Tiarella cordifolia var. *cordifolia*

Foamflower

Saxifragaceae

Tiarella cordifolia var. *cordifolia* by J. S. Dodds, 2020

***Tiarella cordifolia* var. *cordifolia* Rare Plant Profile**

New Jersey Department of Environmental Protection
State Parks, Forests & Historic Sites
State Forest Fire Service & Forestry
Office of Natural Lands Management
New Jersey Natural Heritage Program

501 E. State St.
PO Box 420
Trenton, NJ 08625-0420

Prepared by:
Jill S. Dodds
jsdodds@biostarassociates.com

April, 2022

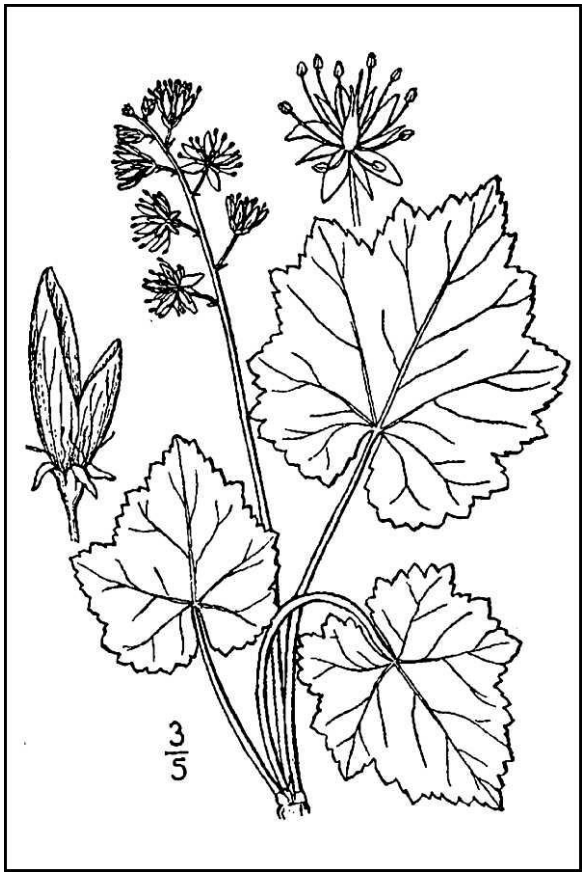
For:
New Jersey Department of Environmental Protection
Office of Natural Lands Management
New Jersey Natural Heritage Program
natlands@dep.nj.gov

This report should be cited as follows: Dodds, Jill S. 2022. *Tiarella cordifolia* var. *cordifolia* Rare Plant Profile. New Jersey Department of Environmental Protection, State Parks, Forests & Historic Sites, State Forest Fire Service & Forestry, Office of Natural Lands Management, New Jersey Natural Heritage Program, Trenton, NJ. 17 pp.

Life History

Two species of *Tiarella* are widely recognized in the United States: *Tiarella cordifolia* occurs in the eastern part of the country while *Tiarella trifoliata* is restricted to the west (Kartesz 2015). Some sources further distinguish varieties of *Tiarella cordifolia* while others do not recognize any subtaxons (see Synonyms and Taxonomy section). *Tiarella cordifolia* var. *cordifolia* is the only variety that occurs in New Jersey—the remaining variations are only reported from southeastern states (USDA NRCS 2022a). Throughout this profile, use of either the specific or the varietal epithet depends upon the taxon level utilized by the cited source.

Tiarella cordifolia (Foamflower) is a perennial wildflower in the Saxifrage family. *Tiarella* can occasionally hybridize with other genera in the Saxifragaceae including *Mitella* and *Heuchera* (Jog 2020), but the hybrids are usually sterile (Fernald 1906, Oliver 2021). *Tiarella cordifolia* var. *cordifolia* has both rhizomes and stolons by which it may reproduce vegetatively (Fernald 1950). The leaves are basal with a long petiole, a heart-shaped base, and 3–5 shallow, toothed lobes (Britton and Brown 1913). The inflorescence is a raceme with a glandular axis that is initially dense but continues to expand as the flowers open and the stalk elongates (Fernald 1950, Gleason and Cronquist 1991). Each flower has 5 sepals and 5 petals, both of which are white or pinkish, and 10 anthers. Flowering may occur from March–July (Jog 2020) but typically takes place during May in New Jersey (Hough 1983).



Left: Britton and Brown 1913, courtesy USDA NRCS 2022b. Right: J. S. Dodds, 2020.

Tiarella cordifolia is able to function as a semi-evergreen species because it can retain its foliage throughout the winter, developing new leaves in the spring (Fields and Brzeskiewicz 2002). That seasonal growth pattern allows Foamflower to take advantage of higher light levels on the forest floor during spring and fall periods when the canopy is not in full leaf. By adjusting the rates of photosynthetic activity in their leaves, *T. cordifolia* plants accumulate biomass rapidly during the spring and autumn months but more slowly during the summer (Rothstein and Zak 2001a). Further investigation by Rothstein and Zak (2001b) examined seasonal patterns of carbon and nitrogen metabolism. They found that nutrient uptake and assimilation did not mirror rates of photosynthetic activity in *T. cordifolia*, instead occurring at a steadier pace which slowly increased as the season progressed. They also observed that nitrogen was preferentially allocated to leaves throughout the growing season but lost as the old foliage was discarded due to poor reabsorption rates.

Pollinator Dynamics

Early descriptions of *Tiarella cordifolia* reported pollination by bees (Keeler 1916). A more extensive study of spring wildflowers in North Carolina by Motten (1986) found that Foamflower's most frequent visitors were the Two-spotted Bumblebee (*Bombus bimaculatus*) and the Greater Bee-fly (*Bombylius major*), both of which occur in New Jersey (BugGuide 2022). Several other kinds of bees were also occasionally noted.

Fertilization experiments demonstrated that *Tiarella cordifolia* is highly self-incompatible, and therefore requires insects for pollination (Motten 1986). Foamflower does not produce nectar, relying instead on its dense mass of small flowers to attract visitors. Bumblebees, and particularly queens, were identified as the most important pollinators for *T. cordifolia* because the smaller insects spent a greater amount of time on a single inflorescence and thus were less likely to fully fertilize the flowers. Motten identified some disadvantages for species that depend on bumblebee queens: As bumblebees tend to forage on multiple species, visitation rates are lower and they sometimes deposit pollen from a plant species other than the host. Because emerging queens preferentially seek out flowers that provide nectar they often do not visit Foamflower until later in its blooming period, but Motten also found that the life of *T. cordifolia* flowers was extended when access by insects was limited so unfertilized flowers may have a longer period of availability. Although reproductive success in several other spring wildflowers reliant on queen bumblebees was limited by inadequate cross-fertilization, only a minimal increase in fruit set resulted from supplemental hand-pollination of *Tiarella cordifolia* flowers (Motten 1986).

Seed Dispersal

Fruiting may take place from April to September (Jog 2020) but in New Jersey it is usually completed by July (Hough 1983). The fruit of *Tiarella cordifolia* is a capsule with two valves of distinctly unequal length that contain 4–15 shiny black seeds (Jog 2020, Bebeau 2014). The primary dispersal mechanism is gravity (Bellemare et al. 2002, Brown and Boutin 2009). Wings on the capsule enhance its movement by wind, allowing the seeds to be shaken out (Bebeau

2014). The small seeds land in the immediate vicinity of the parent plant, but on occasion may be transported for a short distance by overland water flow (Fraterrigo et al. 2009). Fields and Brzeskiewicz (2002) suggested that dispersal may also be facilitated by water when Foamflower plants are situated along a stream course. No reports of long-distance dispersal were found for the species.

Tiarella cordifolia seeds require exposure to high summer temperatures in order to break dormancy and germinate (Baskin and Baskin 1988). Baskin and Baskin also found that, as with many other herbaceous species, germination of *T. cordifolia* is enhanced by exposure to light. When characterizing the traits of plants included in a different study, Dobson and Blossey (2015) indicated that *T. cordifolia* takes 1–2 years to germinate and has a moderate level of mycorrhizal colonization.

Habitat

Tiarella cordifolia grows in forested habitats that span a range of light and moisture regimes. The species occurs at elevations of 40–800 meters in woods that may vary from open to shady and dry to swampy (Jog 2020). It is frequently associated with streams, and has been reported on a variety of substrates including wet hollows, seeps and springy places, old lake bottoms, and moist, rocky, wooded slopes, well-drained bottomland forests, and rock outcrops (Fields and Brzeskiewicz 2002, Rhoads and Block 2007, Weakley 2015). New Jersey populations occupy an assortment of habitats including boggy stream and swamp edges, a wet hemlock forest, open deciduous woods in a rocky floodplain, and sedge tussocks in a stream channel (NJNHP 2022).

Wetland Indicator Status

The U. S. Army Corps of Engineers (2020) has divided the country into a number of regions for use with the National Wetlands Plant List and portions of New Jersey fall into three different regions (Figure 1). *Tiarella cordifolia* has been assigned more than one wetland indicator status within the state. In the Northcentral and Northeast region, *T. cordifolia* is listed as a facultative upland species, meaning that it usually occurs in nonwetlands but may occur in wetlands. In the regions that encompass central and southern New Jersey, *T. cordifolia* is considered a facultative species, meaning that it occurs in both wetlands and nonwetlands.

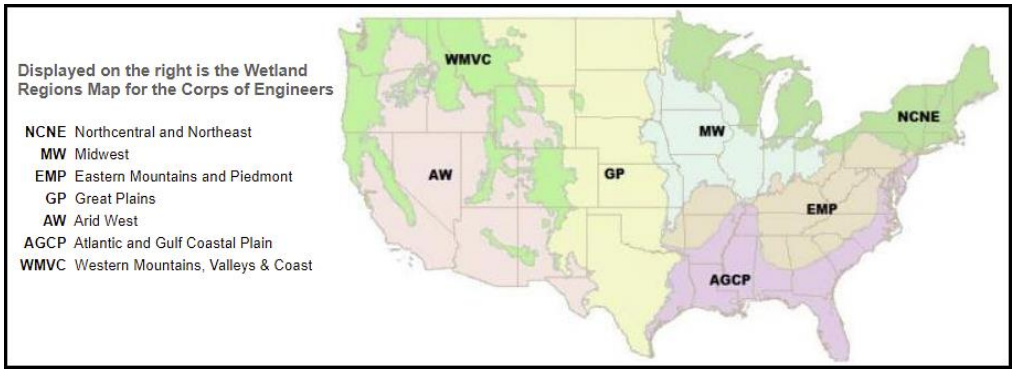


Figure 1. Mainland U. S. wetland regions, adapted from U. S. Army Corps of Engineers (2020).

USDA Plants Code (USDA, NRCS 2022a)

TICOC2

Coefficient of Conservatism (Walz et al. 2018)

CoC = 8. Criteria for a value of 6 to 8: Native with a narrow range of ecological tolerances and typically associated with a stable community (Faber-Langendoen 2018).

Distribution and Range

The native global range of *Tiarella cordifolia* is restricted to North America, and the species has also become established in Norway where it was introduced (POWO 2022). The map in Figure 2 depicts the extent of *Tiarella cordifolia* in the United States and Canada.

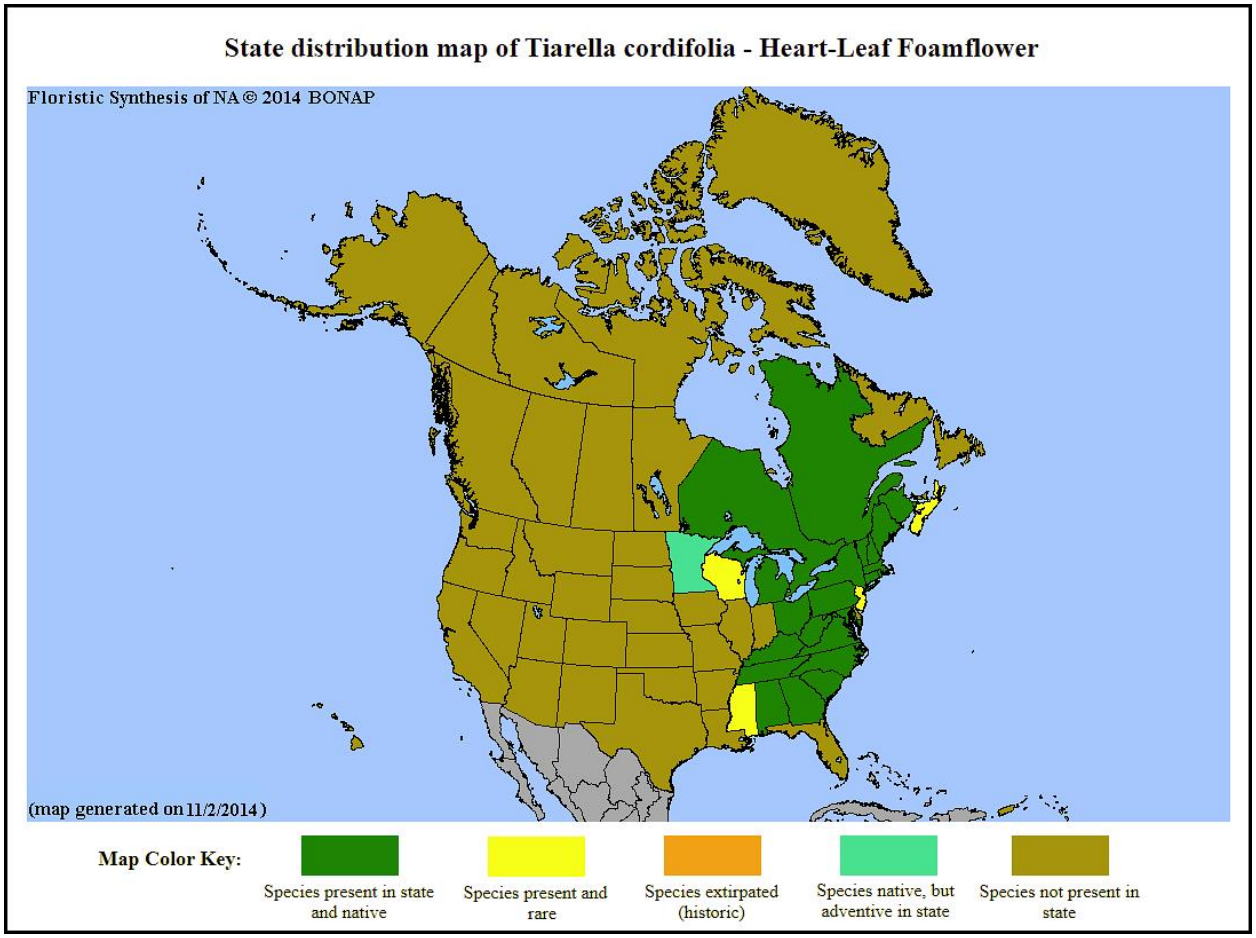


Figure 2. Distribution of T. cordifolia in North America, adapted from BONAP (Kartesz 2015).

The USDA PLANTS Database (2022a) shows records of *Tiarella cordifolia* var. *cordifolia* in six New Jersey counties: Bergen, Mercer, Morris, Passaic, Sussex, and Warren (Figure 3). The data include historic observations and do not reflect the current distribution of the species.

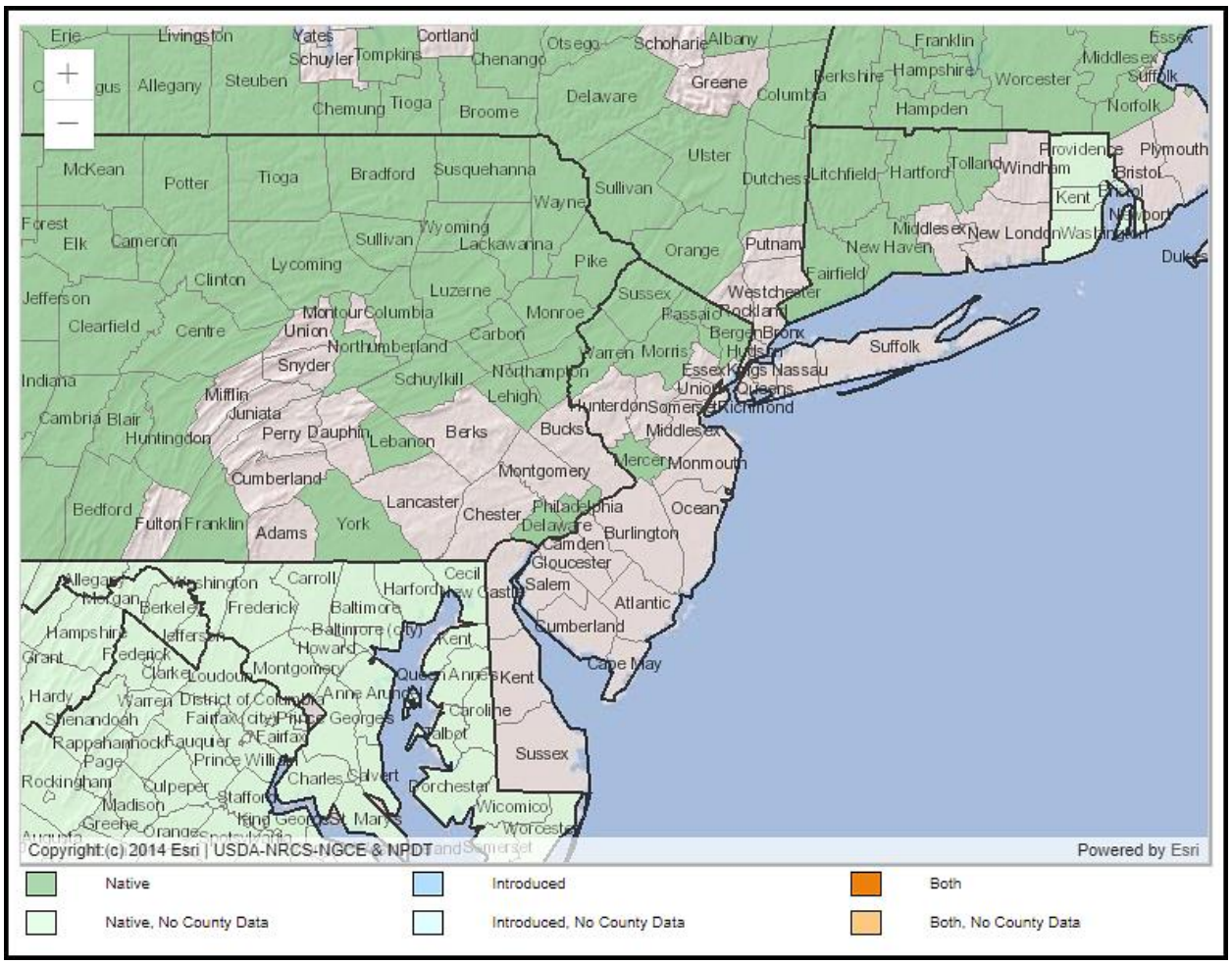


Figure 3. County records of T. cordifolia var. cordifolia in New Jersey and vicinity (USDA NRCS 2022a).

Conservation Status

Tiarella cordifolia is considered globally secure. The G5 rank means the species has a very low risk of extinction or collapse due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats (NatureServe 2022). NatureServe does not currently distinguish between varieties of *T. cordifolia*. If ongoing research on *Tiarella cordifolia* results in the re-establishment of several varieties or division into multiple species (see Synonyms and Taxonomy section), some of the resulting taxa may subsequently be listed for rarity. *T. cordifolia* var. *cordifolia*, the variety present in New Jersey, is the widest ranging type (Nesom 2021) and is likely to remain secure at the global scale.

Figure 4 illustrates the conservation status of *Tiarella cordifolia* in the United States and Canada. Throughout most its native range, the species is unranked or ranked as secure or apparently so. It is illustrated as critically imperiled (very high risk of extinction) in one state and imperiled (high risk of extinction) in one state and one province. Foamflower plants in Minnesota are not considered native.

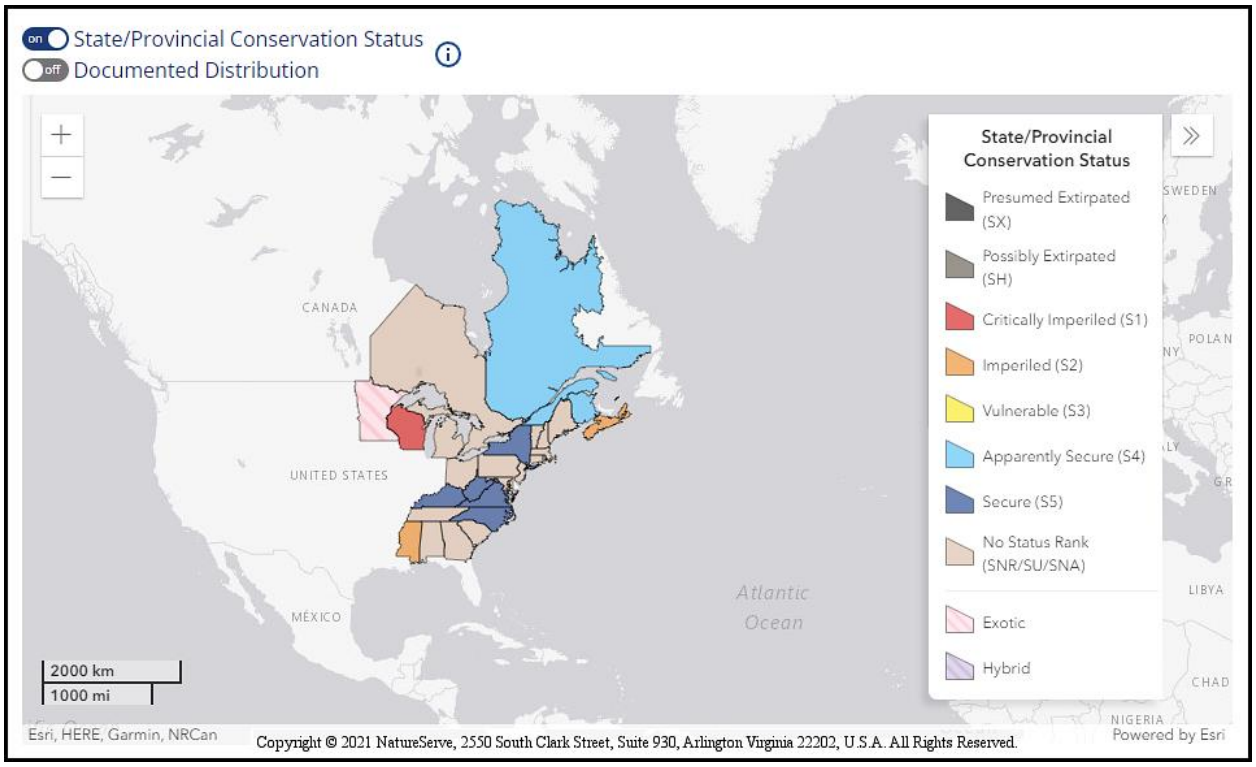


Figure 4. Conservation status of T. cordifolia in North America (NatureServe 2022). The absence of a reported rank for New Jersey may be due to a discrepancy in the taxonomic levels recognized in the state and by NatureServe.

Although it is not shown on the map, *Tiarella cordifolia* var. *cordifolia* is critically imperiled (S1) in New Jersey (NJNHP 2022). The rank signifies five or fewer occurrences in the state. A species with an S1 rank is typically either restricted to specialized habitats, geographically limited to a small area of the state, or significantly reduced in number from its previous status. Foamflower is also listed as an endangered species (E) in New Jersey, meaning that without intervention it has a high likelihood of extinction in the state. Although the presence of endangered flora may restrict development in certain communities, being listed does not currently provide broad statewide protection for plants. Additional regional status codes assigned to *T. cordifolia* var. *cordifolia* signify that the species is eligible for protection under the jurisdictions of the Highlands Preservation Area (HL) and the New Jersey Pinelands (LP) (NJNHP 2010).

Tiarella cordifolia has never been abundant in New Jersey. Britton (1881) reported it from two northern counties, noting that the species was very rare. Fables (1956) said that it was known from only two or three localities in the northern counties. *T. cordifolia* was included on an early list of the state's rare or endangered plants with a notation that it was current at one location in

Mercer County and several in Sussex (Fairbrothers and Hough 1973), and around the turn of the century only two existing occurrences were reported (Breden et al. 2006). Four populations of Foamflower are currently extant in the state—three have estimated viability ranks of 'Good' and the fourth is 'Fair' (NJNHP 2022).

Threats

Destruction of habitat has a lasting detrimental impact on *Tiarella cordifolia* populations. Evaluation of the ways in which land use history affects forest composition found that *T. cordifolia* was strongly associated with undisturbed forests in Massachusetts (Bellemare et al. 2002) and in Ontario (Brown and Boutin 2009). In Quebec, the species was reported to be rare in hedgerows despite being common in regional forests (Liston 2010). Research on gap dynamics and plant vigor detected no difference between *T. cordifolia* plants in openings and those beneath the canopy in terms of root/shoot biomass (Rankin and Tramer 2002) or the number of flowers per stem (Proctor et al. 2012). However, once Foamflower has been eliminated from a site the species may be unable to re-establish. Temperate forest herbs typically do not have extended dormancy periods (Bierzychudek 1982) so *T. cordifolia* may not be able to persist at a particular location following a lengthy disturbance, and limited dispersal puts Foamflower at a disadvantage relative to species that can quickly reach and colonize an available site (Brown and Boutin 2009).

Even when a stand where *Tiarella cordifolia* occurs remains intact, a reduction in the quality of adjacent habitat can have harmful consequences. A North Carolina survey showed that *T. cordifolia* was more likely to be present in large patches of habitat than small ones (Pearson et al. 1998), and a Georgia study found the lowest abundance of Foamflower in sites that were adjacent to Forest Service roads which served as corridors for the introduction of weedy species (Ford et al. 2000).

Mechanical disturbance can degrade a habitat and destroy plants. *Tiarella cordifolia* can be damaged or uprooted by equipment used for timber production or other forest management practices (Fields and Brzeskiewicz 2002). It is likely that similar physical harm could be caused by off-road vehicles. A Massachusetts population of *T. cordifolia* was eliminated by the compounded effects of a large hurricane and mechanical damage from the subsequent cleanup. The species showed an immediate decline, subsequently disappeared, and was still completely absent from the site 50 years later (Mabry and Korsgren 1998).

Like many plant species in New Jersey, *Tiarella cordifolia* is susceptible to herbivory by White-tailed Deer (*Odocoileus virginianus*) and the detrimental impact of deer overabundance on the forest understory has been well documented (Maslo and Wehman 2013, NRCS undated). Heavy deer browse has been identified as a threat to at least one New Jersey Foamflower population (NJNHP 2022). Ruhren and Handel (2003) quantified the impact of browsing on some native herbs by comparing the survival and vigor of plants growing inside and outside of deer exclosures. In contrast to the protected plants, *Tiarella cordifolia* located outside of the fenced areas had low survival and no sexual or clonal reproduction.

Negative impacts from non-native earthworms have been documented for *Tiarella cordifolia*. The worms reduce the organic layer, alter the structure and nutrient cycling patterns of soils, and disrupt mycorrhizal processes (Bohlen et al. 2004, Frelich et al. 2006, Hale et al. 2006). During a study of multiple factors affecting the success of seedling establishment, *T. cordifolia* survival rates significantly decreased in response to greater earthworm biomass in the soil (Dobson and Blossey 2015). Earthworms were also identified as a factor that inhibited the establishment of *T. cordifolia* plants which had been developed using micropropagation techniques (Kitto and Hoopes 1992).

Exotic species are another widespread problem for rare native plants in New Jersey (NJ Division of Science and Research 2021). A number of invasive plants have been identified as particular threats to two New Jersey Foamflower populations, including *Berberis thunbergii*, *Microstegium vimineum, Alliaria petiolata,* and *Rubus phoenicolasius* (NJNHP 2022). All four species are considered highly threatening to native communities in the state (Van Clef 2009, FoHVOS 2021). In addition to forming dense stands that crowd out other plants, *Alliaria* reportedly inhibits the growth of mycorrhizal fungi while the decaying leaves of *Microstegium* can raise soil pH and those of *Berberis* can alter soil chemistry (Kaufman and Kaufman 2007). *Tiarella cordifolia* is also susceptible to an exotic fungus. Boxwood Blight (*Calonectria pseudonaviculata*) was recently introduced from eastern Asia and has rapidly spread, doing extensive damage to ornamental plants (Castroagudín et al. 2020). However, the infection reported for *T. cordifolia* was experimentally induced and the response was relatively minor (Richardson et al. 2020).

The potential effects of climate change on *Tiarella cordifolia* are uncertain. In New Jersey, anticipated increases in temperature and associated shifts in precipitation patterns are expected to intensify periods of both flooding and drought (USEPA 2016). Either extreme could potentially be problematic for a *T. cordifolia* occurrence. A large part of the habitat for one New Jersey Foamflower population was destroyed after being flooded by beaver (*Castor canadensis*) (NJNHP 2022), although climate-induced inundation is usually temporary at inland sites and floods of shorter duration may have lesser impacts. Fields and Brzeskiewicz (2002) noted that *Tiarella cordifolia* is particularly sensitive to drought due to its shallow root system.

Management Summary and Recommendations

Land conservation and habitat protection are essential in order to safeguard *Tiarella cordifolia* populations in areas where the species is imperiled. It is important to preserve large tracts of mature forest, as the Foamflower is less likely to thrive in a fragmented landscape (Pearson et al. 1998). Site-specific plans are needed for the management of established invasive species, and regular monitoring of *T. cordifolia* occurrences should be conducted to identify emerging threats.

Strategies for reducing deer impacts should be explored, as continuous herbivory significantly limits survival and reproductive success in *Tiarella cordifolia* (Ruhren and Handel 2003). At a large scale the solution could include management of herd size, and for small or rapidly declining populations the installation of deer-exclusion fencing might create an opportunity for the plants to regain some vigor and reproduce.

Available information suggests that restoration of *Tiarella cordifolia* populations in states where the species is critically imperiled may be feasible, although not without challenges. Foamflower plants are easy to propagate both by seed and by division (Leopold 2005), and clonal plants grown from microcuttings have also been established in the field (Kitto and Hoopes 1992). However, the success of reintroduction can be reduced by both earthworms and deer. While deer impacts can be reduced by the use of fencing around plants (Ruhren and Handel 2003), the exclusion of deer has been reported to increase the likelihood of rodent damage to seedlings (Dobson and Blossey 2015).

Additional research on *Tiarella cordifolia* would be beneficial in several areas, particularly around topics that affect the success of sexual reproduction. 1) The species appears to depend heavily on bumblebees for pollination, an insect group that is widely reported as declining (Colla and Packer 2008). Updated information is needed regarding *T. cordifolia* pollinators and their relative effectiveness. 2) Even when pollinator activity was supplemented by hand pollination, mean fruit set per inflorescence only increased from 59.7% to 68.1% and the maximum fruit set did not exceed 75% (Motten 1986). Investigation is called for to determine whether other factors limit fruit set in *T. cordifolia*. 3) Healthy populations of *Tiarella cordifolia* are maintained by both clonal growth and the local dispersal of seeds. No documentation was found for long-distance dispersal mechanisms that would allow for the colonization of new habitats. A better understanding of how the species establishes at different sites is required.

Synonyms and Taxonomy

The accepted botanical name utilized in New Jersey is *Tiarella cordifolia* var. *cordifolia* L. Two other varieties currently in use are *T. cordifolia* var. *austrina* Lakela and *T. cordifolia* var. *collina* Wherry, with the species name *Tiarella wherryi* Lakela included as a synonym for the latter variety (USDA, NRCS 2022a). Some authors recognize only *Tiarella cordifolia* and include in the species those varieties and the additional synonyms listed below (ITIS 2022, Jog 2020, Kartesz 2015, POWO 2022). Distinctions between the forms and varieties has been the subject of much debate (Lakela 1937, Wherry 1940, Fernald 1943), and the overall trend toward consolidation was accepted by Weakley (2015) with a cautionary note that further study was needed. The most recent twist was the proposed reorganization of the eastern *Tiarella* into five distinct species, which would result in the renaming of New Jersey's Foamflower as *T. stolonifera* (Nesom 2021).

Botanical Synonyms	**Common Names**
Tiarella cordifolia var. *typica* L.	Foamflower
Tiarella cordifolia var. *bracteata* Farw.	Heartleaf Foamflower
Tiarella cordifolia f. *allanthera* Vict. & J. Rousseau	Gem-fruit
Tiarella cordifolia f. *subaequalis* Lakela	False Mitrewort
Tiarella cordifolia f. *tridentata* Lakela	
Tiarella macrophylla Small	

References

Baskin, Carol C. and Jerry M. Baskin. 1988. Germination ecophysiology of herbaceous plant species in a temperate region. American Journal of Botany 75(2): 286–305.

Bebeau, G. D. 2014. Heartleaf Foamflower. The Friends of the Wild Flower Garden, Inc. Available at https://www.friendsofthewildflowergarden.org/pages/plants/foamflower.html

Bellemare, Jesse, Glenn Motzkin, and David R. Foster. 2002. Legacies of the agricultural past in the forested present: an assessment of historical land-use effects on rich mesic forests. Journal of Biogeography 29: 1401–1420.

Bierzychudek, Paulette. 1982. Life histories and demography of shade-tolerant temperate forest herbs: A review. The New Phytologist 90(4): 757–776.

Bohlen, Patrick J., Stephan Scheu, Cindy M. Hale, Mary Ann McLean, Sonja Migge, Peter M. Groffman, and Dennis Parkinson. 2004. Non-native earthworms as agents of change in northern temperate forests. Frontiers in Ecology and the Environment 2(8: 427–435.

Breden, T. F., J. M. Hartman, M. Anzelone and J. F. Kelly. 2006. Endangered Plant Species Populations in New Jersey: Health and Threats. New Jersey Department of Environmental Protection, Division of Parks and Forestry, Office of Natural Lands Management, Natural Heritage Program, Trenton, NJ. 198 pp.

Britton, N. L. 1881. A preliminary catalogue of the flora of New Jersey. Geological Survey of New Jersey, Office of the Survey, Rutgers College, New Brunswick, NJ. 233 pp.

Britton, N. L. and A. Brown. 1913. An Illustrated Flora of the Northern United States and Canada in three volumes: Volume II (Amaranth to Polypremum). Second Edition. Reissued (unabridged and unaltered) in 1970 by Dover Publications, New York, NY. 735 pp.

Brown, Carissa D. and Céline Boutin. 2009. Linking past land use, recent disturbance, and dispersal mechanism to forest composition. Biological Conservation 142: 1647–1656.

BugGuide. 2022. An online resource for identification, images, and information about insects, spiders and their kin in the United States and Canada. Site hosted by Iowa State University Department of Entomology. Available at https://bugguide.net/node/view/15740

Castroagudín, Vanina L., Jerry E. Weiland, Fulya Baysal-Gurel, Marc A. Cubeta, Margery L. Daughtrey, Nicole Ward Gauthier, James LaMondia, Douglas G. Luster, Francesca Peduto Hand, Nina Shishkoff, Jean Williams-Woodward, Xiao Yang, Nicholas LeBlanc, and Jo Anne Crouch. 2020. One clonal lineage of *Calonectria pseudonaviculata* is primarily responsible for the Boxwood Blight epidemic in the United States. Phytopathology 110: 1845-1853.

Colla, Sheila R. and Laurence Packer. 2008. Evidence for decline in eastern North American

bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. Biological Conservation 17: 1379–1391.

Dobson, Annise and Bernd Blossey. 2015. Earthworm invasion, white-tailed deer and seedling establishment in deciduous forests of north-eastern North America. Journal of Ecology 103: 153–164.

Faber-Langendoen, D. 2018. Northeast Regional Floristic Quality Assessment Tools for Wetland Assessments. NatureServe, Arlington, VA. 52 pp.

Fables, David Jr. 1956. Caesarian flora and fauna, Number 1. Published posthumously in Bartonia 31(1960–61): 3–11.

Fairbrothers, David E. and Mary Y. Hough. 1973. Rare or Endangered Vascular Plants of New Jersey. Science Notes No. 14, New Jersey State Museum, Trenton, NJ. 53 pp.

Fernald, M. L. 1906. Some anomalous plants of *Tiarella* and *Mitella*. Rhodora 8(89): 90–92.

Fernald, M. L. 1943. Virginian botanizing under restrictions: *Tiarella wherryi*. Rhodora 45: 445–449.

Fernald, M. L. 1950. Gray's Manual of Botany. Dioscorides Press, Portland, OR. 1632 pp.

Fields, Douglas and Marjory Brzeskiewicz. 2002. Conservation assessment for Heart-leaved Foam-flower (*Tiarella cordifolia*). Report prepared for USDA Forest Service, Eastern Region. Available at https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054112.pdf

FoHVOS (Friends of Hopewell Valley Open Space). 2021. New Jersey Invasive Species Strike Team. Invasive species list with control recommendations. Available online at https://www.fohvos.info/invasive-species-strike-team/info-center/

Ford, W. Mark, Richard H. Odom, Philip E. Hale, and Brian R. Chapman. 2000. Stand-age, stand characteristics, and landform effects on understory herbaceous communities in southern Appalachian cove-hardwoods. Biological Conservation 93(2): 237–246.

Fraterrigo, Jennifer M., Scott M. Pearson, and Monica G. Turner. 2009. Joint effects of habitat configuration and temporal stochasticity on population dynamics. Landscape Ecology. Published online: https://www.researchgate.net/profile/Monica-Turner/publication/225334237_Joint_effects_of_habitat_configuration_and_temporal_stochasticity_on_population_dynamics/links/0046351edaca615da5000000/Joint-effects-of-habitat-configuration-and-temporal-stochasticity-on-population-dynamics.pdf

Frelich, Lee E., Cindy M. Hale, Stefan Scheu, Andrew R. Holdsworth, Liam Henegan, Patrick J. Bohlen, and Peter B.. Reich. 2006. Earthworm invasion into previously earthworm-free temperate and boreal forests. Biological Invasions 8: 1235–1245.

Gleason, H. A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Second Edition. The New York Botanical Garden, Bronx, NY. 910 pp.

Hale, Cindy M., Lee E. Frelich, and Peter B. Reich. 2006. Changes in hardwood forest understory communities in response to European earthworms. Ecology 87(7): 1637–1649.

Hough, Mary Y. 1983. New Jersey Wild Plants. Harmony Press, Harmony, NJ. 414 pp.

ITIS (Integrated Taxonomic Information System). Accessed March 23, 2022 at http://www.itis.gov

Jog, Suneeti. Page updated November 5, 2020. *Tiarella cordifolia* Linnaeus. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico [Online]. 22+ vols. New York and Oxford. Accessed March 23, 2022 at http://floranorthamerica.org/Tiarella

Kartesz, J. T. 2015. The Biota of North America Program (BONAP). Taxonomic Data Center. (http://www.bonap.net/tdc). Chapel Hill, NC. [Maps generated from Kartesz, J. T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP) (in press)].

Kaufman, Sylvan Ramsey and Wallace Kaufman. 2007. Invasive Plants: Guide to the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA. 458 pp.

Keeler, Harriet L. 1916. Our early wild flowers : a study of the herbaceous plants blooming in early spring in the northern states. Charles Scribner's Sons, New York, NY.. 252 pp.

Kitto, S. L. and A. Hoopes. 1992. Micropropagation and field establishment of *Tiarella cordifolia*. Journal of Environmental Horticulture 10(3): 171–174.

Lakela, Olga. 1937. A monograph of the genus *Tiarella* L. in North America. American Journal of Botany 24: 344–351.

Leopold, Donald J. 2005. Native Plants of the Northeast: A Guide for Gardening and Conservation. Timber Press, Portland, OR. 308 pp.

Liston, Alexandra. 2010. Enhancing connectivity through corridors for the dispersal and biodiversity conservation of forest herbaceous species in agroecosystems. Master's Thesis, McGill University, Montréal, Québec, Canada. Available at https://escholarship.mcgill.ca/concern/theses/rx913q219

Mabry, Cathy and Tobe Korsgren. 1998. A permanent plot study of vegetation and vegetation-site factors fifty-three years following disturbance in central New England, U.S.A. Écoscience 5(2): 232–240.

Maslo, Brooke and Samantha Wehman. 2013. An overview of white-tailed deer status and management in New Jersey. Rutgers University, New Jersey Agricultural Experiment Station, Cooperative Extension Fact Sheet FS1202. Available at https://njaes.rutgers.edu/fs1202/

Motten, Alexander F. 1986. Pollination ecology of the spring wildflower community of a temperate deciduous forest. Ecological Monographs 56(1): 21–42.

NatureServe. 2022. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed March 23, 2022 at https://explorer.natureserve.org/

Nesom, Guy L. 2021. Taxonomy of *Tiarella* (Saxifragaceae) in the eastern USA. Phytoneuron 31: 1–61.

NJ Division of Science and Research. 2021. Endangered Plants. From Environmental Trends: Plants and Wildlife, N. J. Department of Environmental Protection, available at https://www.nj.gov/dep/dsr/trends/

NJNHP (New Jersey Natural Heritage Program). 2010. Special Plants of NJ - Appendix I - Categories & Definitions. Site updated March 22, 2010. Available at https://nj.gov/dep/parksandforests/natural/docs/nhpcodes_2010.pdf

NJNHP (New Jersey Natural Heritage Program). 2022. Biotics 5 Database. NatureServe, Arlington, VA. Accessed February 1, 2022.

NRCS (Natural Resource Conservation Service). Undated. New Jersey Fact Sheet: White-tailed Deer Impacts and Forest Management. United States Department of Agriculture. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_017804.pdf

Oliver, Charles G. 2021. An introduction to *Heucherella*. From The Primrose Path (Perennial Breeders and Introducers). Available at https://www.theprimrosepath.com/Featured_Plants/Heucherella/heucherella.htm

Pearson, Scott M., Alan B. Smith, and Monica G. Turner. 1998. Forest patch size, land use, and mesic forest herbs in the French Broad River Basin, North Carolina. Castanea 63(3): 382–395.

POWO (2022). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Retrieved March 23, 2022 from http://www.plantsoftheworldonline.org/

Proctor, Eleanor, Erica Noi, Dawn Burke, and William J. Crins. 2012. Responses of insect pollinators and understory plants to silviculture in northern hardwood forests. Biodiversity and conservation 21: 1703–1740.

Rankin, W. T. and Elliot J. Tramer. 2002. Understory succession and the gap regeneration cycle in a *Tsuga canadensis* forest. Canadian Journal of Forest Research 32(1): 16–23.

Rhoads, Ann Fowler and Timothy A. Block. 2007. The Plants of Pennsylvania. University of Pennsylvania Press, Philadelphia, PA. 1042 pp.

Richardson, Patricia A., Margery Daughtrey, and Chuanxue Hong. 2020. Indications of susceptibility to *Calonectria pseudonaviculata* in some common groundcovers and Boxwood companion plants. Plant Disease 104: 1127–1132.

Rothstein, D. E. and D. R. Zak. 2001a. Photosynthetic adaptation and acclimation to exploit seasonal periods of direct irradiance in three temperate, deciduous-forest herbs. Functional Ecology 15: 722–731.

Rothstein, David E. and Donald R. Zak. 2001b. Relationships between plant nitrogen economy and life history in three deciduous-forest herbs. Journal of Ecology 89: 385–394.

Ruhren, Scott and Steven N. Handel. 2003. Herbivory constrains survival, reproduction and mutualisms when restoring nine temperate forest herbs. Journal of the Torrey Botanical Society 130(1): 34–42.

U. S. Army Corps of Engineers. 2020. National Wetland Plant List, version 3.5. https://cwbi-app.sec.usace.army.mil/nwpl_static/v34/home/home.html U. S. Army Corps of Engineers Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

USDA, NRCS. 2022a. PLANTS profile for *Tiarella cordifolia* var. *cordifolia* (Heartleaf Foamflower). The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed March 23, 2022 at http://plants.usda.gov

USDA, NRCS. 2022b. *Tiarella cordifolia* illustration from Britton, N. L. and A. Brown, 1913, An illustrated flora of the northern United States, Canada and the British Possessions, 3 vols., Kentucky Native Plant Society, New York, Scanned By Omnitek Inc. Image courtesy of The PLANTS Database (http://plants.usda.gov). National Plant Data Team, Greensboro, NC.

USEPA (U. S. Environmental Protection Agency). 2016. What climate change means for New Jersey. EPA 430-F-16-032. Available at https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-nj.pdf

Van Clef, M. 2009. New Jersey Strategic Management Plan for Invasive Species: The Recommendations of the New Jersey Invasive Species Council to Governor Jon S. Corzine, Pursuant to New Jersey Executive Order #97. Appendix II, Prioritized Listing of New Jersey's Nonindigenous Plant Species, prepared by David Snyder. Available at http://www.nj.gov/dep/njisc/docs/Final%20NJ%20Strategic%20Management%20Plan%20for%20Invasive%20Species%2011.09.pdf

Walz, Kathleen S., Linda Kelly, Karl Anderson and Jason L. Hafstad. 2018. Floristic Quality Assessment Index for Vascular Plants of New Jersey: Coefficient of Conservativism (CoC)

Values for Species and Genera. New Jersey Department of Environmental Protection, New Jersey Forest Service, Office of Natural Lands Management, Trenton, NJ. Submitted to United States Environmental Protection Agency, Region 2, for State Wetlands Protection Development Grant, Section 104(B)(3); CFDA No. 66.461, CD97225809.

Weakley, A. S. 2015. Flora of the southern and mid-Atlantic states, working draft of May 2015. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, NC.

Wherry, E. T. 1940. A novelty in the genus *Tiarella* (Saxifragaceae). Notulae Naturae (Academy of Natural Sciences of Philadelphia) 42: 1–4.