Thuja occidentalis

Arborvitae

Cupressaceae

Thuja occidentalis by John Hilty

***Thuja occidentalis* Rare Plant Profile**

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

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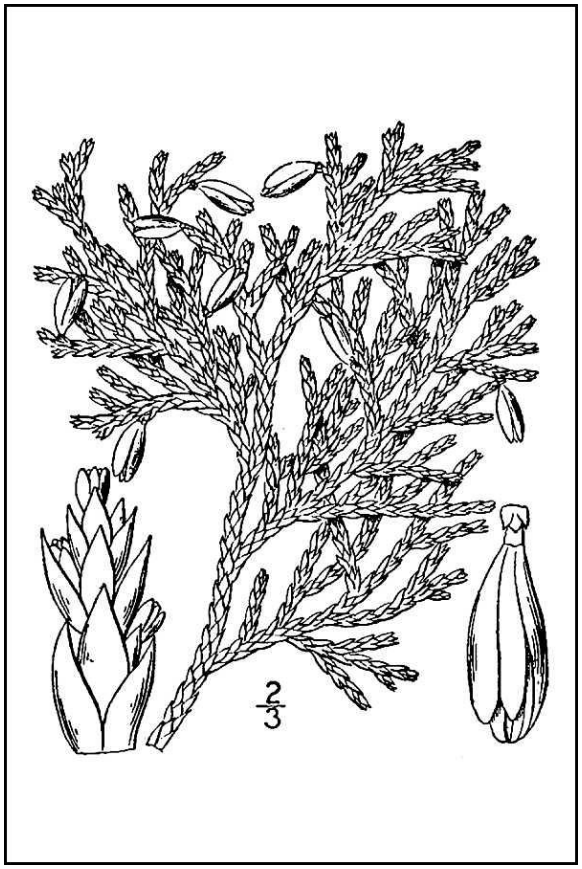
Life History

Thuja occidentalis (Arborvitae) is an evergreen tree in the cypress family that has shallow, spreading roots. The trees may attain heights of 20 meters or more but a prostrate form of the species has sometimes been found in harsh environments. Typical trees have primary branches that become shorter as they ascend the trunk, forming a conical shape. The ridged bark is gray-brown to red-brown and often fibrous. The flattened, scale-like leaves are arranged in rows of four. Male and female cones are borne on separate branches. The pollen cones are yellow or reddish and 1–2 mm long, and the seed cones are brown, somewhat bell-shaped, and 0.9–1.4 cm in length. (See Britton and Brown 1913, Curtis 1946, Fernald 1950, Gleason and Cronquist 1991, Petrides 1998, Chambers 2020).



Left: Britton and Brown 1913, courtesy USDA NRCS 2025a. Right: Jean-Marc Vallières, 2021.

The reproductive cones of *Thuja occidentalis* begin to form during the fall and expand the following spring. Male cones release their pollen between March and early June in various parts of the species' range. The female cones develop over a single growing season, ripening from late summer to early autumn and shedding the majority of their seeds by late autumn or early winter (Johnston 1990, Miller 1990, Weakley et al. 2024). Clonal reproduction is common in *Thuja occidentalis*. It frequently occurs when low-hanging branches or fallen trees become embedded in mossy substrate, develop roots, and form new stems (Curtis 1946, Johnston 1990), but living branches that are cut and dropped by animals may also take root (Miller 1990). In some *T.*

occidentalis populations vegetative propagation is the primary means of recruitment (Walker 1987, Young 1996, Lamy et al. 1999, Paul et al. 2014, Visnadi et al. 2019).

Thuja occidentalis is generally slow-growing and long-lived. For the first few years the seedlings only increase in height by an average of about 8 cm (Johnston 1990). Cone development has occasionally been reported in six-year-old saplings but under normal circumstances it takes 20–30 years for sexual reproduction to occur on a regular basis (Curtis 1946, Miller 1990). Mature trees can persist for hundreds of years (Miller 1990, Heinrichs 2009). In particularly harsh settings like cliff edge habitats the species develops exceptionally slowly—relying on a modular growth strategy to replace damaged parts—and some individuals may attain ages of 1,600–1,900 years (Matthes-Sears and Larson 1999, Larson 2001).

Commercial uses of *Thuja occidentalis* include timber, horticulture, and medicine. The soft, decay-resistant wood has been utilized for canoes, fencing, shingles, and other construction materials. Over 120 ornamental cultivars have been reported (Curtis 1946, Johnston 1990, Petrides 1998, Chambers 2020). The common name, Arborvitae or "tree of life", dates back to the 1500s when the French explorer Jacques Cartier and his crew successfully employed an Iroquois remedy derived from the branches as a cure for scurvy (Durzan 2009). Bioactive compounds extracted from *T. occidentalis* also exhibit a high potential for usage in a assortment of modern health applications (Baisane et al. 2025).

Pollinator Dynamics

Like most gymnosperms, *Thuja occidentalis* is pollinated by wind. As the male cones release their pollen, the ovules of the female cones exude sticky droplets of liquid known as pollination drops. The cones and their associated droplets are initially held at an angle that maximizes their exposure to air currents. Small amounts of pollen may occasionally be brought into contact with the droplets via rainwater flow. The deposition of conspecific pollen, or that of a closely related species, triggers drop withdrawal but pollen originating from taxa outside of the cypress family does not. Compatible pollen sinks into the fluid, which changes its shape and decreases in volume via evaporation until it is fully absorbed by the ovule. For most species in the Cupressaceae the withdrawal process takes less than an hour. *T. occidentalis* has one of the most rapid responses, averaging 8 minutes for conspecific pollen and 10 minutes for pollen from another family member. Later-acting incompatibility mechanisms may also take place within the ovules. Once fertilized the female cones change their orientation, shifting to an upright position (Owens et al. 1998, Xing et al. 1999, Gelbart and Aderkas 2002, Dörken and Jagel 2014).

Owens et al. (1990) found that *Thuja plicata* was highly self-compatible and that seems to be the case for *Thuja occidentalis* as well. Genetic studies of the latter species recorded low levels of outcrossing and it appeared that most seed development had resulted from self-fertilization or gene exchange with near relatives (Perry and Knowles 1990, Lamy et al. 1999). Although the native ranges of *T. occidentalis* and *T. plicata* do not overlap the two species can hybridize when they are grown in close proximity (Zielinski et al. 2019).

Seed Dispersal and Establishment

Thuja occidentalis produces about eight seeds per cone although crop size can vary considerably from one year to the next (Johnson 1990, Chambers 2020). The seeds are broadly winged (Fernald 1950), which facilitates wind dispersal. However, they rarely travel more than 60 meters from the parent tree so most distribution is local (Asselin et al. 2001, Cornett et al. 2001, Forester et al. 2008). Squirrels that consume *Thuja* seeds may occasionally disperse a few over greater distances (Miller 1990).

T. occidentalis seeds can germinate without stratification but a short period of exposure to cold seems to be helpful. Germination usually occurs the first year after dispersal, stimulated by the alternation of warm days and cool nights. Daytime temperatures of 29–30° C are required, so germination often takes place in May or June but it may be delayed in years when spring temperatures remain low (Johnston 1990, Miller 1990, Leopold 2005). Arborvitae does not form a seed bank in natural settings although the seeds can be maintained in storage for several years.

Johnston (1990) noted that *Thuja occidentalis* seeds can sprout readily on a variety of moist substrates but they only establish successfully on a few. In forested habitats *T. occidentalis* seedlings are most often found on decaying logs or other slightly elevated microsites. In flat spots or slight depressions, germination is inhibited when a thick litter layer is present and newly emerged seedlings can be overwhelmed by the rapid growth of sphagnum mosses. Young plants are sensitive to desiccation so a reliable moisture supply is critical, and survival into the sapling stage is dependent on the availability of sufficient light (Curtis 1946, Scott and Murphy 1987, Miller 1990, Bartlett et al. 1991, Cornett et al. 2000a & 2001, Forester et al. 2008, Heinrichs 2009, Larouche et al. 2011, Paul et al. 2014, Saucier et al. 2018, Allogio et al. 2021).

Habitat

Thuja occidentalis occurs at elevations of 0–900 meters above sea level, occupying disparate habitats that range from wet lowlands to cliff tops and faces (Matthes-Sears and Larson 1995, Young 1996, Grotte et al. 2012, Chambers 2020, Weakley et al. 2024). Arbuscular mycorrhizae have been documented in the species, and the fungal associations are probably critical in some of the more challenging habitats utilized by the trees (Matthes-Sears et al. 1992, Wang and Qiu 2006). In the northeastern United States *T. occidentalis* is often associated with calcareous substrates, which typically have pH values of 5.5–6.7 (Fernald 1919, Curtis 1946, Walker 1987, Ehrenfeld 2011, Johnson and Walz 2013). In other parts of its range soil pH values of 4.0 and 7.5 have been recorded (Beals 1965, Ogle 1989). Arborvitae was formerly found in a cliff-like setting in New Jersey (Torrey 1819) but the more recently known populations in the state have been situated in fens (NJNHP 2024). Comparative studies of *T. occidentalis* populations found no broad habitat-related trends that accounted for local differences in productivity, development, or survival (Musselman et al. 1975, Bartlett and Larson 1990, Matthes-Sears and Larson 1991, Briand et al. 1992a & 1992b).

In a few places *Thuja occidentalis* is the most prominent component of the canopy but it is much more likely to be found growing in mixed stands as a non-dominant species (Johnston 1990,

Bergeron et al. 2004). It is often associated with other conifers such as *Abies*, *Larix*, *Picea*, *Pinus*, or *Tsuga* but it also co-occurs with deciduous trees including *Acer*, *Betula*, *Fraxinus*, *Carya*, and *Quercus* species (Beals 1965, Breden et al. 2001, Quinn 2004, Grotte 2007, Heinrichs 2009, Ehrenfeld 2011, Grotte et al. 2012). *T. occidentalis* is shade tolerant at maturity but requires a relatively high amount of light during the seedling and sapling stages (Cornett et al. 2001, Weakley et al. 2024). Established populations generally lack juvenile Arborvitae plants in the understory unless they have experienced periodic canopy disturbances (Grotte et al. 2012, Kincaid 2016, Fraver et al. 2020, Allogio et al. 2021).

Wetland Indicator Status

Thuja occidentalis is a facultative wetland species, meaning that it usually occurs in wetlands but may occur in nonwetlands (U. S. Army Corps of Engineers 2022).

USDA Plants Code (USDA, NRCS 2025b)

THOC2

Coefficient of Conservancy (Walz et al. 2020)

CoC = 10. 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

The native range of *Thuja occidentalis* is restricted to eastern and central North America. The tree is also widely planted throughout that region, and it has been introduced into a number of Asian and European countries as well (Chambers 2020, POWO 2025). The map in Figure 1 depicts the extent of the species in the United States and Canada.

The USDA PLANTS Database (2025b) shows records of *Thuja occidentalis* in five New Jersey counties: Bergen, Hudson, Monmouth, Sussex, and Warren (Figure 2). It was also reported in Burlington, Camden, Essex, Mercer, Salem, and Somerset counties (Mid-Atlantic Herbaria 2025), although some records were probably based on specimens obtained from planted trees.

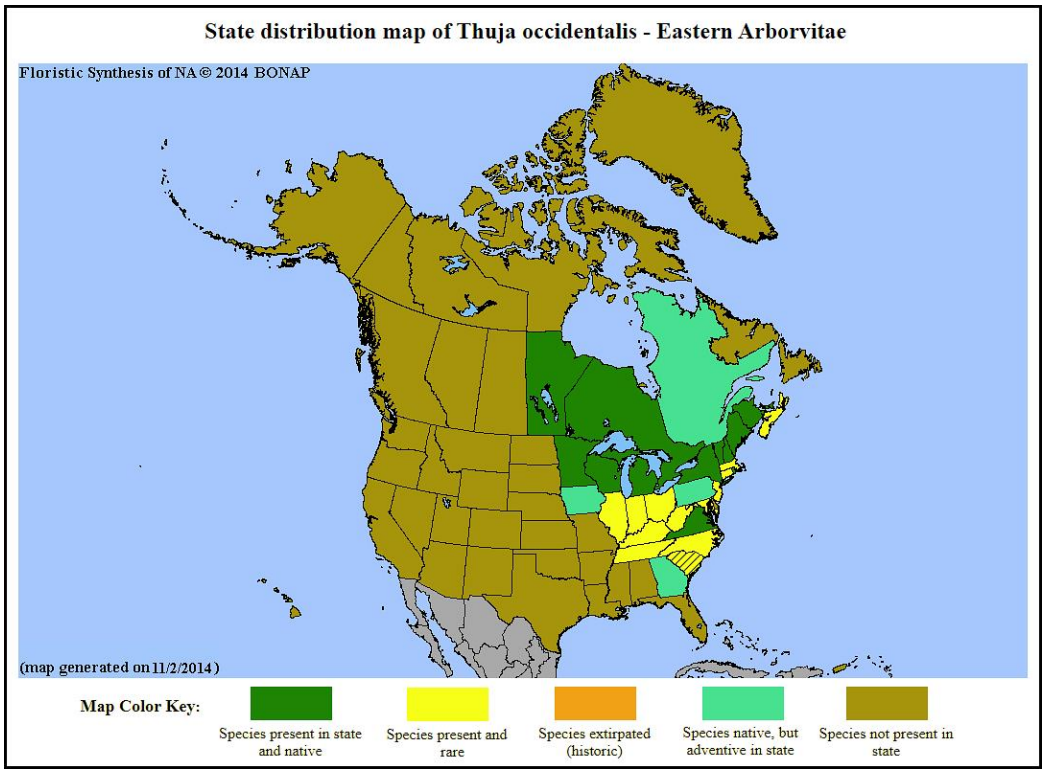


Figure 1. Distribution of T. occidentalis in North America, adapted from BONAP (Kartesz 2015).

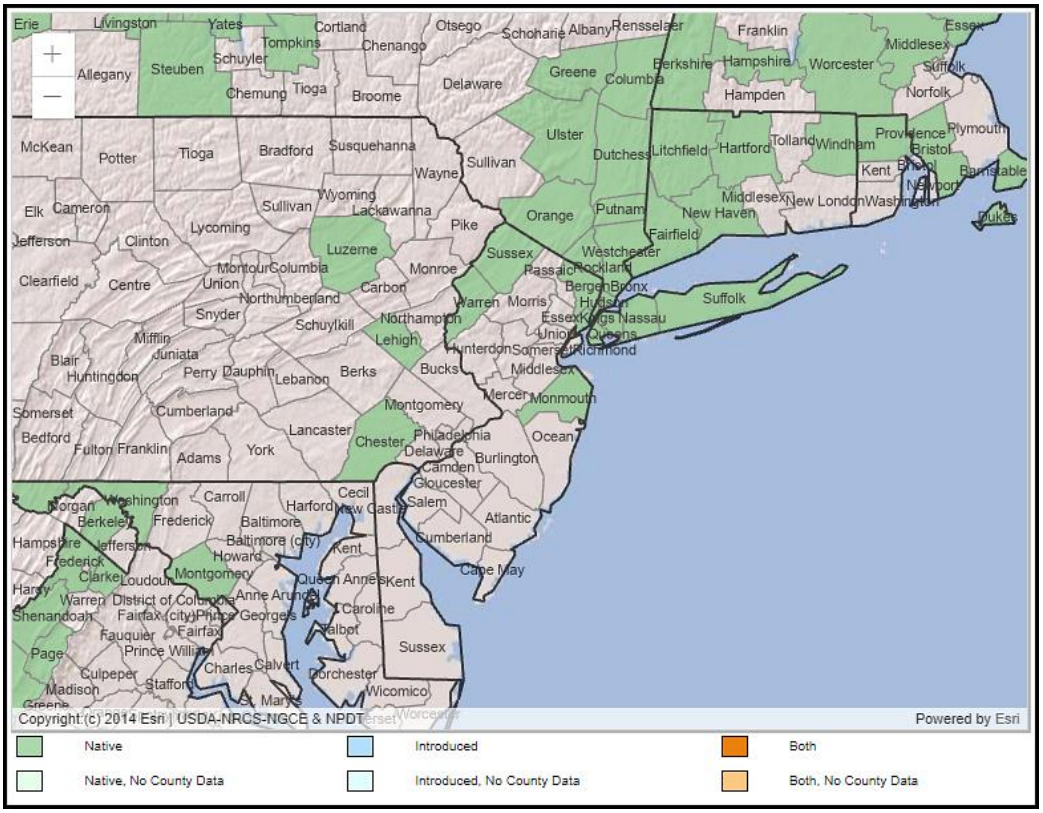


Figure 2. County records of T. occidentalis in New Jersey and vicinity (USDA NRCS 2025b).

Conservation Status

Thuja occidentalis 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 2025). The map below (Figure 3) illustrates the conservation status of *T. occidentalis* in North America. The tree is vulnerable (moderate risk of extinction) in three states and one province, imperiled (high risk of extinction) in three states and one province, and critically imperiled (very high risk of extinction) in four states. In the north-central part of its range Arborvitae is generally secure, apparently secure, or unranked. In two states near the center of its range (Delaware and Pennsylvania) only a few occurrences have been recorded and the species is considered non-native but not invasive (Rhoads and Block 2007, Delaware Trees 2025). According to Weakley et al. (2024), records of *T. occidentalis* from North Carolina are questionable and it has not recently been observed in that state.

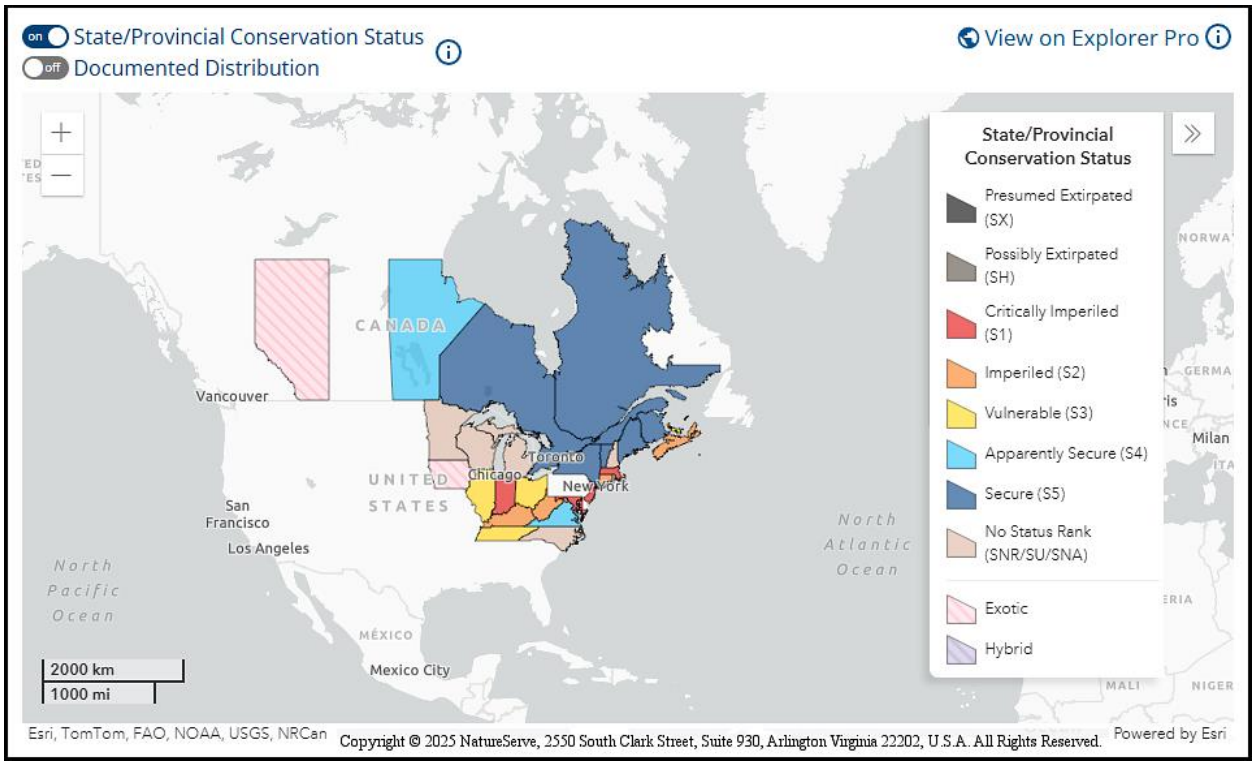


Figure 3. Conservation status of T. occidentalis in North America (NatureServe 2025).

Thuja occidentalis is critically imperiled (S1) in New Jersey (NJNHP 2024). 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. *T. occidentalis* 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 tree 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).

Native occurrences of *Thuja occidentalis* have always been rare in New Jersey. Torrey (1819) indicated that Arborvitae could be found on rocky banks along both sides of the lower Hudson River, and it was collected in Bergen and Warren counties during the 1800s (Willis 1877, Britton 1889). The species was subsequently documented in Sussex County (Taylor 1915), and by the 1980s that was the only county where it was extant (Hough 1983, Snyder 1989). *T. occidentalis* was one of the earliest plants to be identified as threatened, and then listed as endangered, in the state (NJONLM 1984, 1990). A Sussex County population that was extant at the turn of the century (Breden et al. 2006) has since disappeared. A single tree discovered by David Snyder at another site during 2022 appears to be the last naturally occurring example of the species in New Jersey (NJNHP 2024).

Threats

Thuja occidentalis is rare or extirpated at numerous sites in the southeastern portion of its range (Chambers 2020), and the extensive losses may have led to a genetic decline in some of the populations that remain (Pandey and Rajora 2012). A New Jersey population first discovered in 1965 was still extant in 2018, when it consisted of 18 plants that were under two meters in height. Just four years later no Arborvitae could be found at the site although it was searched twice, and the reason for the rapid decline of that occurrence is not known. No imminent threats were noted to the sole extant tree that was documented at another location (NJNHP 2024). However, that individual was situated in a calcareous fen, a community type that faces an assortment of threats in the state and is particularly susceptible to changes in hydrology and water quality (Johnson and Walz 2013).

Thuja occidentalis is vulnerable to both dehydration and inundation. Drying can limit tree growth, inhibit seedling establishment, and facilitate the introduction of more competitive species while excessively wet soils can cause the shallowly-rooted trees to topple more readily. Flooding by beavers or humans can wipe out entire stands, although some trees may persist vegetatively following inundation depending on local conditions (Beals 1965, Walker 1987, Johnston 1990, Miller 1990, Denneler et al. 2000a & 2000b, Kincaid 2016). Runoff that contains road salts has a detrimental effect on *T. occidentalis* vigor, reproduction, and survival (Johnson et al. 2022, Janssen et al. 2024). In places where Arborvitae grows on cliff faces and edges the inadvertent destruction of young plants by hikers and climbers takes a toll on the populations (Larson 1990). *T. occidentalis* is also highly susceptible to fire: The thin, oil-rich bark is flammable, carrying flames up to treetops, and even light ground fires can damage the roots. Burning is usually fatal for the trees and without a nearby seed source regeneration is unlikely once a population has been destroyed (Johnston 1990, Miller 1990, Carey 1993).

Red Squirrels (*Tamiasciurus hudsonicus*) and an assortment of birds that feed on the seeds of coniferous species can reduce the reproductive potential of mature *Thuja occidentalis* trees (Johnston 1990, Hilty 2020), but one of the most frequently noted impediments to regeneration is browsing by mammals. Moose (*Alces alces*), Snowshoe Hares (*Lepus americanus*), and

Porcupines (*Erethizon dorsatum*) all contribute to the problem in some parts of the tree's range but the greatest offenders are White-tailed Deer (*Odocoileus virginianus*). *T. occidentalis* is a very important winter food source for deer—the animals often use *T. occidentalis* stands for both shelter and browse during the winter months (Curtis 1946, Miller 1990), and Ozaga and Verme (1970) found that a herd could subsist on a diet made up entirely of Arborvitae from January through March. The loss of seedlings and saplings to deer herbivory has repeatedly been identified as a significant barrier to the maintenance of *T. occidentalis* populations (Johnston 1990, Cornett et al. 2000b, Rooney et al. 2002, Forester et al. 2008, Larouche et al. 2011, Saucier et al. 2018, Allogio et al. 2021, VanderMolen and Webster 2021). One exception was noted a site in Quebec where *T. occidentalis* appeared to benefit from the preferential browsing of more competitive plants (deBlois and Bouchard 1995).

Thuja occidentalis is relatively free of serious diseases or insect pests: Most pose little threat to natural populations and are mainly problematic in terms of lumber value or cosmetic damage to ornamental plantings. Even as older trees decay internally they can continue to maintain a vigorous crown (Curtis 1946, Johnston 1990, Miller 1990, Fraver et al. 2020).

Climate Change Vulnerability

An assessment of the potential effects of climate change on selected plants determined that *Thuja occidentalis* was moderately vulnerable in New Jersey (Ring et al. 2013). As the climate continues to warm plant communities in the state are progressively being exposed to higher temperatures, while shifting precipitation patterns have increased the frequency and intensity of both droughts and floods (Hill et al. 2020).

Thuja occidentalis is well-adapted to a cool climate and a short growing season (Johnston 1990). The species' vigor and productivity do not appear to be greatly influenced by temperature (Paul et al. 2014) and an analysis of the fossil record suggests that Arborvitae has exhibited a limited response to environmentally-induced stresses (Stein et al. 2019). The most direct climate-related threats to *T. occidentalis* in New Jersey will probably be associated with extended periods of drought, which could curb growth and reproduction and increase the risk of wildfires (Walker 1987, Bergeron et al. 2004, Housset et al. 2015, Visnadi et al. 2019). Projections by Iverson et al. (2005) indicated that the amount suitable habitat for *T. occidentalis* in the eastern United States is likely to decrease in the future.

Management Summary and Recommendations

The primary conservation strategies for *Thuja occidentalis* throughout its range generally focus on creating conditions that will increase its opportunities to reproduce from seed. Selective, small-scale canopy disturbances are frequently recommended in order to promote seedling establishment, and the importance of preserving mature trees as seed sources during the course of forest management activities is emphasized. Management of local deer populations or safeguarding young plants from herbivory is also essential throughout the seedling and sapling stages (Walker 1987, Asselin et al. 2001, Larouche et al. 2011, Kincaid 2016, Saucier et al. 2018,

Fraver et al. 2020). Allogio et al. (2021) suggested using techniques that maintain a diverse microtopography to provide safe germination sites. The utilization of fire in *T. occidentalis* habitats is generally inadvisable, although small, low-intensity burns that create open patches in the vicinity of mature, reproductive trees may be effective in some situations (Bergeron et al. 2004, Paul et al. 2014).

Since the New Jersey occurrence consists of a single mature tree in a shrubby fen, habitat preparation should be adapted from the guidelines cited by Miller (1990), which entail clearing narrow (20 meter) strips or small (1,000 m^2) patches downwind from the seed source. It will also be necessary to protect seedlings and saplings from browsing. According to Villemaire-Côté et al. (2017), the exclusion of mammalian herbivores for a nine-year period should be sufficient to allow the trees to attain heights of three meters or more.

Synonyms

The accepted botanical name of the species is *Thuja occidentalis* L. A selection of orthographic variants, synonyms, and common names are listed below (ITIS 2025, POWO 2025, USDA NRCS 2025b).

Botanical Synonyms	Common Names
Thuja occidentalis var. *fastigiata* H. Jaeger	Arborvitae
Thuja occidentalis f. *malonyana* C. K. Schneid.	Arbor Vitae
Thuja occidentalis var. *nigra* L. H. Bailey	Northern White-cedar
Thuja occidentalis var. *pyramidalis* Zederb.	Eastern White Cedar
Cupressus arborvitae O. Targ. Tozz.	
Cupressus nobleana (Beissn.) Lavallée	
Juniperus ericoides Mast.	
Retinispora devriesiana Mast.	
Retinispora dubia Carrière	
Retinispora ellwangeriana Carrière	
Retinispora glaucescens Hochst. ex Beissn.	
Retinispora keteleeri Beissn.	
Retinispora meldensis Carrière	
Retinispora nobleana Beissn.	
Retinispora pygmaea Beissn.	
Retinispora troubetzkoyana Mast.	
Thuja bodmeri Beissn.	
Thuja canadensis K. Koch	
Thuja caucasica Gordon	
Thuja compacta Standish ex Gordon	
Thuja ellwangeriana Carrière	
Thuja ericoides Gordon	
Thuja globosa Beissn.	
Thuja hoveyi Gordon	

Thuja obtusa Moench
Thuja odorata Marshall
Thuja recurvata-nana Stelzner
Thuja sibirica Gordon
Thuja tatarica Gordon
Thuja triangularis Defresne ex Beer
Thuja variegata Marshall
Thuja vervaeneana Van Geert ex Gordon
Thuja wareana var. *lutea* Van Geert

References

Allogio, Jeanette A., Shawn Fraver, Laura S. Kenefic, Jay W. Wason, and John-Pascal Berrill. 2021. Microsite requirements for successful regeneration in lowland Northern White-cedar (*Thuja occidentalis* L.) forests. Forest Ecology and Management 499: 119639.

Asselin, H., M. J. Fortin, and Y. Bergeron. 2001. Spatial distribution of late-successional coniferous species regeneration following disturbance in southwestern Quebec boreal forest. Forest Ecology and Management 140: 29–37.

Baisane, Vrushali, Sakshi Shejwal, Pritam Sawant, Sanika Chavan, and Priya Salunke. 2025. A review on *Thuja* plant species. International Journal of Scientific Research and Technology 2(2): 14–24.

Bartlett, R. M. and D. W. Larson. 1990. The physiological basis for the contrasting distribution patterns of *Acer saccharum* and *Thuja occidentalis* at cliff edges. Journal of Ecology 78(4): 1063–1078.

Bartlett, R. M., R. J. Reader, and D. W. Larson. 1991. Multiple controls of cliff-edge distribution patterns of *Thuja occidentalis* and *Acer saccharum* at the stage of seedling recruitment. Journal of Ecology 79(1): 183–197.

Beals, Edward W. 1965. An anomalous White Cedar-Black Spruce swamp in northern Wisconsin. The American Midland Naturalist 74(1): 244.

Bergeron, Y., S. Gauthier, M. Flannigan, and V. Kafka. 2004. Fire regimes at the transition between mixedwood and coniferous boreal forest in northwestern Quebec. Ecology 85: 1916–1932.

Breden, Thomas F., Yvette R. Alger, Kathleen Strakosch Walz, and Andrew G. Windisch. 2001. Classification of Vegetation Communities of New Jersey: Second iteration. Association for Biodiversity Information and New Jersey Natural Heritage Program, Office of Natural Lands Management, Division of Parks and Forestry, NJ Department of Environmental Protection, Trenton, NJ. 230 pp.

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.

Briand, Christopher H., Usher Posluszny, and Douglas W. Larson. 1992a. Comparative seed morphology of *Thuja occidentalis* (Eastern White Cedar) from upland and lowland sites. Canadian Journal of Botany 70(2): 434–438.

Briand, Christopher H., Usher Posluszny, Douglas W. Larson, and Uta Matthes-Sears. 1992b. Patterns of architectural variation in *Thuja occidentalis* L. (Eastern White Cedar) from upland and lowland sites. Botanical Gazette 152(4): 494–499.

Britton, N. L. 1889. Catalogue of plants found in New Jersey. Geological Survey of New Jersey, Final Report of the State Geologist 2: 27–642.

Britton, N. L. and A. Brown. 1913. An Illustrated Flora of the Northern United States and Canada in three volumes: Volume I (Ferns to Buckwheat). Second Edition. Reissued (unabridged and unaltered) in 1970 by Dover Publications, New York, NY. 680 pp.

Carey, Jennifer H. 1993. *Thuja occidentalis*. In: Fire Effects Information System, U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Accessed September 19, 2025 at https://www.fs.usda.gov/database/feis/plants/tree/thuocc/all.html

Chambers, Kenton L. Page updated November 5, 2020. *Thuja occidentalis* 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 September 19, 2025 at https://floranorthamerica.org/Thuja_occidentalis

Cornett, Meredith W., Peter B. Reich, Klaus J. Puettmann, and Lee E. Frelich. 2000a. Seedbed and moisture availability determine safe sites for early *Thuja occidentalis* (Cupressaceae) regeneration. American Journal of Botany 87(12): 1807–1814.

Cornett, Meredith W., Lee E. Frelich, Klaus J. Puettmann, and Peter B. Reich. 2000b. Conservation implications of browsing by *Odocoileus virginianus* in remnant upland *Thuja occidentalis* forests. Biological Conservation 93: 359–369.

Cornett, Meredith W., Klaus J. Puettmann, Lee E. Frelich, and Peter B. Reich. 2001. Comparing the importance of seedbed and canopy type in the restoration of upland *Thuja occidentalis* forests of northeastern Minnesota. Restoration Ecology 9(4): 386–396.

Curtis, James D. 1946. Preliminary observations on northern white-cedar in Maine. Ecology 27(1): 23–36.

de Blois, Sylvie and André Bouchard. 1995. Dynamics of *Thuja occidentalis* in an agricultural landscape of southern Quebec. Journal of Vegetation Science 6(4): 531–542.

Delaware Trees. 2025. Unusual Trees, Delaware Forest Service, Urban and Community Forestry Program. Accessed September 19, 2025 at https://delawaretrees.com/bigtrees/unusual-trees/

Denneler, Bernhard, Hugo Asselin, Yves Bergeron, and Yves Bégin. 2008a. Decreased fire frequency and increased water levels affect riparian forest dynamics in southwestern boreal Quebec, Canada. Canadian Journal of Forest Research 38: 1083–1094.

Denneler, Bernhard, Yves Bergeron, Yves Bégin, and Hugo Asselin. 2008b. Growth responses of riparian *Thuja occidentalis* to the damming of a large boreal lake. Botany 86: 53–62.

Dörken, Veit Martin and Armin Jagel. 2014. Orientation and withdrawal of pollination drops in Cupressaceae s. l. (Coniferales). Flora - Morphology, Distribution, Functional Ecology of Plants 209(1): 34–44.

Durzan, Don J. 2009. Arginine, scurvy and Cartier's "tree of life". Journal of Ethnobotany and Ethnomedicine 5(5): doi:10.1186/1746-4269-5-5.

Ehrenfeld, Joan G. 2011. Wetlands of the Highlands Region. In Richard G. Lathrop, Jr. (ed.), The Highlands: Critical Resources, Treasured Landscapes. Rutgers University Press, New Brunswick, NJ.

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

Fernald, M. L. 1919. Lithological factors limiting the ranges of *Pinus banksiana* and *Thuja occidentalis*. Contributions from the Gray Herbarium of Harvard University 58: 41–67.

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

Forester, James D., Dean P. Anderson, and Monica G. Turner. 2008. Landscape and local factors affecting Northern White Cedar (*Thuja occidentalis*) recruitment in the Chequamegon-Nicolet National Forest, Wisconsin (USA). The American Midland Naturalist 160(2): 438–453.

Fraver, Shawn, Laura S. Kenefic, Andrew R. Cutko, and Alan S. White. 2020. Natural disturbance and stand structure of old-growth Northern White-cedar (*Thuja occidentalis*) forests, northern Maine, USA. Forest Ecology and Management 456: 117680.

Gelbart, Galatea and Patrick von Aderkas. 2002. Ovular secretions as part of pollination mechanisms in conifers. Annals of Forest Science 59(4): 345–357.

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.

Grotte, Karine. 2007. Old Growth Northern White-cedar (*Thuja occidentalis* L.) Stands in the Mid-boreal Lowlands of Manitoba. Honors Thesis, University of Manitoba, Winnipeg, Manitoba. 49 pp.

Grotte, K. L., D. K. Heinrichs, and J. C. Tardif. 2012. Old-growth characteristics of disjunct *Thuja occidentalis* stands at their northwestern distribution limit, central Canada. Natural Areas Journal 32(3): 270–282.

Heinrichs, Derrick Ko. 2009. Ecology of Northern White-cedar (*Thuja occidentalis* L.) Stands at Their Northwestern Limit of Distribution in Manitoba, Canada. Master's Thesis, University of Manitoba, Winnipeg, Manitoba. 121 pp.

Hill, Rebecca, Megan M. Rutkowski, Lori A. Lester, Heather Genievich, and Nicholas A. Procopio (eds.). 2020. New Jersey Scientific Report on Climate Change, Version 1.0. New Jersey Department of Environmental Protection, Trenton, NJ. 184 pp.

Hilty, John. Undated image of *Thuja occidentalis*. Photo from Illinois Wildflowers https://www.illinoiswildflowers.info/trees/plants/white_cedar.html, used with permission https://www.illinoiswildflowers.info/files/photo_use.html

Hilty, John. 2020. *Thuja occidentalis*. Illinois Wildflowers. Accessed September 19, 2025 at https://www.illinoiswildflowers.info/trees/plants/white_cedar.html

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

Housset, Johann M., Martin P. Girardin, Mathieu Baconnet, Christopher Carcaillet, and Yves Bergeron. 2015. Unexpected warming-induced growth decline in *Thuja occidentalis* at its northern limits in North America. Journal of Biogeography 42(7): 1233–1245.

ITIS (Integrated Taxonomic Information System). Accessed February 6, 2025 at http://www.itis.gov

Iverson, Louis R., Anantha M. Prasad, and Mark W. Schwartz. 2005. Predicting potential changes in suitable habitat and distribution by 2100 for tree species in the eastern United States. Journal of Agricultural Meteorology 61(1): 29–37.

Janssen, Eric, Sara A. Johnson, Nichole Reed, Patricia Dickerson, Christopher J. Whelan, and Brenda Molano-Flores. 2024. Impacts of road salt on seed germination of *Thuja occidentalis* found in natural communities adjacent to the Illinois Tollway in northeastern IL, USA. Botany 102: 340–348.

Johnson, Elizabeth A. and Kathleen Strakosch Walz. 2013. Integrated Management Guidelines for Four Habitats and Associated State Endangered Plants and Wildlife Species of Greatest Conservation Need in the Skylands and Pinelands Landscape Conservation Zones of the New Jersey State Wildlife Action Plan. Report prepared for NatureServe #DDCF-0F-001a, Arlington, VA. 140 pp.

Johnson, Sara A., Eric Janssen, Nichole Reed, Patricia Dickerson, Christopher J. Whelan, and Brenda Molano-Flores. 2022. The role of environmental stressors on reproduction, seed morphology, and germination: A case study of Northern White Cedar, *Thuja occidentalis* L. Botany 100: 839–847.

Johnston, William F. 1990. *Thuja occidentalis* L. Northern White-cedar. Silvics of North America 1(10): 580–589.

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)].

Kincaid, Joshua A. 2016. Structure and dendroecology of *Thuja occidentalis* in disjunct stands south of its contiguous range in the central Appalachian Mountains, USA. Forest Ecosystems 3: Article 25.

Lamy, Sylvie, André Bouchard, and Jean-Pierre Simon. 1999. Genetic structure, variability, and mating system in Eastern White Cedar (*Thuja occidentalis*) populations of recent origin in an agricultural landscape in southern Quebec. Canadian Journal of Forest Research 29(9): 1383–1392.

Larouche, Catherine, Jean-Claude Ruel, and Jean-Martin Lussier. 2011. Factors affecting Northern White-cedar (*Thuja occidentalis*) seedling establishment and early growth in mixedwood stands. Canadian Journal of Forest Research 41(3): 568–582.

Larson, D. W. 1990. Effects of disturbance on old-growth *Thuja occidentalis* at cliff edges. Canadian Journal of Botany 68: 1147–1155.

Larson, D. W. 2001. The paradox of great longevity in a short-lived tree species. Experimental Gerontology 36(4/6): 651–673.

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

Matthes-Sears, Uta and Douglas W. Larson. 1991. Growth and physiology of *Thuja occidentalis* L. from cliffs and swamps: Is variation habitat or site specific? Botanical Gazette 152(4): 500–508.

Matthes-Sears, Uta and Douglas W. Larson. 1995. Rooting characteristics of trees in rock: A study of *Thuja occidentalis* on cliff faces. International Journal of Plant Sciences 156(5): 679–686.

Matthes-Sears, U. and D. W. Larson. 1999. Limitations to seedling growth and survival by the quantity and quality of rooting space: Implications for the establishment of *Thuja occidentalis* on cliff faces. International Journal of Plant Sciences 160(1): 122–128.

Matthes-Sears, Uta, Christoph Neeser, and Douglas W. Larson. 1992. Mycorrhizal colonization and macronutrient status of cliff-edge *Thuja occidentalis* and *Acer saccharum*. Ecography 15(3): 262–266.

Mid-Atlantic Herbaria. 2025. Accessed at https://midatlanticherbaria.org/portal/index.php on September 19, 2025.

Miller, R. O. 1990. Ecology and management of northern white-cedar. Presentation from the Regenerating Conifer Cover in Deer Yards workshop, December 5, 1990, North Bay, Ontario.

Musselman, Robert C., Donald T. Lester, and Michael S. Adams. 1975. Localized ecotypes of *Thuja occidentalis* L. in Wisconsin. Ecology 56(3): 647–655.

NatureServe. 2025. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed September 19, 2025 at https://explorer.natureserve.org/

NJNHP (New Jersey Natural Heritage Program). 2010. Explanation of Codes Used in Natural Heritage Reports. Updated March 2010. Available at https://nj.gov/dep/parksandforests/natural/docs/nhpcodes_2010.pdf

NJNHP (New Jersey Natural Heritage Program). 2024. Biotics 5 Database. NatureServe, Arlington, VA. Accessed March 15, 2024.

NJONLM (New Jersey Office of Natural Lands Management). 1984. New Jersey's Threatened Plant Species. New Jersey Department of Environmental Protection, Division of Parks and Forestry, Trenton, NJ. 14 pp.

NJONLM (New Jersey Office of Natural Lands Management). 1990. State of New Jersey Endangered Plant Species List. New Jersey Department of Environmental Protection, Division of Parks and Forestry, Trenton, NJ. 10 pp.

Ogle, Douglas W. 1989. Barns Chapel Swamp: An unusual Arbor-vitae (*Thuja occidentalis* L.) site in Washington County, Virginia. Castanea 54(3): 200–202.

Owens, John N., Anna M. Colangeli, and Sheila J. Morris. 1990. The effect of self-, cross-, and no pollination on ovule, embryo, seed, and cone development in western red cedar (*Thuja plicata*). Canadian Journal of Forest Research 20(1): 66–75.

Owens, John N., Tokushiro Takaso, and C. John Runions. 1998. Pollination in conifers. Trends in Plant Science 3(12): 479–485.

Ozoga, J. J. and L. J. Verme. 1970. Winter feeding patterns of penned White-tailed Deer. Journal of Wildlife Management 34: 431–439.

Pandey, Madhav and Om P. Rajora. 2012. Higher fine-scale genetic structure in peripheral than in core populations of a long-lived and mixed-mating conifer - Eastern White Cedar (*Thuja occidentalis* L.). Evolutionary Biology 12: Article 48.

Paul, Véronique, Yves Bergeron, and Francine Tremblay. 2014. Does climate control the northern range limit of Eastern White Cedar (*Thuja occidentalis* L.)?. Plant Ecology 215(2): 181–194.

Perry, Daniel J. and Peggy Knowles. 1990. Evidence of high self-fertilization in natural populations of eastern white cedar (*Thuja occidentalis*). Canadian Journal of Botany 68(3): 663–668.

Petrides, George A. 1988. Eastern Trees. Peterson Field Guides, Houghton Mifflin Company, Boston. 272 pp.

POWO. 2025. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Accessed August 1, 2025 at http://www.plantsoftheworldonline.org/

Quinn, Norman W. S. 2004. The presettlement hardwood forests and wildlife of Algonquin Provincial Park: A synthesis of historic evidence and recent research. The Forestry Chronicle 80(6): 705–717.

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

Ring, Richard M., Elizabeth A. Spencer, and Kathleen Strakosch Walz. 2013. Vulnerability of 70 Plant Species of Greatest Conservation Need to Climate Change in New Jersey. New York Natural Heritage Program, Albany, NY and New Jersey Natural Heritage Program, Department of Environmental Protection, Office of Natural Lands Management, Trenton, NJ, for NatureServe #DDCF-0F-001a, Arlington, VA. 38 pp.

Rooney, Thomas P., Stephen L. Solheim, and Donald M. Waller. 2002. Factors affecting the regeneration of Northern White Cedar in lowland forests of the Upper Great Lakes region, USA. Forest Ecology and Management 163(1-3): 119–130.

Saucier, Laurence, Jean-Claude Ruel, and Catherine Larouche. 2018. Variations in Northern White-cedar (*Thuja occidentalis*) regeneration following operational selection cutting in mixedwood stands of western Quebec. Canadian Journal of Forest Research 48: 1311–1319.

Scott, Michael L. and Peter G. Murphy. 1987. Regeneration patterns of Northern White Cedar, an old-growth forest dominant. American Midland Naturalist 117(1): 10–16.

Snyder, David B. 1989. On the edge of extirpation: New Jersey's most critically imperiled flora. In Eric F. Karlin (ed.), New Jersey's Rare and Endangered Plants and Animals. Institute for Environmental Studies, Ramapo College, Mahwah, NJ.

Stein, Rebekah A., Nathan D. Sheldon, and Selena Smith. 2019. Rapid response to anthropogenic climate change by *Thuja occidentalis*: Implications for past climate reconstructions and future climate predictions. PeerJ 7: e7378.

Taylor, Norman. 1915. Flora of the vicinity of New York - A contribution to plant geography. Memoirs of the New York Botanical Garden 5: 1–683.

Torrey, John. 1819. Catalogue of Plants Growing Spontaneously Within Thirty Miles of the City of New York. Websters and Skinners, Albany, NY. 100 pp.

U. S. Army Corps of Engineers. 2022. National Wetland Plant List, version 3.6. https://nwpl.sec.usace.army.mil/ U. S. Army Corps of Engineers Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2025a. *Thuja occidentalis* 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.

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2025b. PLANTS profile for *Thuja occidentalis* (Arborvitae). The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed February 6, 2025 at http://plants.usda.gov

Vallières, Jean-Marc. 2021. Photo of *Thuja occidentalis* from Québec. Shared via iNaturalist at https://www.inaturalist.org/observations/98016990, licensed by https://creativecommons.org/licenses/by-nc/4.0/

VanderMolen, Matthew and Christopher R. Webster. 2021. Influence of deer herbivory on regeneration dynamics and gap capture in experimental gaps, 18 years post-harvest. Forest Ecology and Management 501(4): Article 119675.

Villemaire-Côté, Olivier, Jean-Claude Ruel, and Luc Sirois. 2017. Development of Northern White-cedar (*Thuja occidentalis* L.) plantations within and outside deer yards. Forests 8(9): Article 326.

Visnadi, Isabelle, Johann Housset, Cécile Leroy, Christopher Carcaillet, Hugo Asselin, and Yves Bergeron. 2019. Limited recruitment of Eastern White Cedar (*Thuja occidentalis* L.) under Black Spruce canopy at its northern distribution limit. Ecoscience 26(2): 123–132.

Walker, Gary L. 1987. Ecology and Population Biology of *Thuja occidentalis* L. in its Southern Disjunct Range. Doctoral Dissertation, University of Tennessee, Knoxville, TN. 159 pp.

Walz, Kathleen S., Jason L. Hafstad, Linda Kelly, and Karl Anderson. 2020. Floristic Quality Assessment Index for Vascular Plants of New Jersey: Coefficient of Conservancy (CoC) Values for Species and Genera (update to 2017 list). New Jersey Department of Environmental Protection, New Jersey Forest Service, Office of Natural Lands Management, Trenton, NJ.

Wang, B. and Y. L. Qiu. 2006. Phylogenetic distribution and evolution of mycorrhizas in land plants. Mycorrhiza 16(5): 299–363.

Weakley, A. S. and Southeastern Flora Team. 2024. Flora of the Southeastern United States. Edition of March 4, 2024. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, NC. 2203 pp.

Willis, Oliver R. 1877. Flora of New Jersey. Revised Edition. A. S. Barnes and Company, New York, NY. 88 pp.

Xing, Shu-Ping, Quan Zhang, Yu-Xi Hu, Zu-Keng Chen, and Jin-Xing Lin. 1999. The mechanism of pollination in *Platycladus orientalis* and *Thuja occidentalis* (Cupressaceae). Journal of Integrative Plant Biology 41(2): 130–132.

Young, John M. 1996. The Cliff Ecology and Genetic Structure of Northern White Cedar (*Thuja occidentalis* L.) in its Southern Disjunct Range. Master's Thesis, University of Tennessee, Knoxville, TN. 108 pp.

Zieliński, Jerzy, Władysław Danielewicz, and Piotr Kosiński. 2019. Hybrids of *Thuja occidentalis* and *T. plicata* (Cupressaceae) – Fact or misunderstanding? Rocznik Polskiego Towarzystwa Dendrologicznego 67: 9–24.