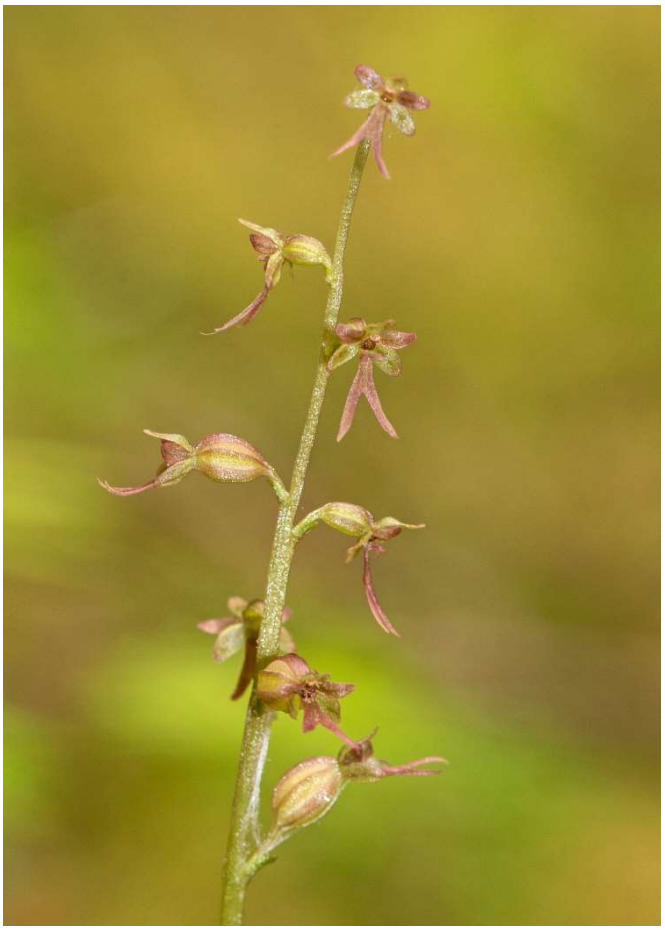
Listera cordata var. *cordata*

Heartleaf Twayblade

Orchidaceae



Listera cordata var. cordata by Benoit Dorion, 2020

***Listera cordata var. cordata* 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

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Life History

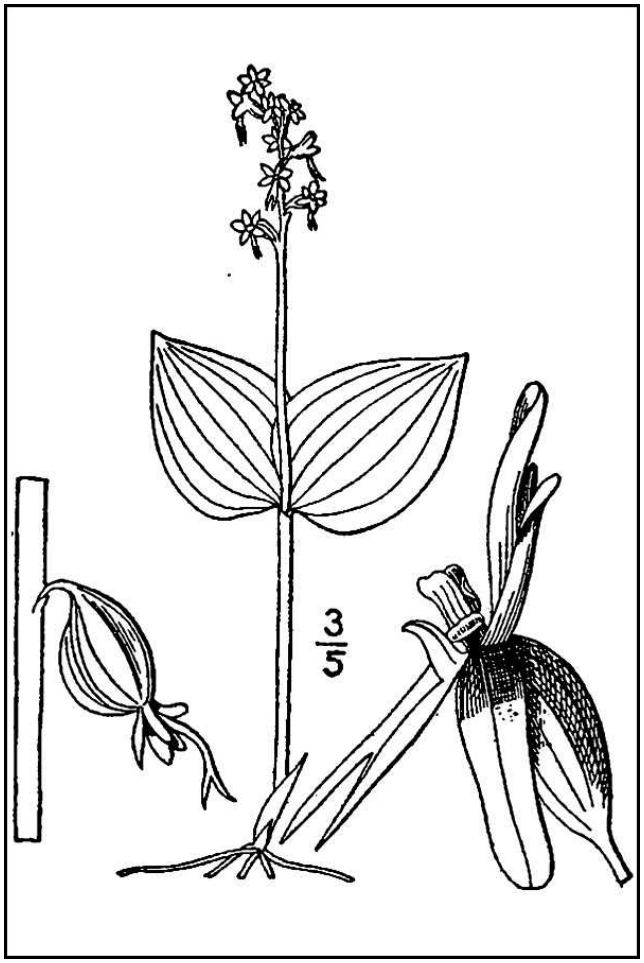
Listera cordata var. *cordata* (Heartleaf Twayblade) is a delicate orchid that may reach up to 33 cm in height (Magrath and Coleman 2020) although it is usually shorter. The species is often described as inconspicuous (e.g. Reddoch and Reddoch 1997, Kotilínek et al. 2018) but Henry Baldwin (1884) put it this way: "*With so much that is immediately presented to the eye, how can the Twayblade, Listera cordata, tiniest of our Orchids, hope to turn your steps toward her bower? True, you may not appreciate her after you have brushed away the branches of Kalmia and Labrador Tea, and found her to be a plainly dressed little thing, perhaps six inches high, but she is entitled to as much respect as any of her race".*

The slender stems of *Listera cordata* var. *cordata* have a single pair of stalkless leaves near the middle which are heart-shaped or oval and about 1–3 cm long. Rare individuals may also have a small bract between the leaves and the inflorescence. The stems sometimes have a reddish tint. The inflorescence is a loose raceme of 4–20 short-stalked flowers that may be green, purple, or red. The three sepals and two upper petals are similar and about 1.5–2.5 mm long. The lower petal (lip) is about twice as long (3–5 mm) and is split into two linear lobes for half to two-thirds of its length. The stems, floral pedicels, and axis of the inflorescence are smooth. Mature capsules are round or ovoid and 5 x 4 mm. (See Britton and Brown 1913, Fernald 1950, Gleason and Cronquist 1991, Reddoch and Reddoch 1997, Magrath and Coleman 2020). The other variety of *Listera cordata* (var. *nephrophylla*) does not occur in New Jersey. The two varieties may be distinguished by leaf shape but there is overlap and some plants do not fit readily into either subtaxon so many authors do not recognize the division (Magrath and Coleman 2020). Two other species of *Listera* can be found in the state. The lip of *L. smallii* is split for only a third of its length and has blunt lobes, while *L. australis* has a longer lip (6-10 mm) and glandular hairs are present on its central flower stalk and pedicels (Rhoads and Block 2007, Weakley 2015).

Listera cordata is a perennial herb that appears to rely heavily on clonal reproduction to maintain its populations (Kotilínek et al. 2018). The plants have rhizomes that generate new stems during the growing season (Nieuwdorp 1972) but the genus is unusual in that some stems can also be produced by buds that develop on the roots (Dressler 1981, Rasmussen 1995). Once new plants become established the underground connections disappear (Kotilínek et al. 2018). *L. cordata* is also exceptional among orchids because the plants are able to form vegetative buds on their roots even during the juvenile and immature phases (Batygina et al. 2003). The clonal growth habit typically results in a clumped distribution within populations so that relatively dense groups of plants may be separated by considerable distances (Bakka and Kiseleva 2021). Occurrences of Heartleaf Twayblade may consist of lone individuals or close aggregations of hundreds of plants, and the number of stems produced by established colonies can fluctuate considerably from one year to the next (Hoy 2002, Kotilínek et al. 2018).

Listera cordata plants overwinter as grey-green shoots about 1–1.5 cm high that form near the base of the current year's stem but remain concealed in the mossy substrate until the following growing season (Doyle and Kirby 1987, Reddoch and Reddoch 1997). Upon emergence, the aboveground stems of *L. cordata* may be either sterile or reproductive, but the majority of plants in any given year are usually nonflowering (Kotilínek et al. 2018). In populations studied by

Bakka and Kiseleva (2021) about 95% of the stems were vegetative. Reddoch and Reddoch (1997) observed that the shoots for the following year were already present at flowering time. The plants emerge during mid-spring (Kotilínek et al. 2018) and may bloom from late May through August (Magrath and Coleman 2020) although mid-June to July is typical in New Jersey (Hough 1983). The number of flowers per inflorescence can vary widely between populations: Ackerman and Mesler (1979) reported an average of 11.7 but Bakka and Kiseleva (2021) reported a mean of 5.7. The flowers open from bottom to top and last for an average of 15.4 days (Ackerman and Mesler 1979). The fruits mature rapidly and seeds may be released by the lower flowers on a stalk while the upper flowers are still open, sometimes even occurring while the capsules are green and floral parts remain present on the fruits (Stoutamire 1964, Reddoch and Reddoch 1997).



Left: Britton and Brown 1913, courtesy USDA NRCS 2022a. Right: Todd Boland, 2017.

Pollinator Dynamics

Listera cordata flowers utilize an explosive mechanism to facilitate cross-pollination by insects (Darwin 1890). Despite the coloration and fetid odor which suggest pollination by carrion flies no egg-laying has been observed on the plants (Ackerman 1986); instead the floral visitors come seeking nectar that is secreted in furrows on the lips of the flowers (Baldwin 1884). While

feeding on the nectar, the insects come into contact with minute trigger hairs on the rostellum (a flap of tissue that initially enfolds the pollinia). Contact with a hair triggers the rapid ejection of a tiny drop of sticky liquid onto the insect followed by the immediate release of the pollinia which adhere to the quick-drying droplet. The rostellum simultaneously unfurls and covers the stigma, and after the insect exits it carries the pollinia to another flower. After about a day the rostellum lifts and exposes the receptive stigma to new visitors. When pollinia come into contact with stigmas they break into chunks, so a single insect may fertilize several flowers with the same pollen mass. (See Baldwin 1884, Darwin 1890, Ackerman and Mesler 1979, Burns-Balogh et al. 1987).

The primary pollinators of *Listera cordata* are fungus gnats in the families Mycetophylidae and Sciaridae (Ackerman and Mesler 1979). Although fungus gnats have a low probability of achieving fertilization in a single visit they are usually present in large numbers and make numerous visits, thereby serving as effective pollinators for the orchids (Mesler et al. 1980). Sporadic visits by other insects (flies, wasps, or beetles) accounted for less than 0.1 of the potential pollinator activity observed by Mesler et al. (1980) but such insects may play a greater role in other parts of the orchid's range (Hoy 2002).

Mesler et al. (1980) observed that the fungus gnats often visited more than one flower per inflorescence before moving on to another plant. The movements of the rostellum assure that a flower is not immediately self-pollinated. However, if the pollinia have not been removed after four days the rostellum lifts anyway, exposing the stigma and increasing the likelihood of receiving closely related pollen. Well-developed seeds resulted from the experimental self-pollination of *L. cordata* flowers, demonstrating that the species was self-compatible (Ackerman and Mesler 1979). Nevertheless, seed production is higher in cross-pollinated flowers and it can be limited when plants are isolated and attract fewer insects (Melendez-Ackerman and Ackerman 2001). In natural populations a high proportion of *L. cordata* flowers are likely to set fruit: Reported rates include 61-78% (Ackerman and Mesler 1979) and 84% (Bakka and Kiseleva 2021).

Seed Dispersal and Establishment

Orchid seeds lack endosperm and consist mainly of an embryo surrounded by a loose, papery coating (Dressler 1981). Individual plants produce numerous tiny propagules that are often referred to as dust seeds. The seeds of *Listera cordata* are 597 µm long and 165 µm in diameter (Kotilínek et al. 2018). Close examination of assorted orchid seeds reveals ribbed seed coats that give them a cage-like structure, and the ribs of *L. cordata* seeds are arranged into square or polygonal shapes surrounding clear cell walls (Curtis 1893). Without a microscope the seeds of Heartleaf Twayblade simply appear to be yellowish-white (Reddoch and Reddoch 1997). *Listera cordata* produces a relatively low number of seeds per capsule in comparison to other orchid species (Johansson et al. 2014). Stoutamire (1964) counted 376 seeds in a *L. cordata* capsule and calculated that a typical inflorescence would produce 2,860 seeds based on an average of 7.6 capsules per plant.

The majority of orchid seeds are designed for wind dispersal (Dressler 1981), including those of *Listera cordata* which are often distributed only three weeks after pollination (Kotilínek et al. 2018). Relatively large spaces within the seeds allow them to float in the air for long periods, and the seeds of *L. cordata* apparently also have some ability to float on water although the duration was not reported (Arditti and Ghani 2000). Arditti and Ghani observed that the general characteristics of orchid seeds might also permit their transport by adherence to birds or mammals. Once an orchid seed has been deposited on the ground, the presence or absence of a suitable fungus will determine whether a seedling can establish and develop (Batty et al. 2002).

Dormancy in orchid seeds varies between species, ranging from 0–7 years (Eriksson and Kainulainen 2011). Morin and Payette (1987) found a small number of *Listera cordata* seeds in the seed bank of a study site in Quebec, although subsequent testing indicated that they were not viable. Dressler (1981) noted that the seeds of orchids may survive for long periods if they are cool and dry. When the seeds become hydrated, limited metabolic activity is initiated but germination requires appropriate physical conditions and, in nature, the right kind of fungi (Dressler 1981, Arditti and Ghani 2000). In addition to contact with a suitable mycorrhizal fungus, *Listera cordata* seeds require moisture in order to germinate (Kotilínek et al. 2018).

Low germination and high seedling mortality have been reported for *Listera cordata* (Stoutamire 1964, Těšitelová et al. 2015, Kotilínek et al. 2018). When a plant is able to establish it develops slowly beneath the surface of the substrate. *L. cordata* seedlings (protocorms) are about 2 mm long and 0.8 mm wide with a slightly curved whitish bodies that are covered with numerous long hairs. Roots develop before the shoots, and the plants remain below the surface for 3–4 years before producing their first green leaves (Kotilínek et al. 2018).

Prior to leaf development, orchid seedlings are completely dependent on their fungal partners for nutrients (Dressler 1981). Some types of orchids rely on mycorrhizae only during the establishment phase while others continue to need fungal associations throughout their lives (Eriksson and Kainulainen 2011). Mature *Listera cordata* plants often team up with fungi in the genus *Rhizoctonia* (Nieuwdorp 1972, Rasmussen 1995) and form typical orchid-type mycorrhizae (Harley and Harley 1987, Wang and Qiu 2006). Fungi in the roots of *L. cordata* plants do not enter the rhizomes, so clonally produced individuals must establish their own associations (Rasmussen 1995). Rasmussen suggested that the presence of mycorrhizae could allow fragments of the orchid's roots to persist in the soil for some time.

Těšitelová et al. (2015) found that mycorrhizal *Listera cordata* plants had total nitrogen concentrations which were significantly higher than those of autotrophic (photosynthetic) plants and equal to or higher than those of most fungal fruiting bodies. They noted that the Heartleaf Twayblades were also slightly enriched in carbon (^{13}C) compared with surrounding autotrophic plants but the difference was not significant. However, research by Schiebold et al. (2017) indicated that *L. cordata* was significantly enriched in ^{13}C relative to autotrophic reference plants and the authors concluded that the orchid was a partial mycoheterotroph, obtaining carbon through both photosynthetic activity and its fungal associations. In the majority of mycorrhizal relationships carbon flows in the opposite direction, being transferred from the plants to their fungal partners in exchange for other benefits.

Habitat

In North America *Listera cordata* var. *cordata* is usually found at sites that are 0–1200 meters above sea level (Magrath and Coleman 2020) although it has been reported at slightly higher elevations in West Virginia (Brooks 1936). In mountainous parts of Europe Heartleaf Twayblade may occur at elevations up to 2300 meters (Kotilínek et al. 2018). Characteristic North American habitat is damp or swampy coniferous or coniferous-deciduous forest with a mossy substrate, although the orchid occasionally grows in moist hardwood forests. Dominant species in the tree canopy may be *Picea spp.*, *Tsuga canadensis*, *Thuja occidentalis*, *Abies balsamea*, or *Pinus spp.* while common associates include *Betula alleghaniensis*, *Alnus incana*, or *Acer rubrum* (See Brooks 1936, Fairbrothers and Hough 1973, Coddington and Field 1978, Morin and Payette 1988, Reddoch and Reddoch 1997, Hoy 2002, Locky et al. 2005, Nazaire and Crow 2008, Weakley 2015, Rhoads and Block 2017, Magrath and Coleman 2020, NAOCC 2022). Habitats reported in New Jersey include *Black Spruce* (*Picea mariana*) bogs and swampy woods under *Tsuga*, *Betula*, and *Rhododendron* (NJNHP 2022). The European habitats of *L. cordata* are generally similar but the orchid may also occur in wet Heather (*Calluna vulgaris*) moorlands or *Sphagnum* bogs (Westhoff 1959, Doyle and Kirby 1987). In Scotland the species has been found in both natural and artificial pine forests (Westhoff 1959).

Bakka and Kiseleva (2021) observed that habitat suitability for *Listera cordata* appeared to be determined by the soil or moss cover. While the plants are usually found in a layer of *Sphagnum* or other mosses (e.g. *Hypnum*, *Polytrichum*), they have also been reported to grow on subacid humus or leaf mould (Westhoff 1959, Reddoch and Reddoch 1997, Magrath and Coleman 2020). Research by Bayu et al. (2017) suggested that *L. cordata* was dependent on the presence of needle litter. When growing in mossy sites, Heartleaf Twayblade plants are often situated on hummocks (Locky et al. 2005, NAOCC 2022) but they may be set so deeply into the moss that their leaves just reach the surface (Reddoch and Reddoch 1997). *L. cordata* habitats are often described as shady (Brooks 1936, Reddoch and Reddoch 1997) but Bayu et al. (2017) indicated that light availability was a critical factor for the species. Morin and Payette (1988) described seasonal snow accumulation as an important component of a Quebec site.

Some tips relative to searching for *Listera cordata* were provided by Brooks (1936), who noted that the easiest method of finding new occurrences was "following up the tiny streams." He also pointed out that the small orchids often grew in close association with Canada Mayflower (*Maianthemum canadense*) and could be difficult to find among the other plants.

Wetland Indicator Status

Listera cordata is a facultative wetland species, meaning that it usually occurs in wetlands but may occur in nonwetlands (U. S. Army Corps of Engineers 2020).

USDA Plants Code (USDA, NRCS 2022b)

LICOC2

Coefficient of Conservatism (Walz et al. 2018)

CoC = 9. Criteria for a value of 9 to 10: Native with a narrow range of ecological tolerances, high fidelity to particular habitat conditions, and sensitive to anthropogenic disturbance (Faber-Langendoen 2018).

Distribution and Range

Listera cordata occurs globally throughout the northern hemisphere (POWO 2022). The map in Figure 1 shows the extent of *L. cordata* in North America but it includes both varieties. *Listera cordata* var. *cordata* does not occur in the western United States, although the variety is present in Canada's western provinces where it overlaps with *L. cordata* var. *nephrophylla* (Magrath and Coleman 2020). The North American ranges of the two varieties are depicted in Figure 2.

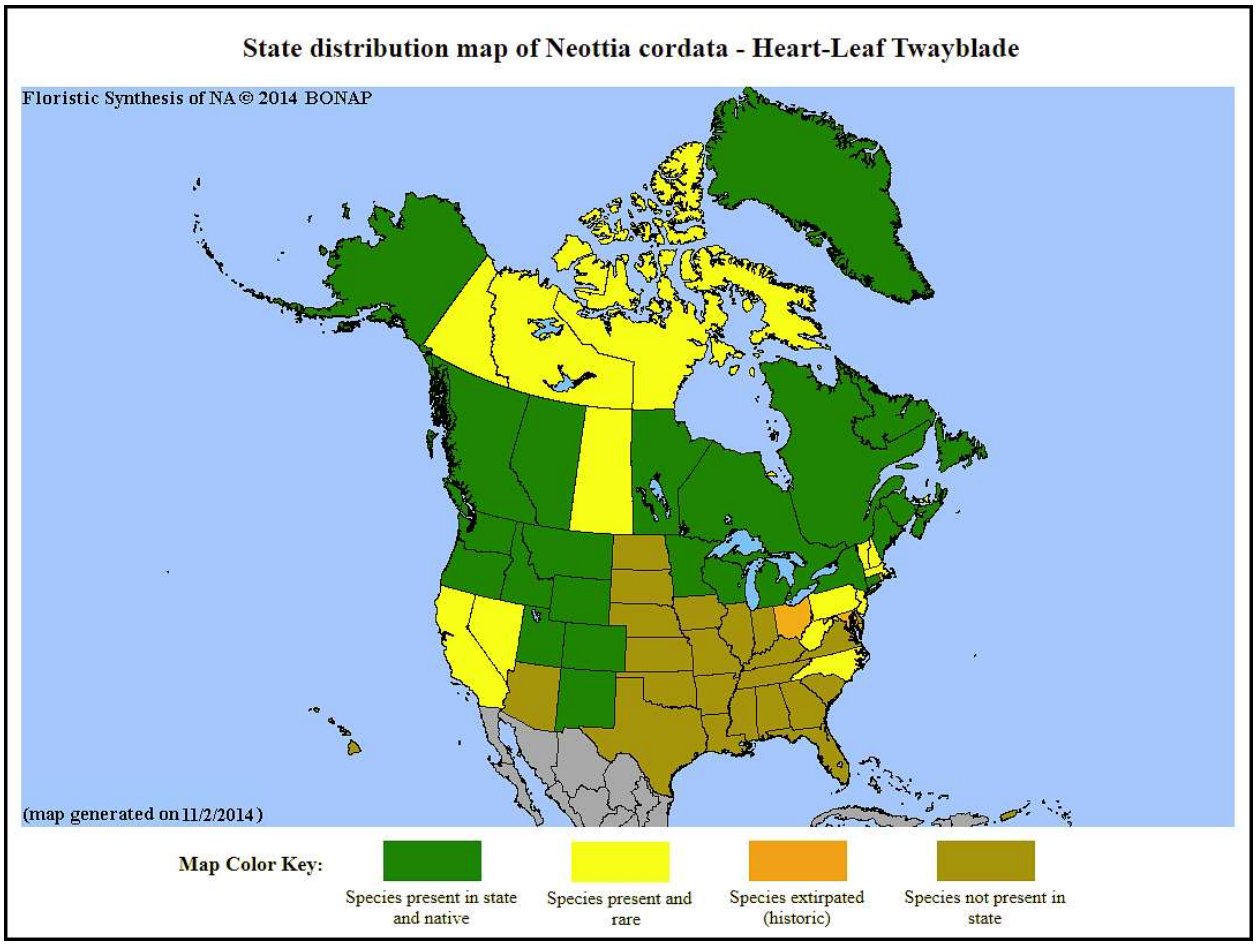


Figure 1. Distribution of Listera cordata in North America, adapted from BONAP (Kartesz 2015).

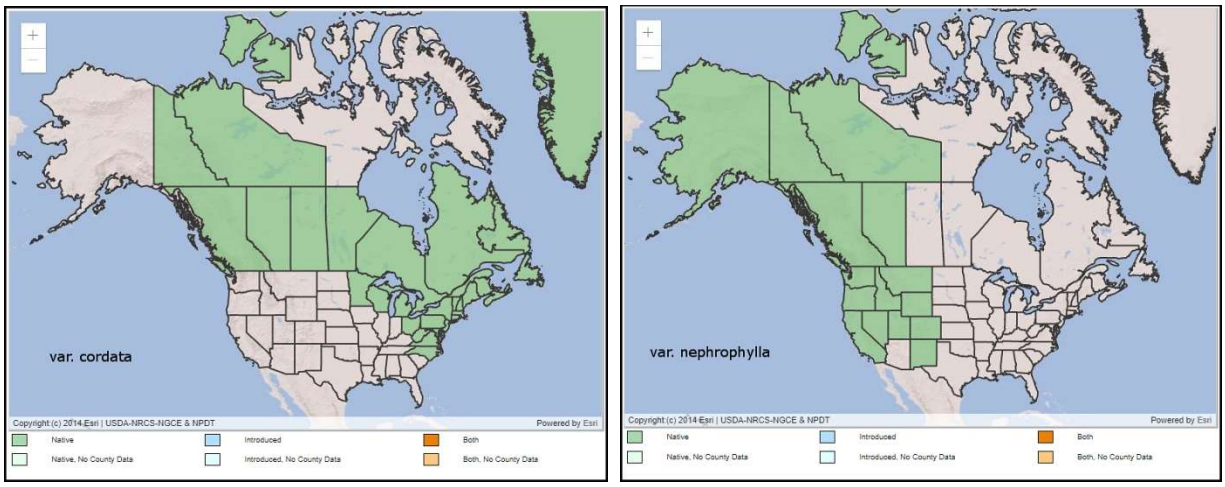


Figure 2. The North American range of L. cordata var. cordata (left) and the global range of L. cordata var. nephrophylla (right) (USDA NRCS 2022b).

The USDA PLANTS Database (2022b) shows records of *Listera cordata* var. *cordata* in five New Jersey counties: Bergen, Hudson, Mercer, Middlesex, and Sussex (Figure 3). The data include historic observations and do not reflect the current distribution of the species.

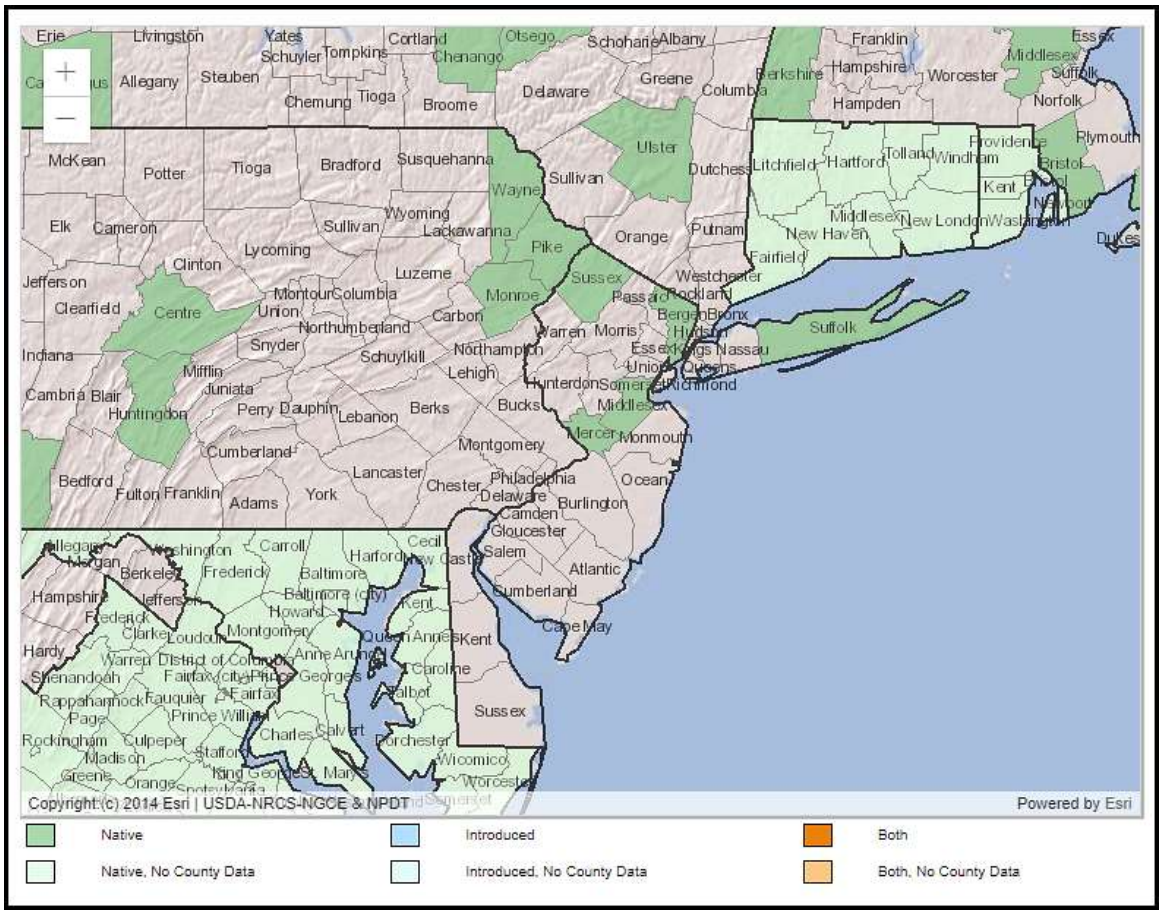


Figure 3. County records of L. cordata var. cordata in New Jersey and vicinity (USDA NRCS 2022b).

Conservation Status

Listera cordata var. *cordata* is considered globally secure. The G5T5 rank means both the species and the subtaxon have 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). The maps below (Figures 4a and 4b) illustrate the conservation status of Heartleaf Twayblade throughout North America. *Listera cordata* var. *cordata* is shown as vulnerable (moderate risk of extinction) in New York, imperiled (high risk of extinction) in West Virginia, critically imperiled (very high risk of extinction) in New Jersey, and possibly extirpated in North Carolina (Figure 4a). However, a number of other districts have listed *Listera cordata* without naming a variety, and some of those are in states or provinces where only var. *cordata* occurs (refer to Figure 2). Based on the known range information, *L. cordata* var. *cordata* is critically imperiled in three additional states, imperiled in two additional states and one province, and vulnerable in three provinces (Figure 4b). The status of *Listera cordata* var. *cordata* is unclear in Yukon and Northwest Territories, where both varieties occur but the orchid has only been listed at the species level.

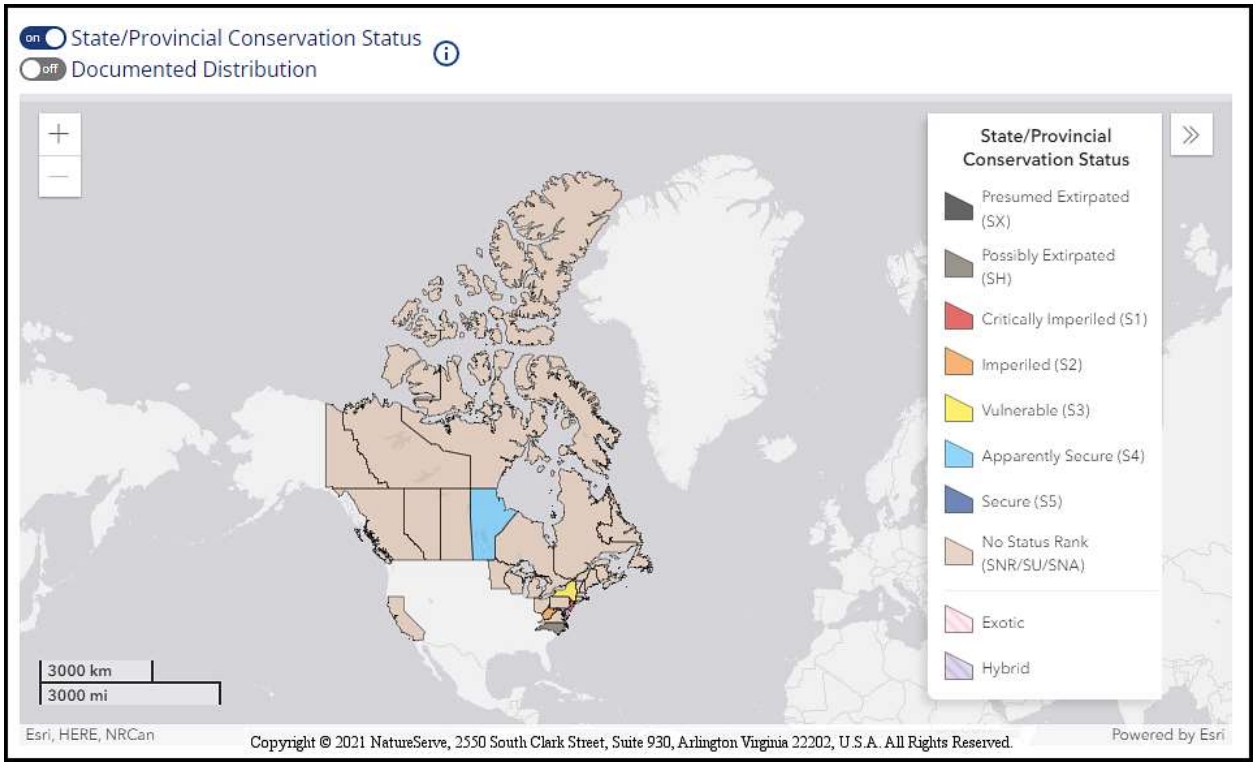


Figure 4a. Conservation status of L. cordata var. cordata in North America (NatureServe 2022).

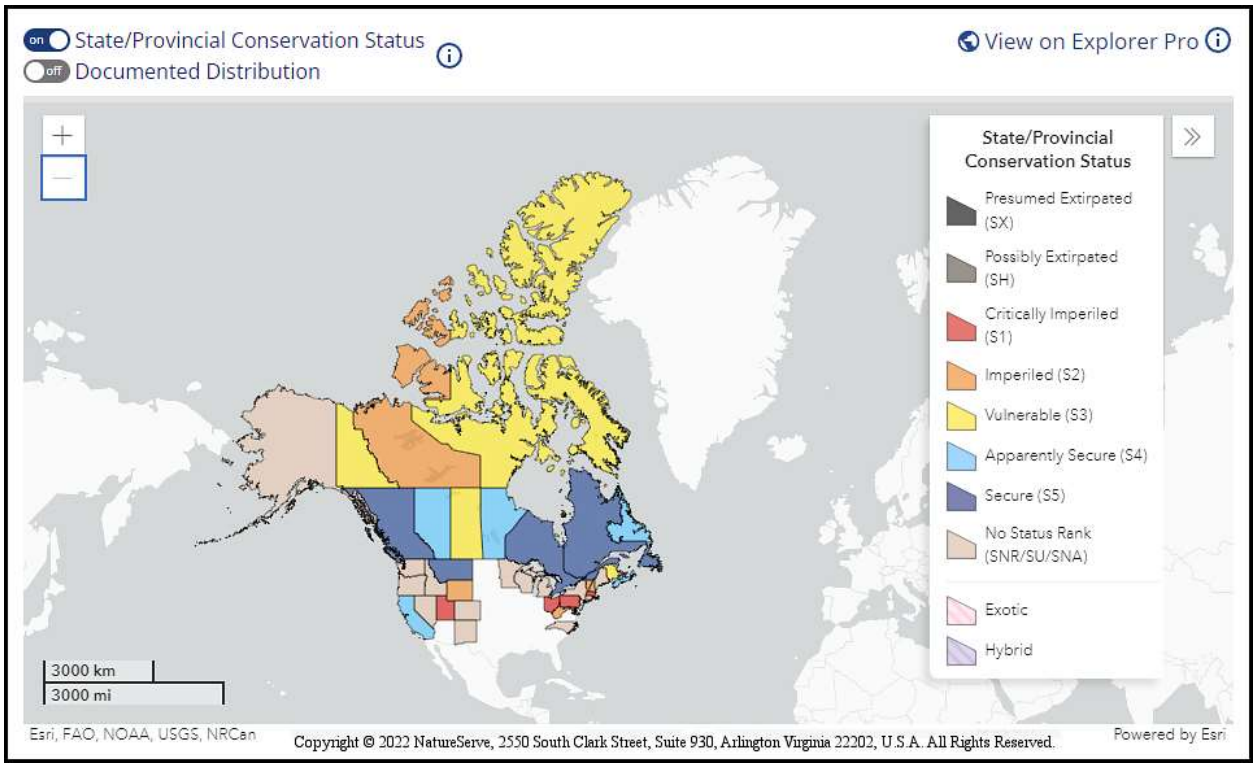


Figure 4b. Conservation status of L. cordata in North America (NatureServe 2022).

The critically imperiled (S1) status of *Listera cordata* var. *cordata* in New Jersey signifies five or fewer occurrences in the state (NJNHP 2022). 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. Heartleaf Twayblade 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 such as wetlands or coastal habitats, being listed does not currently provide broad statewide protection for the plants. Additional regional status codes assigned to the orchid 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).

The first report of *Listera cordata* in New Jersey was from Mercer County (Willis 1874) and Britton (1889) noted that the orchid was also known from Hudson County although it had not been collected recently. Fables (1956) reported that the Hudson County site had been "long ago destroyed" but that the species had been found at one or two sites in Sussex County. A total of five populations were eventually documented in Sussex County: Three are still extant but two have been extirpated (NJNHP 2022).

Threats

Changes in hydrology pose a significant threat to *Listera cordata*. Historical losses of populations in Great Britain were caused by the drainage of wetlands during the nineteenth century (Kotilínek et al. 2018). In New Jersey, flooding resulting from beaver (*Castor*

canadensis) activity has eliminated two former occurrences and threatens another (NJNHP 2022). Natural patterns of water flow that maintain *L. cordata* populations can also be altered by activities that create local obstructions, channels, or compaction of the substrate such as road construction, logging, off-road vehicular traffic, and trail maintenance. Activities in other parts of the watershed that lower the water table can also make some sites unsuitable for *L. cordata* (Hoy 2002).

The drying of sites makes habitats unsuitable for *L. cordata* by reducing the moss cover and accelerating the decomposition of soil organic matter, which typically leads to colonization by plant species with higher nutrient demands such as shrubs and trees (Kotilínek et al. 2018). Another species noted by Kotilínek et al. (2018) to appear when habitats are altered is *Phragmites australis. P. australis* ssp. *australis* is native in Europe (POWO 2022) but invasive in the United States where it often forms monospecific stands. Encroachment by other invasive species, such as Glossy Buckthorn (*Rhamnus frangula*) and Purple Loosestrife (*Lythrum salicaria*), has been reported as a threat to *Listera cordata* populations in Canada (Reddoch and Reddoch 1997). Native species can also threaten Heartleaf Twayblade because it is a poor competitor, so changes in habitat that increase soil productivity are likely to favor the establishment of other plants (Bayu et al. 2017). *Listera cordata* can tolerate some understory development (Islam et al. 2011) but continued growth of a shrub layer eventually leads to increased shading and canopy closure to the detriment of the orchid (Bayu et al. 2017).

Once *Listera cordata* has been extirpated from a site it does not readily reestablish, perhaps due to the species' poor development from seed and heavy reliance on vegetative reproduction. Bakka and Kiseleva (2021) observed that *L. cordata* was absent from suitable habitat in forested sites that had been logged 30–40 years earlier. The species also appears to be intolerant of fire, as it disappeared from sections of heather moors that had been repeatedly burned (Kotilínek et al. 2018).

Herbivory by White-tailed Deer (*Odocoileus virginianus*) has been cited as a threat to *Listera cordata* (Reddoch and Reddoch 1997, Hoy 2002) although Mckenzie (2009) reported that the species was not particularly sensitive to browsing. A study in Norway by Hegland and Rydgren (2016) found that *L. cordata* benefitted from exclosures that protected the plants from Red Deer (*Cervus elaphus*). Threats to the orchid from browsing may vary between sites depending on its visibility within the surrounding vegetation and the availability of alternative food sources.

Listera cordata plants can be damaged by *Parallelomma vittatum*, a leaf-mining fly that occurs in eastern North America and attacks several genera of orchids (BugGuide 2022). During the course of studying the insect's impact on other species, Light and MacConaill (2014) found documentation of its activity on *L. cordata* plants in the form of eggs, mines, and larvae that had been preserved in herbarium specimens. While some leaves may be injured by the insects, there is currently no evidence that the fly is a threat to populations of *L. cordata*.

Changing climactic conditions are likely to have a detrimental effect on *Listera cordata* throughout its global range. An analysis by Harrison et al. (2008) projected a significant loss of suitable habitat for *L. cordata* in England. Although Fay (2015) reported that the species had increased in the British Isles between 1987 and 2004, he cautioned against interpreting the

results as tolerance of climate change due to the likelihood that populations of the orchid had been under-recorded during the earlier surveys. A vulnerability assessment in Lithuania categorized *L. cordata* as highly sensitive to climate change, noting that the species in that group were likely to be among the first to go extinct (Ignatavicius and Tolekiene 2017), and a study of how various alpine orchids are shifting their distributions along elevation gradients found that *Listera cordata* had moved upwards but still showed a decrease in overall range because the upward movement was not sufficient to keep up with climate change or to compensate for losses at lower elevations (Geppert et al. 2020). New Jersey has been experiencing longer and more frequent summer droughts, a trend that is expected to continue along with rising temperatures (Hill et al. 2020). If hotter, drier growing seasons significantly alter the hydrology at sites that currently support *L. cordata*, the composition of the local plant communities could be altered in ways that adversely affect the orchid populations.

Management Summary and Recommendations

The most immediate concern for New Jersey's *Listera cordata* populations is loss of suitable habitat to changes in hydrology, although the causes could range from flooding to drought. Site-specific conservation planning should consider both land preservation and the establishment of significant buffer zones to prevent activities on adjacent properties or elsewhere in the watersheds from altering the water quantity or quality in communities where *L. cordata* occurs.

Routine monitoring of extant occurrences may not be helpful in assessing the vigor of individual populations, which normally fluctuate in size. However, regular visits could keep track of changes in habitat conditions and also evaluate the extent of any potential threats from herbivory. It is possible that searches of favorable sites near known populations could turn up additional occurrences. Kotilínek et al. (2018) pointed out that the species may be under-recorded throughout its range because it is easily overlooked, although the fact that the plants are somewhat inconspicuous may have provided some protection from both orchid collectors and browsing mammals.

Additional information regarding the species' light requirements and competitive abilities would be useful. The germination and establishment requirements of *Listera cordata* are poorly understood, and research in that area would also be beneficial. Propagation of the species from seed has proven difficult in laboratories and botanical gardens (Stoutamire 1964, Kotilínek et al. 2018). Even when *L. cordata* seeds were planted in natural settings where mature plants were present, germination was minimal (<0.2%), mortality was very high (> 98%), and no protocorms were formed (Těšitelová et al. 2015). Nevertheless, *L. cordata* has been cited as a "hardy" species (Baldwin 1884), so it is possible that cultivated plants are more easily maintained once they have matured.

Synonyms

The accepted botanical name of the species is *Listera cordata* var. *cordata* (L.) R. Br. (Magrath and Coleman 2020). A number of current sources utilize the synonym *Neottia cordata* (L.)

Rich. and do not recognize any varieties (e.g. Kartesz 2015, ITIS 2022, POWO 2022). Orthographic variants, synonyms, and common names are listed below (Magrath and Coleman 2020, USDA NRCS 2022b).

Botanical Synonyms	**Common Names**
Neottia cordata (L.) Rich.	Heartleaf Twayblade
Ophrys cordata L.	Lesser Twayblade
Bifolium cordatum (L.) Nieuwl.	Long-lipped Listera
Diphryllum cordatum (L.) Kuntze	
Distomaea cordata (L.) Spenn.	
Pollinirhiza cordata (L.)	

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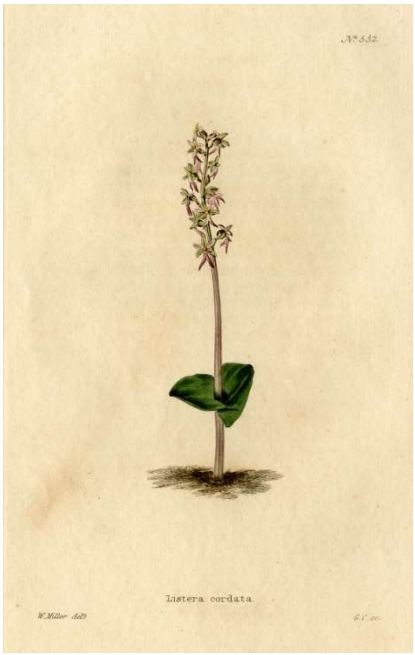

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