mean it will flourish in the wild outside of its currently known range. On the other hand, an apparently introduced colony does appear to be thriving in natural woodland approximately 300 miles to the west, in Stearns County, Minnesota. One might reasonably expect that suitable habitat having the right climatic conditions exists between the Minnesota population and those in northeastern Wisconsin. Stebbins (1999) noted that the species appeared to be rarer than its habitat.

2) *Tiarella* was more widespread in pre-settlement northern Wisconsin but was unable to withstand the logging and subsequent fires. This possibility was mentioned in the Population Viability Assessment workshop for the species (USDA Forest Service 2000). Admittedly, the literature is very limited, but it does seem to indicate that *Tiarella* often disappears after the loss of the forest canopy and disturbance of the soil surface and, furthermore, is slower than most groundlayer species in re-colonizing previously occupied habitat. But many places in the eastern U.S. where the species is common may have experienced devastation similar to that in northern Wisconsin, particularly the Lower Peninsula of Michigan. Perhaps opportunities for re-colonization were greater closer to the center of its range. There might also be a time factor; Wisconsin's forests were logged more recently than those in New England and the Appalachians.

3) T*iarella* lacks suitable pollinators at the edge of its range in Wisconsin. As noted previously, a northern Wisconsin gardener reported that her cultivated plants of *T. cordifolia* rarely set seed (Sperka 1973). It was suggested that the lack of a suitable pollinator might be responsible. However, would a species with as wide a range as *Tiarella* likely be dependent on one or a very few pollinator species? Or if it was, how likely would it be that those pollinators are absent in Wisconsin, in forests similar to those in which foamflower occurs through much of its range? The length of the Wisconsin growing season is an unlikely cause for failure to produce seed since the first seed reportedly matures shortly after the flowers fade, probably no later than July. Could an unnoticed seed predator be responsible?

4) *Tiarella* was still in the process of postglacial migration and had not yet reached equilibrium with its potential habitat at the time of white settlement. The fossil pollen record indicates that white spruce (*Picea glauca*) reached the western Great Lakes region by about 13,000 B.P. On the other hand, American beech did not enter eastern Wisconsin until sometime after 4,000 B.P. In the east, American chestnut (*Castanea dentata*) was even slower in its advance, finally arriving in southern New England around 2000 B.P. (Sauer 1988). Clearly, plant species vary in their dispersal ability. An efficient method of dispersing its seed is not evident in *Tiarella* and, as already mentioned, the species seems especially slow in colonizing suitable habitat when that habitat is fragmented. To reach Wisconsin after the last glacial period, *Tiarella* would have had to migrate north and west from the mid or southern Appalachians. The Great Lakes and the Prairie Peninsula of Ohio, Indiana, and Illinois would have been significant barriers for a species that appears to have difficulty migrating across a road. (Rare long-distance dispersal events could explain the isolated populations in Wisconsin and the western UP—mud on a bird's foot?) Still, though intriguing, this seems the least likely hypothesis. And in any case, implications for conservation of the species would be similar to 2), above.

Research and Monitoring needs

Considering how common and widespread this species is (or perhaps because of it), there is very little in the literature concerning its general life history and ecology in the wild. Cultural information is readily available, but almost any research regarding the conservation of *Tiarella cordifolia,* specifically, will be breaking new ground. The following list of research and monitoring needs may seem over-ambitious but does reflect a very real lack of knowledge.

- **Monitor Wisconsin and Upper Peninsula colonies.** Are they are growing or have they filled the immediately available habitat? If colonies are spreading, is it through seed, stolons, or both? Are earthworms or other exotic species present at these sites? Is there evidence of deer browsing or other herbivory? Is there evidence of inbreeding depression due to genetic isolation? Is there a danger of flooding because of beaver activity?

- **Study effects of clearcutting, canopy thinning, and disturbance of the soil surface.** This would be difficult to accomplish in Wisconsin where only one population is on Forest Service land. A cooperative agreement with a National Forest (or other entity) in which *Tiarella* is common might be considered.

- **Especially in Wisconsin and Upper Michigan, identify pollinators or other means of pollination and determine if wild plants are producing viable seed, or if seed predators are present.** Other life history information is also lacking, including seed dispersal strategies and life-span of individual plants.

- **Ascertain conditions favorable for seed germination and establishment.** Conditions such as soil types, soil nutrients and pH, moisture needs, light and shade, and other habitat requirements. Consider transplant experiments in apparently-suitable habitat using plants either from local wild populations or grown from their seed.

- **Continue searching for additional wild populations in suitable habitat.**

Conclusion

Available evidence suggests that *Tiarella cordifolia* is in need of protection in Wisconsin and the western Upper Peninsula of Michigan. A Conservation Approach (for areas on the edge of foamflower's range) is necessary to provide for its long-term conservation, to maintain management options for its future, and to minimize conflict with other resource activities. Results of monitoring and research should provide managers with the data necessary to develop a Conservation Strategy. It is likely that such a strategy will only be necessary for habitats of *Tiarella cordifolia* on the edge of its range. Initiating a strategy would involve developing goals for maintaining viability of the species and writing management prescriptions for known sites as well as other suitable habitat. Public education and outreach may be critical elements in efforts to protect this and other rare species.

Public awareness of the habitats of sensitive species and their need for protection will definitely be more important for the future of this species, especially in Wisconsin and other areas on the edge of its range. Perhaps lack of knowledge is as big a threat as any to sensitive species. Public education efforts are crucial as habitat quality and size continue to dwindle. It may become the duty of public land stewards to reach out to private landowners in order to educate them on the needs of rare species. Together, private and public landowners can maintain critical habitat for foamflower in Wisconsin and Upper Michigan.

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Database Managers for state Natural Heritage Programs: (people who ran queries on this species)

CT: Karen Zyko, Environmental Analyst, Connecticut Natural Diversity Database, Dept. of Environmental Protection (860) 424-3378
GA: Jim Allison, botanist, Georgia Natural Heritage Program, Social Circle, GA (www.dnr.state.ga.us/dnr/wild/natural.html)
ME: Emily Pinkham, Information Manager, Maine Natural Areas Program, Augusta, ME
MD: Christopher T. Frye, Maryland State Botanist, Maryland Natural Heritage Program
MI: Rebecca Boehm, Conservation and GIS, Information Technology Professional, Michigan Natural Features Inventory, MSU Extension (mnfi@msue.msu.edu)
MN: Sharon Nelson (651) 296-8324
MS: Christopher C. Szell, Database Manager/Biologist, Mississippi Natural Heritage Program, MS Museum of Natural Science, Jackson, MS 39202
NJ: Elena A. Williams, Data Manager, Natural Heritage Program, Trenton, NJ
NH: Lionel Chute, Coordinator, New Hampshire Natural Heritage Program
NY: Nicholas Conrad, Information Resources Coordinator, New York Natural Heritage Program, NY State Dept of Environmental Conservation, Albany.NY (518) 402-8944
NC: Jame Amoroso, Botanist, North Carolina Natural Heritage Program, Dept. of Environment and Natural Resources, Raleigh, NC (919)715-8700 (www.ncsparks.net/nhp)
OH: Butch Greiszmer Ohio Natural Heritage Program

PA: Steve Grund, Botanist, Western Pennsylvania Conservancy/PA Natural Diversity Inventory-Western Office, Pittsburgh, PA (412) 288-5401
SC: Julie Holling, Data Manager, SCDNR, Heritage Trust Program, Columbia, SC (803) 734-3917
TN: Roger McCoy, Database Manager, TN Division of Natural Heritage, Nashville, TN (615) 532-0437
VT: Bob Popp, Information Manager VT Natural Heritage Program (802) 241-3718
VA: Steve Carter-Lovejoy, Natural Heritage Information Manager, VA Dept. of Conservation and Recreation, Division of Natural Heritage, Richmond, VA (www.dcr.state.va.us/dnh)
WV: Barbara Sargent, Environmental Resources Specialist, WVDNR –Nongame Wildlife & Natural Heritage Program, Elkins, WV (www.dnr.state.wv.us)
WI: Kristin Westad, Mapping specialist/botanist, Wisconsin Natural Heritage Inventory program (608) 266-7714
ON: Michael Oldham, Botanist/herpetologist, Ontario Natural heritage Information Center, Ministry of Natural Resources, Peterborough, ON (http://www.mnr.gov.on.ca/MNR/nhic/nhic.html)
Maritime Provinces (New Brunswick, Nova Scotia, Prince Ed. Is., Newfoundland & Newfoundland Island): Stefen Gerriets, Atlantic Canadian Conservation Data Center (ACCDC)
QC: Jacques Labrecque, botaniste, Ministère de l'Environnement du Québec (418)521-3907

Additional Botanical Information Provided by:

Sean Blaney– Botanist, Atlantic Canada Conservation Data Center
Theodore Cochrane – Botanist, University of Wisconsin Madison
Emmet Judziewicz – Botanist, University of Wisconsin Stevens Point

US Forest Service contacts:
Allegheny, PA: Mike Hays - Botanist
Chequamegon-Nicolet, WI: Steven Spickerman, Steve Janke, Marjory Brzeskiewicz, Mariquita Sheehan – plant ecologists, Linda Parker – Forest ecologist, Norman Weiland – former Forest biologist
Finger Lakes, NY: Mary B. Deller – Botanist
Green Mountain, VT: Mary B. Deller – Botanist
Hiawatha, MI: Janet Schultz – Forest Plant Ecologist
Huron Manistee, MI: Alix Cleveland – Forest Ecologist (acleveland@fs.fed.us)
Idaho Panhandle, ID: Betsy Hammet – Zone Botanist (ahammet@fs.fed.us)
Monongahela, Ohio: Carol J Garrett – Botanist/Ecologist (jgarrett@fs.fed.us)
Ottawa, MI: Susan Trull – Forest botanist
Superior, MN: Jack Greenlee – Botanist
Wayne, OH: Erin H. Larson – Botanist/Ecologist (ehlarson@fs.fed.us)
White Mountain, NH (ME): John R. Williams - T&E Monitoring (jrwilliams@fs.fed.us)

APPENDICES

Appendix A.

Some habitats and plant associates of *Tiarella cordifolia*

Wisconsin (from Wisconsin Natural Heritage Program element occurrence data)
Habitat descriptors: *Selectively cut mature hemlock-hardwood stand, dominated by sugar maple, on rolling ground; South-facing mesic forest dominated by sugar maple; Northeast-facing moist area in colluvium of ravine in a rich mesic forest dominated by sugar maple and beech; Rich deciduous woods dominated by sugar maple, beech, and yellow birch; rich understory; Growing in more open micro-sites of old logging roads; Along both sides of a creek within about 1.5 miles of it.*

Associated species:
Trees: *Acer saccharum, Tsuga canadensis, Fagus grandifolia, Betula papyrifera, Betula allegheniensis, Tilia americana, Populus grandidentata*
Herbs: *Actea pachypoda, Allium tricoccum, Carex sprengellii, Caulophyllum thalyctroides, Dicentra* spp., *Dentaria* spp., *Erythronium americanum, Hieracium lanatum, Maianthemum canadense, Mitella diphylla, Trientalis borealis, Uvularia grandiflora, Viola canadensis, Viola pubescens, Viola sororia, Viola cucullaria*
Ferns: *Matteuccia struthiopteris, Gymnocarpium dryopteris*

New Jersey (from New Jersey Natural Heritage Program element occurrence data)
Habitat descriptors: *Moist woods; Woodlands; Boggy edge of stream in deep woods; Seepage areas along small streamlet in dense woods with hemlock dominant in places; Growing in damp to wet mossy seeps along edge of flooded swamps, also occurring on sedge tussocks in stream channel; Growing in somewhat open woods on rocky floodplain with canopy mostly tulip poplar with ash, elm, white pine, and red maple.*

Associated species:
Trees: *Acer rubra, Fraxinus* sp., *Liriodendron tulipfera, Pinus strobes, Ulmus* sp.
Herbs: *Arisaema triphyllum, Mitella diphylla, Symplocarpus foetidus*
Ferns: *Botrychium virginianum*

New York ─ Finger Lakes National Forest sites (from Deller [2000, 2002])
Habitat descriptors: Moist, usually somewhat enriched woods; sugar maple usually dominant

Associated species:
Trees: *Acer saccharum, Acer rubrum, Carya ovata, Betula allegheniensis, Fagus grandifolia, Fraxinus americana, Ostrya virginiana, Pinus strobes, Quercus rubra, Ulmus* spp.,
Shrubs: *Cornus* spp.. *Parthenocissus quinquefolia, Prunus virginiana, Rhus radicans, Rubus allegheniensis, Sambucus* spp., *Viburnum acerifolium, Viburnum lentago*

Herbs: *Actaea pachypoda, Agrimonia* spp., *Amphicarpa bracteata, Arisaema triphyllum, Aster macrophyllus, Aster* spp., *Caltha palustris, Carex intumescens, Carex* spp., *Caulophyllum thalyctroides, Circaea quadrisculata, Fragaria vesca, Galium triflorum, Geum canadense, Laportea canadensis, Maianthemum canadense, Sanicula trifoliate, Smilacina racemosa, Viola* spp.
Ferns: *Athyrium filix-femina, Dryopteris carthusiana, Osmunda claytonii*

Pennsylvania — Allegheny National Forest sites (from Hays [2002])
Habitat descriptors: *Along brooks and seeps; Moist slopes in rich, mesic northern hardwood forests.*

Associated species:
Trees: *Acer saccharum, Fagus grandifolia, Tsuga canadensis, Fraxinus americana, Betula allegheniensis*
Herbs: *Cardamine diphylla, Carex scabrata, Carex laxiflora, Carex prasina, Chrysosplenium americanum, Poa alsodes, Ranunculus abortivus, Ranunculus recurvatus, Senecio aureus, Viola cucullata*
Ferns: *Onoclea sensibilis*

Appendix B

Element occurrences of *T. cordifolia* on Great Lakes states National Forest lands

National Forest	State	# of EOs	Typical mitigation of EO if not in