Juglans cinerea

Butternut

Juglandaceae

Juglans cinerea by Michael Henry, 2019

***Juglans cinerea* 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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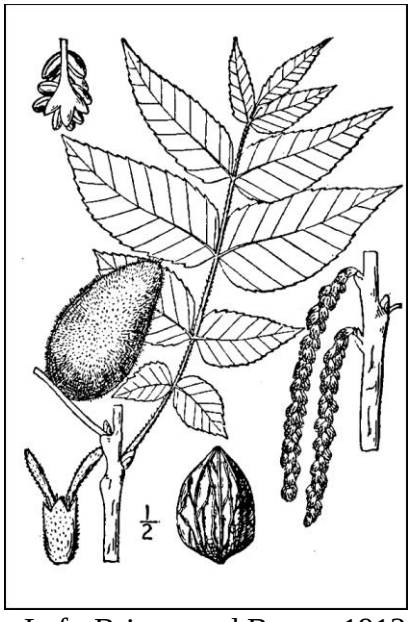
Life History

Juglans cinerea (Butternut) is a moderately-sized tree in the walnut family. Butternuts may reach up to 30 meters in height but they are typically under 20 meters. Britton and Brown (1913) noted that the trunk diameter of *J. cinerea* trees was generally less than a meter, although the largest known specimen in New Jersey had a dbh (diameter at 1.37 m above ground level) of 1.6 meters (Johnson 1998). Butternut trees usually develop both a deep taproot and widely spreading lateral roots (Van Dersal 1938). The bark is ashy gray and has smooth or scaly plates that are separated by deep fissures. The branches of *J. cinerea* are stout with large (12–18 mm) conic terminal buds, and distinctive pads of velvety tan hairs are present above the leaf scars. The pinnately compound leaves are 30–60 cm long and have an odd number of leaflets: 11–19 is typical but an individual with 3–5 leaflets was reportedly documented in New Jersey during 1886 (Britton 1889). The inflorescences of *Juglans cinerea* are dense clusters of unisexual flowers known as a catkins or aments. Staminate (male) catkins are located above the previous season's leaf scars while the pistillate (female) catkins can be found at the tips of the new growth. The fruits are deeply ridged ovoid nuts that are initially enclosed in thick husks, and they may occur singly or in small clusters of up to five. (See Trelease 1896, Britton and Brown 1913, Manning 1938, Fernald 1950, Elias 1972, Hatterman 1984, Gleason and Cronquist 1991, Whittemore and Stone 2020).



Left: Britton and Brown 1913, courtesy USDA NRCS 2024a. Right: Peter M. Dziuk, 2005.

Juglans cinerea trees rarely live for more than 75 years (Clark 1965). They begin to reproduce at about 20 years of age and optimal seed production occurs when they are 30–60 years old (Rink 1990). Butternut catkins begin to form during the fall but then growth is halted and the nascent inflorescences are protected by 2–4 scale-like bracts through the winter months (Manning 1938, Hatterman 1984). After the leaves have started to unfold in the spring the flowers appear, typically between April and June. The fruits usually ripen at some time between September and November, and the leaves turn yellow or brown and fall from the trees before the

fruits drop (Elias 1972, Hough 1984, Hatterman 1984, Whittemore and Stone 2020, Weakley et al. 2022).

Juglans cinerea trees yield a sweet sap that was once used to make syrup (Van Dersal 1938, NCCE 2024). The practice is presently discouraged in order to protect the health of both consumers with tree nut allergies and the trees themselves (eg. Chelsea Green Publishing 2024, Indiana Nature 2024). Like the more common Black Walnut (*Juglans nigra*), *J. cinerea* also produces a chemical called juglone that can be toxic to other plants. The substance is present throughout the trees including the roots, bark, leaves, and fruit hulls. Susceptible plant species are most likely to be affected when their roots come into contact with, or close proximity to, the roots of a *Juglans* tree (Heimann and Stevenson 1997). In *J. cinerea* the zone of potential toxicity usually extends 18–24 meters beyond the trunk (NCCE 2024).

Peter M. Dziuk, 2004.

Juglans twigs have chambered pith, which can help to distinguish the trees from *Carya* species in the winter (Elias 1972), but the pith only becomes chambered as the twigs mature so the characteristic cannot be observed in new growth (Harlow 1930). *Juglans cinerea* can be separated from all other North American *Juglans* species by its large buds (those of other species do not exceed 10 mm), ovoid fruits, and velvety ridges above the leaf scars. Other walnuts also have distinct notches in the leaf scars which are lacking in *J. cinerea* (Whittemore and Stone 2020). However, *J. cinerea* is able to hybridize with a number of other *Juglans* species (Elias 1972. Rink 1990). Multiple traits must be examined to distinguish Butternut from hybrids, including pith color; lenticel size, shape or abundance; and the presence or absence of notches in the upper margins of leaf scars (Ross-Davis et al. 2008). A tabular summary of characteristics that can help to separate *J. cinerea* from hybrid trees is provided by Woeste et al. (2009).

Pollinator Dynamics

Species in the Juglandaceae are pollinated by wind. The male and female catkins of *Juglans cinerea* mature at different times, which deters self-fertilization. In individual trees, either the staminate or pistillate flowers may open first, but blooming of the two sexes is usually separated by a period of about ten days (Pringle 1879, Trelease 1896). A source cited by Trelease indicated that the staminate flowers opened explosively. Pringle (1879) deduced that the temporal separation of male and female flowering could be a barrier to fruit production in secluded *J. cinerea* trees and that seems to be occurring—Coladonato (1991) indicated that natural pollination failures due to isolation were frequent in the species. Throughout its range, *J. cinerea* is fairly uncommon in the landscape (Clark 1965, Rink 1990, Morin et al. 2018) and a study of pollen records in Maine suggested that this has always been the case (Potzger and Friesner 1948). However, there have been some exceptions: For example, Harshberger (1905) reported that Butternut was a dominant canopy component in some deciduous forests of the Catskill Mountains.

Seed Dispersal and Establishment

Juglans cinerea is a mast fruiting species, typically producing an abundant seed crop every 2–3 years and lighter crops during intervening years (Hatterman 1984, Rink 1990). The seeds are initially dispersed by gravity, falling to the ground beneath the trees when they are ripe. Longer distance dispersal may be achieved by animals including birds, squirrels, or other rodents. The dispersers are also consumers and the nuts are eaten by insects as well so a significant portion are lost (Clark 1965, Rink 1990, Coladonato 1991). The mast fruiting strategy improves the odds that some seeds will be overlooked and have an opportunity to germinate.

Butternut seeds that survive the winter usually germinate during the first spring although some occasionally remain dormant longer (Van Dersal 1938, Clark 1965, Rink 1990). Barton (1936) found that *Juglans cinerea* seeds required a 2–4 month period of low temperatures in order to overcome their initial dormancy and germinate. When propagated in controlled conditions, stratified *J. cinerea* seeds began to sprout after 14 days, 65% germinated by day 17, and 86.6% germinated by day 45. Buried seeds cracked open along the main seams, permitting the emergence of root initials (radicles), and subsequently hooked hypocotyls pushed up through the soil and straightened to form the first shoots (Brennan and Jacobs 2020).

Juglans cinerea forms associations with arbuscular mycorrhizal fungi (Jantzen et al. 2023). Fungal partners do not appear to be essential for the establishment of the species but they are likely beneficial during early development. Butternut has been characterized as easy to propagate from seed but relatively difficult to transplant (Van Dersal 1938, Rink 1990, Michler et al. 2006). Mortier et al. (2020) indicated that early inoculation with arbuscular mycorrhizal fungi could enhance the survival and performance of transplanted *Juglans* seedlings. Young *J. cinerea* trees can grow rapidly when conditions are favorable (Van Dersal 1938, Clark 1965).

Habitat

Juglans cinerea has been found at elevations ranging from 0–1500 meters above sea level. Habitat for the species is usually described as well-drained nutrient-rich woodlands but Butternut trees also grow in riparian floodplains or on rocky slopes (Willis 1874, Taylor 1915, Elias 1972, Hough 1983, Breden et al. 2001, Rhoads and Block 2007, Clark et al. 2008, Whittemore and Stone 2020, Weakley et al. 2022, Nesom undated). Van Dersal (1938) observed that while *J. cinerea* usually occurred on rich soils it could also establish on somewhat poorer soils than those favored by *J. nigra*. *Juglans cinerea* is intolerant of overhead shade at all life stages (Van Dersal 1938, Clark 1965, Rink 1990, Nesom undated). Consequently the species is unlikely to regenerate in well established forests without some type of canopy disturbance (Morin et al. 2018).

Prior to the spread of chestnut blight (*Cryphonectria parasitica*), *Juglans cinerea* was sometimes seen in forests where American Chestnut (*Castanea dentata*) was the dominant canopy species (eg. Harshberger 1903, 1905). Elias (1972) remarked that *J. cinerea* could be found in many mesic forests and Rink (1990) reported that Butternut was usually associated with one of four hardwood forest cover types: *Acer saccharum- Tilia americana, Liriodendron tulipifera-Quercus alba-Quercus rubra, Fagus grandifolia-Acer saccharum,* or *Betula nigra-Platanus occidentalis*. *Juglans cinerea* was noted as a characteristic associate in several specific vegetation communities that are rare (S2) in New Jersey including *Acer saccharum—Fraxinus americana—Juglans cinerea* / *Staphylea trifolia* Forest, *Acer saccharum — Fraxinus* spp.*— Tilia americana* / *Osmorhiza claytonii—Caulophyllum thalictroides* Forest, and *Acer saccharum — Fraxinus* spp.*— Tilia americana* / *Matteuccia struthiopteris—Ageratina altissima* Forest (Breden et al. 2001). During a recent study, dry upland sites supporting large-diameter stands of *Acer*/*Fagus*/*Betula* forest were identified as particularly favorable habitat for Butternut growth and survival (Morin et al. 2018).

Juglans cinerea has been documented in a variety of habitats in New Jersey, ranging from alluvial floodplains to steep talus slopes. Populations have occurred over gneiss, basalt, and limestone (Buell et al. 1966). Some of the reported communities were the typical hardwood forest types discussed above while others were dominated by species like *Acer negundo*, *Juglans nigra*, *Paulownia tomentosa*, or *Quercus montana* (Niering 1953, NJNHP 2024).

Wetland Indicator Status

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

USDA Plants Code (USDA, NRCS 2024b)

JUCI

Coefficient of Conservancy (Walz et al. 2020)

CoC = 6. 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

Juglans cinerea is native to the eastern and central United States and Canada. The species has been introduced in the State of Washington and about a half dozen European countries (Kartesz 2015, POWO 2024). The map in Figure 1 depicts the extent of *J. cinerea* in the United States and Canada.

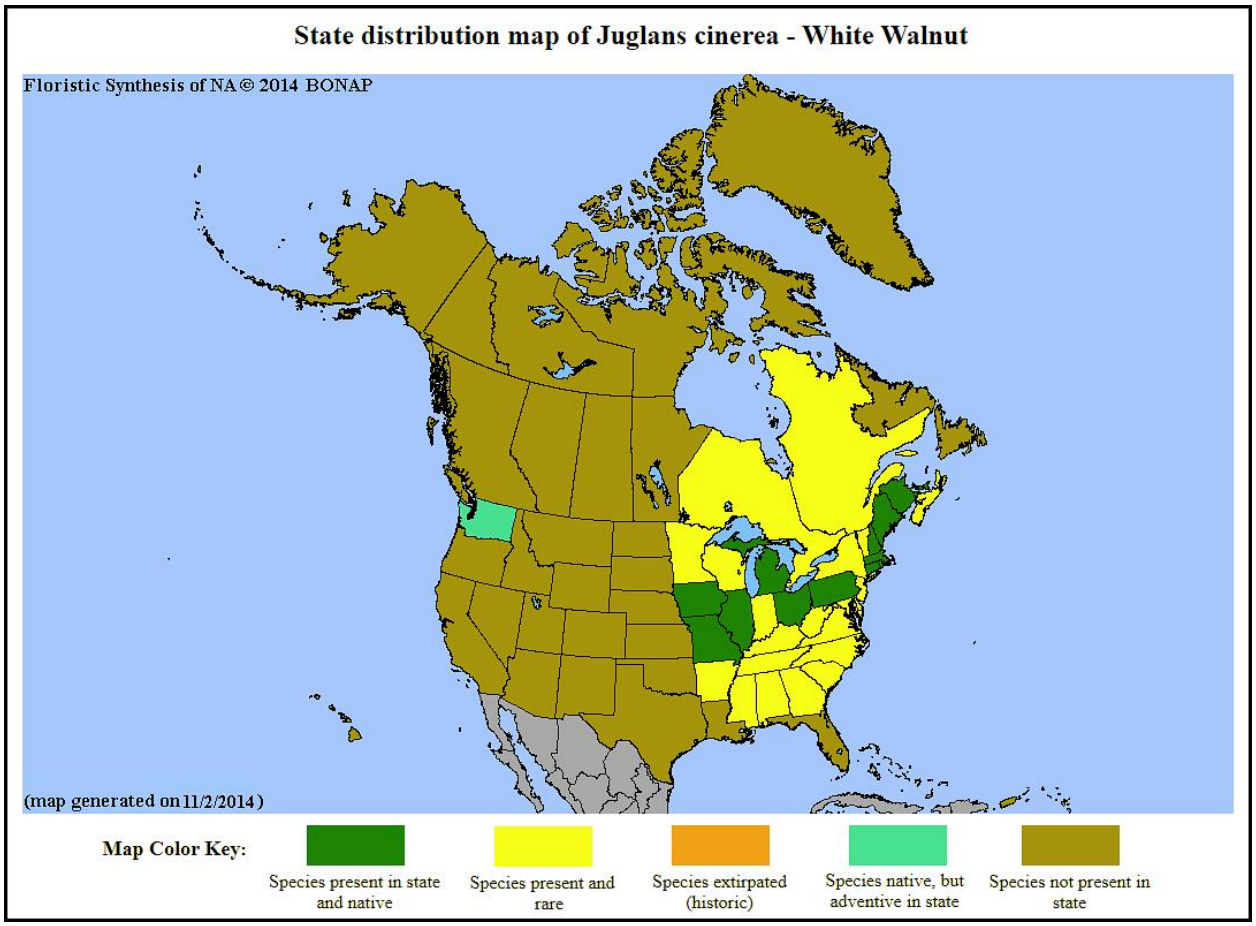


Figure 1. Distribution of J. cinerea in North America, adapted from BONAP (Kartesz 2015).

The USDA PLANTS Database (2024b) shows records of *Juglans cinerea* in 16 New Jersey counties: Bergen, Burlington, Camden, Essex, Gloucester, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, and Warren (Figure 2 below). The data include historic observations and do not reflect the current distribution of the species.

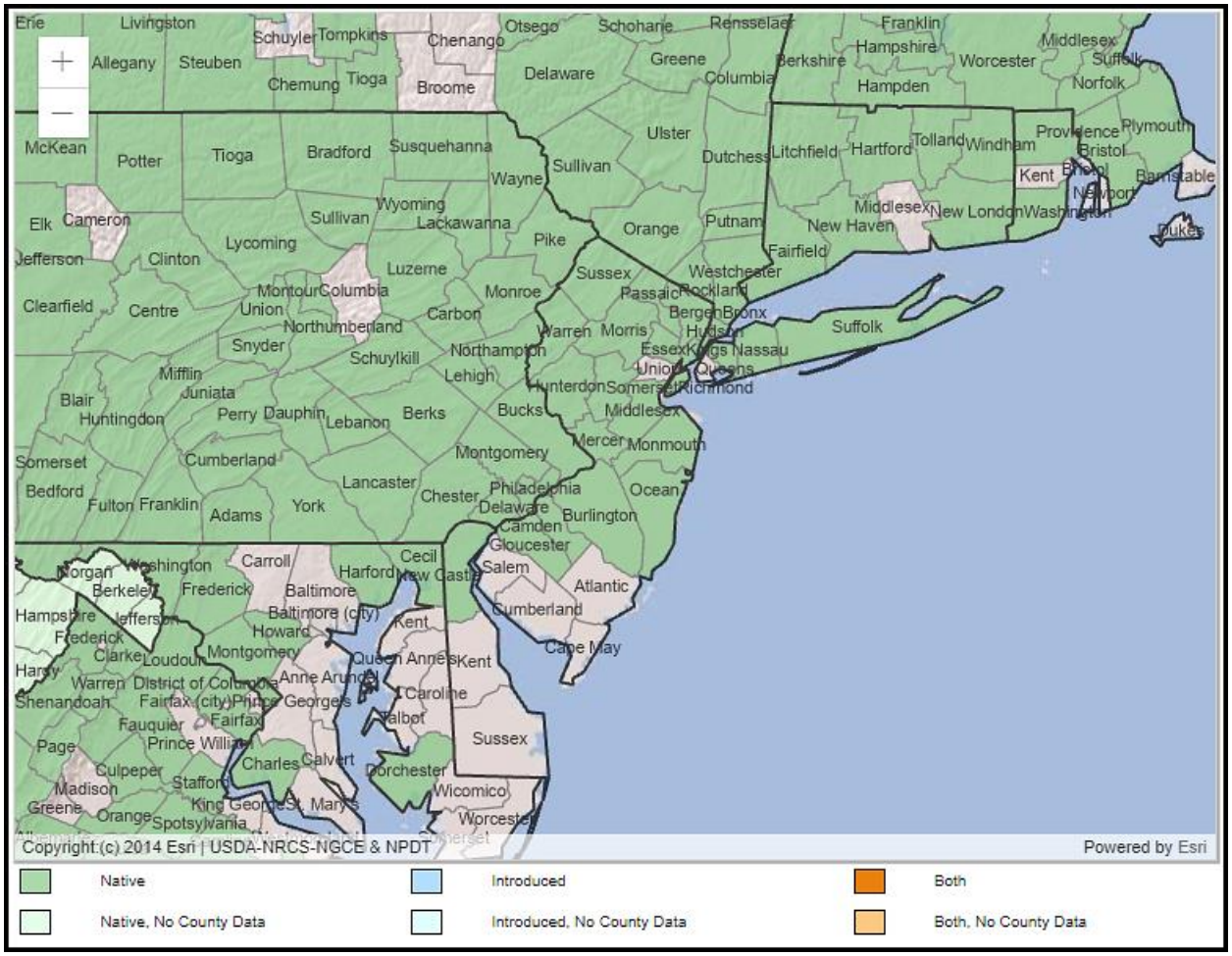


Figure 2. County records of J. cinerea in New Jersey and vicinity (USDA NRCS 2024b).

Conservation Status

Juglans cinerea is globally vulnerable. The G3 rank means the species has a moderate risk of extinction or collapse due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors (NatureServe 2024). The map below (Figure 3) illustrates the conservation status of *J. cinerea* in North America. Butternut is vulnerable (moderate risk of extinction) in seven states, imperiled (high risk of extinction) in eleven states and one province, and critically imperiled (very high risk of extinction) in four states and two provinces. *J. cinerea* is apparently secure in three states and unranked in four other states where it occurs. The species is not considered native in Manitoba, Nova Scotia, Prince Edward Island, or the western United States.

Juglans cinerea is listed as an endangered species in Canada, having first received that designation in 2003 (COSEWIC 2013, 2023). In the North Atlantic region, which includes four Canadian provinces and twelve U. S. states, *J. cinerea* was categorized as likely to be a high conservation priority but currently unrankable (Frances 2017). Butternut is classified as endangered on the IUCN Red List (Stritch and Barstow 2019).

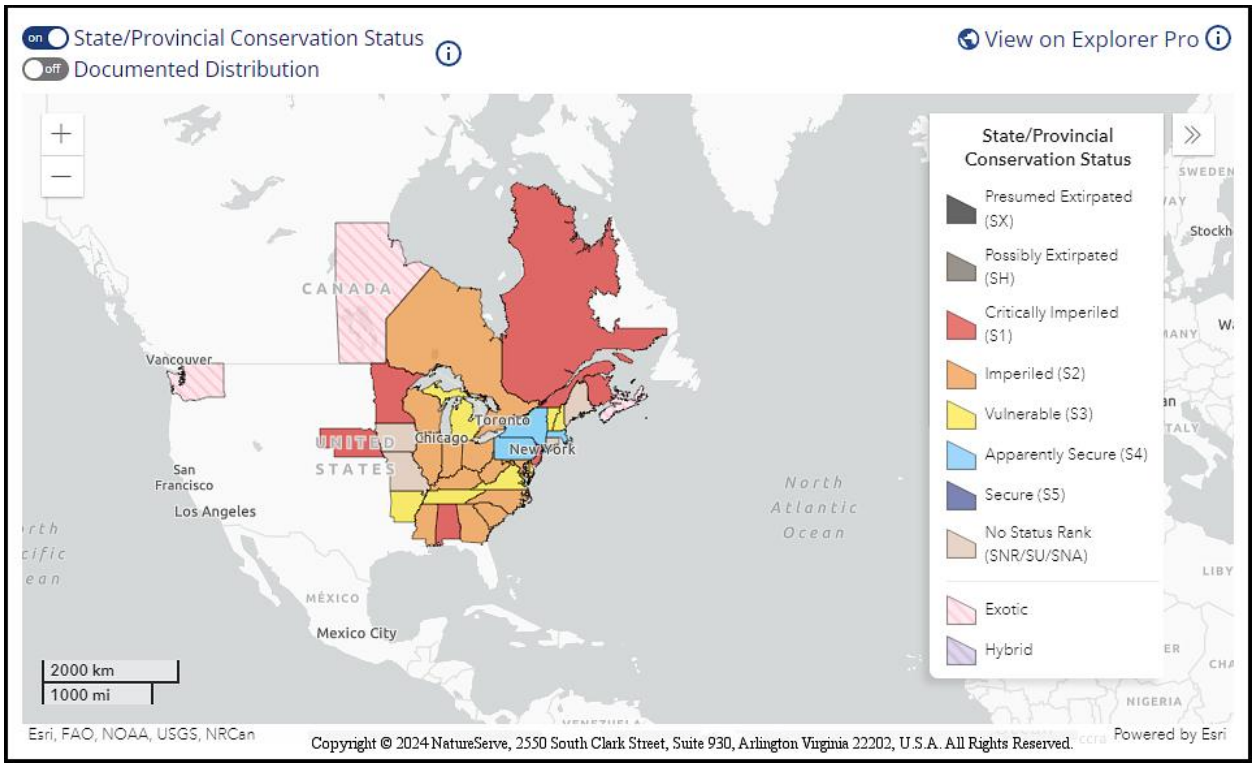


Figure 3. Conservation status of J. cinerea in North America (NatureServe 2024).

Juglans cinerea is critically imperiled (S1) in New Jersey (NJNHP 2024). The rank typically 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. *J. cinerea* has also been assigned a regional status code of HL, signifying that the species is eligible for protection under the jurisdiction of the Highlands Preservation Area (NJNHP 2010).

Studies based on analyses of pollen and macrofossil records indicate that *Juglans cinerea* was regionally common between 10,000 and 12,000 years ago (Watts 1979). Barton (1818) spoke of having several encounters with *J. cinerea* in the greater Philadelphia metropolitan area during the early 1800s and Willis (1874) characterized it as "common in the hills near Princeton." Other early floras indicated that while there were some records of Butternut from central New Jersey (eg. Burlington, Monmouth, and Ocean counties) it was considerably more abundant in the northern part of the state and absent from the southern counties (Britton 1881, Stone 1911, Taylor 1910 & 1915). Hough (1983) indicated that all of the records of *J. cinerea* from southern New Jersey were over 50 years old, although the species continued to be present in six northern counties. *Juglans cinerea* was not considered rare in the state through most of the 1900s. It was initially listed as an S3S4 species at the beginning of the current century and within two decades it had been downgraded to an S1 (NJNHP 2001, 2021). Twelve occurrences in seven counties are presently tracked by the Natural Heritage Program but only two of those include ten or more individuals: The rest have three or fewer and the majority consist of a single tree (NJNHP 2024).

Threats

Among the many threats to *Juglans cinerea*, the most significant by far is caused by Butternut Canker Disease, *Ophiognomonia clavigignenti-juglandacearum* (formerly identified as *Sirococcus clavigignenti-juglandacearum*). Butternut Canker is an introduced fungal pathogen that was first detected in the United States in 1967 but may have been present earlier. The disease spread rapidly throughout the entire range of *J. cinerea* and mortality rates ranging from 27% to 91% have been reported in different regions. *O. clavigignenti-juglandacearum* has taken a particularly heavy toll on southeastern Butternut populations, while the infection of northeastern populations was a relatively recent occurrence. The canker can affect *J. cinerea* trees in all age classes, and the Butternut's declining trend is expected to continue. However, there is evidence that some *J. cinerea* trees are naturally resistant to the fungus so the species might eventually be able to recover. (See Ostry and Woeste 2004, Clark et al. 2008, Woeste et al. 2009, Environment Canada 2010, Farlee et al. 2010, Parks et al. 2013, Broders et al. 2015, Morin et al. 2018, Oliver 2019, Stritch and Barstow 2019, Whittemore and Stone 2020, Williams et al. 2020, Pike et al. 2021, Weakley et al. 2022, USDA NISIC 2024, Nesom undated). Recent observations in New Jersey have included both healthy and unhealthy trees (NJNHP 2024).

O. clavigignenti-juglandacearum can be locally transmitted by rain splash (Rink 1990) and dispersed over long distances by insects. At least seventeen species of beetles have been identified as vectors (Moore and Ostry 2015). The fungus is also passed along in seeds (Michler et al. 2006). Alternate hosts for the canker include other *Juglans* and *Carya* species that can become infected with less devastating consequences (Ostry and Woeste 2004, Broders et al. 2015). Broders et al. noted that the ability to utilize novel hosts also signals the potential for a more virulent strain of the pathogen to emerge.

Mortality in infected *Juglans cinerea* trees may result from a slow decline over a period of 30–40 years but it often occurs quite rapidly (Farlee et al. 2010, Oliver 2019). Early symptoms typically include dying branches and stems (Rink 1990), but lower and interior Butternut branches can also be lost as a result of shading so the death of upper or outer branches is more indicative of the disease (Woeste et al. 2009). Tufts of epicormic shoots may initially be present below dead sections. Early cankers originate near leaf scars and buds, but as the disease progresses they spread to the trunk, eventually coalescing and girdling the tree (Rink 1990, Farlee et al. 2010, Oliver 2019). The cankers often have dark centers and pale margins; they may also be bordered by layers of callus tissue or loose bark. Images of canker disease on branches and stems are available in Farlee et al. (2010). A secondary impact of canker disease is the intentional harvesting of healthy *Juglans cinerea* trees in anticipation of their demise. Landowners have been cutting trees for their lumber before they can become infected and lose their potential market value, but in doing so they are also removing potentially disease-resistant individuals from the gene pool (Environment Canada 2010, Oliver 2019).

Even before the spread of *O. clavigignenti-juglandacearum* in North America, *Juglans cinerea* was facing some significant challenges. Clark (1965) noted that the species was not common anywhere in its range, and that its frequency was declining. Key contributing factors included the loss of suitable habitat and poor regeneration (Clark et al. 2008, Woeste et al. 2009, Environment Canada 2010, Parks et al. 2013, Morin et al. 2018, Oliver 2019, Pike et al. 2021).

Because Butternut is intolerant of shading, natural succession can threaten some populations. Juglone produced by *J. cinerea* may deter the establishment of competitive species within the root zone (Heimann and Stevenson 1997) but taller overstory trees growing in close proximity can cause even mature Butternut trees to decline (Clark et al. 2008). Additionally, *J. cinerea* seedlings require abundant sunlight so the species is generally reliant on the presence of disturbed areas or gaps for suitable germination sites (Woeste et al. 2009). Not all disturbances favor *J. cinerea*: For example, the species is very susceptible to fire. Butternuts rarely resprout after burning and populations can be eradicated by a single hot fire or a series of lower-intensity burns (Clark 1965, Coladonato 199, Nesom undated).

Hatterman (1984) listed sixteen diseases or pests in addition to *O. clavigignenti-juglandacearum* that can have an impact on Butternut trees. Rink (1990) noted that *Juglans cinerea* was particularly prone to Bunch Disease, which induces sprouting in normally dormant buds and makes the trees vulnerable to frost damage. An assortment of insects have been documented on *J. cinerea* including wood borers, defoliators, nut weevils, lacebugs, husk flies, and bark beetles, but only one (*Conotrachelus juglandis*) is considered a serious pest because it can damage young stems and fruits (Rink 1990). The majority of native insects and diseases that affect *Juglans cinerea* are unlikely to cause mortality on their own but may contribute to canker-induced declines by increasing stress levels (Environment Canada 2010). The larvae of *Lymantria dispar*, an introduced moth that typically causes widespread damage to many tree species, generally avoid *J. cinerea* (Maufette et al. 1983). However, a recent introduction to the northeast—the Spotted Lanternfly (*Lycorma delicatula*)—could prove to be a significant threat. According to Murman et al. (2020), *J. cinerea* is one of only eight North American species known to support Spotted Lanternfly development through all of its life stages. Heavy feeding by the lanternfly can cause branch dieback or flagging in an assortment of tree species and in some cases the activity has resulted in mortality. Butternut leaves are also palatable to White-tailed Deer (Van Dersal 1938, Coladonato 1991), which could be a significant barrier to seedling establishment in New Jersey.

Studies of *Juglans cinerea* have documented relatively high levels of genetic diversity throughout much of its range (Hoban et al. 2010, Pike et al. 2021). However, the genetic integrity of the species is threatened by hybridization (Woeste et al. 2009). *J. cinerea* crosses readily with *Juglans ailantifolia*, a species that was deliberately introduced to North America and marketed as a nut tree (Oliver 2019). Hybrid offspring are vigorous and fertile but very similar to Butternut in appearance, making it difficult to evaluate the extent of the problem (Ostry and Woeste 2004, Ross-Davis et al. 2008). Cross-breeding between *J. cinerea* and *J. ailantifolia* appears to occur more often in fragmented landscapes so patches of intact forest may help to reduce the frequency of hybridization (Hoban et al. 2012).

Climate Change Vulnerability

Information from the references cited in this profile was used to evaluate the vulnerability of New Jersey's *Juglans cinerea* populations to climate change. The species was assigned a rank from NatureServe's Climate Change Vulnerability Index using the associated tool (Version 3.02) to estimate its exposure, sensitivity, and adaptive capacity to changing climactic conditions in

accordance with the guidelines described by Young et al. (2016) and the state climactic computations by Ring et al. (2013). Based on available data *J. cinerea* was assessed as Moderately Vulnerable, meaning that it is likely to show some decrease in abundance or range extent in New Jersey by 2050. Range-wide models have also predicted that the decline in *J. cinerea* will be exacerbated by climate change (Iverson et al. 2005, Schumacher et al. 2022). Poor dispersal is likely to limit the species' ability to establish in new locations when existing sites become unsuitable.

As the climate becomes warmer New Jersey is experiencing rising temperatures, increasingly intense storms, and more extreme weather patterns that result in prolonged periods of inundation or drought (Hill et al. 2020). While *Juglans cinerea* is considered to be exceptionally cold-hardy, the species has historically experienced widely varying climactic regimes throughout its range (Clark 1965, Rink 1990, Brennan and Jacobs 2020). Even though Butternut might not be directly affected by warming conditions, rising temperatures could exacerbate the spread of the canker fungus, which develops more slowly in cooler weather (Moore and Ostry 2015). Established *J. cinerea* trees are able to tolerate periods of drought (NCCE 2024) but a study of their ring characteristics indicated that moisture availability can have a measurable impact on annual growth (Clark et al. 2008). Negative impacts to Butternut resulting from storm damage (Clark 1965) and floods (Crystal and Jacobs 2014) have also been reported.

Management Summary and Recommendations

The rapid decline of *Juglans cinerea* following the introduction of Butternut canker triggered a significant investment in research focused on long-term conservation of the trees. Initial efforts focused on locating canker-resistant stands or individuals, distinguishing them from hybrids, and identifying the characteristics of healthy trees (Ostry and Woeste 2004, Michler et al. 2006, Ross-Davis et al. 2008, Hoban et al. 2010, Parks et al. 2013, Moore et al. 2015). In some regions, a moratorium on harvesting was put into place to improve the likelihood of finding resistant trees (Oliver 2019). Other interim strategies included early detection and treatment of infected trees (Nesom undated) and the creation of canopy gaps in the vicinity of healthy stands to promote regeneration (Woeste et al. 2009, Oliver 2019).

Resistant Butternuts are likely to need assistance with the establishment of new populations so additional studies of propagation techniques have been undertaken (Pijut and Moore 2002, Ross-Davis et al. 2008, Woeste et al. 2009, Farlee et al. 2010, Williams et al. 2020, Pike et al. 2021). Schumacher et al. (2022) pointed out that areas where the species currently grows may not be suitable in the future so climate impacts must be considered in restoration planning.

As in other locations, the health of *Juglans cinerea* trees in New Jersey should be monitored closely. Resistant stands could be managed to enhance regeneration by creating openings in the canopy or protecting seedlings from deer browse. Because *J. cinerea* is usually infrequent in the places where it occurs, it seems likely that some undetected occurrences are present in the state.

Synonyms

The accepted botanical name of the species is *Juglans cinerea* L. Orthographic variants, synonyms, and common names are listed below (ITIS 2024, POWO 2024, USDA NRCS 2024b).

Botanical Synonyms	Common Names
Juglans cathartica F. Michx.	Butternut
Juglans oblonga Mill.	White Walnut
Nux cinerea (L.) M. Gómez	Oilnut
Wallia cinerea (L.) Alef.	

References

Barton, William P. C. 1818. Compendium Floræ Philadelphicæ: Containing a Description of the Indigenous and Naturalized Plants Within A Circuit of Ten Miles Around Philadelphia. Volume II. M. Carey and Son, Philadelphia, PA. 234 pp.

Barton, L. V. 1936. Seedling production in *Carya ovata* (Mill.) K. Koch, *Juglans cinerea* L., and *Juglans nigra* L. Contributions from Boyce Thompson Institute 8: 1–5.

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.

Brennan, Andrea N. and Douglass F. Jacobs. 2020. Seed propagation protocol for pure and hybrid Butternut (*Juglans cinerea* L.). Tree Planters' Notes 63(1): 39–50.

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. 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.

Broders, Kirk, A. Boraks, L. Barbison, J. Brown, and Greg J. Boland. 2015. Recent insights into the pandemic disease butternut canker caused by the invasive pathogen *Ophiognomonia clavigignenti-juglandacearum*. Forest Pathology 45(1): 1–8.

Buell, Murray F., Arthur N. Langford, Donald W. Davidson, and Lewis F. Ohmann. 1966. The upland forest continuum in northern New Jersey. Ecology 47(3): 416–432.

Chelsea Green Publishing. 2024. Pass the Walnut Syrup? Online article accessed April 22, 2024 at https://www.chelseagreen.com/2018/pass-walnut-syrup/

Clark, F. Bryan. 1965. Butternut (*Juglans cinerea* L.). In H. A. Fowells (ed.), Silvics of Forest Trees of the United States. USDA Agriculture Handbook 271, Washington, DC.

Clark, Stacy L., Sunshine L. Brosi, Scott E. Schlarbaum, and Henri D. Grissino-Mayer. 2008. Dendrochronology of two Butternut (*Juglans cinerea*) populations in the southeastern United States. Forest Ecology and Management 255: 1772–1780.

Coladonato, Milo. 1991. *Juglans cinerea*. In: Fire Effects Information System, [Online]. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Accessed October 1, 2023 at https://www.fs.usda.gov/database/feis/plants/tree/jugcin/all.html

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2013. *Juglans cinerea* entry on Species at Risk Public Registry. Accessed April 16, 2024 at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/butternut.html

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2023. Canadian Wildlife Species at Risk. Accessed April 16, 2024 at https://species-registry.canada.ca

Crystal, Philip A. and Douglass F. Jacobs. 2014. Drought and flood stress tolerance of Butternut (*Juglans cinerea*) and naturally occurring hybrids: Implications for restoration. Canadian Journal of Forest Research 44(10): 1206–1216.

Dziuk, Peter M. 2004 and 2005. Three photos of *Juglans cinerea*. Images courtesy of Minnesota Wildflowers, https://www.minnesotawildflowers.info/tree/butternut licensed by https://creativecommons.org/licenses/by-nc-nd/3.0/.

Elias, Thomas S. 1972. The genera of Juglandaceae in the southeastern United States. Journal of the Arnold Arboretum 53(1): 26–51.

Environment Canada. 2010. Recovery Strategy for the Butternut (*Juglans cinerea*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, Ontario. 24 pp.

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

Farlee, Lenny, Keith Woeste, Michael Ostry, James McKenna, and Sally Weeks. 2010. Conservation and Management of Butternut Trees. Publication FNR-421-W, Purdue University Extension, West Lafayette, IN. 10 pp.

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

Frances, Anne (Principal Investigator). 2017. Prioritization and Conservation Status of Rare Plants in the North Atlantic - Final Report. Report prepared for NatureServe by the North Atlantic Landscape Conservation Cooperative, Hadley, MA. Available at https://www.natureserve.org/publications/prioritization-and-conservation-status-rare-plants-north-atlantic-final-report

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.

Harlow, W. M. 1930. The formation of chambered pith in the twigs of butternut and black walnut. Journal of Forestry 28: 739–741.

Harshberger, John W. 1903. An ecologic study of the flora of mountainous North Carolina. Botanical Gazette 36(5): 368–383.

Harshberger, John W. 1905. The plant formations of the Catskills. The Plant World 8(11): 276–281.

Hatterman, Dennis Robert. 1984. *Juglans cinerea*: The American White Walnut. Master's Thesis, Eastern Illinois University, Charleston, IL. 54 pp.

Heimann, M. F., and W. R. Stevenson. 1997. Walnut and Butternut Toxicity. Urban Phytonarian Series, A3182. University of Wisconsin-Extension, Madison, WI. 2 pp.

Henry, Michael. 2019. Photo of *Juglans cinerea* from Ontario. Shared via iNaturalist at https://www.inaturalist.org/observations/25207355, licensed by https://creativecommons.org/licenses/by-nc/4.0/

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.

Hoban, Sean M., Daniel S. Borkowski, Sunshine L. Brosi, Tim S. McCleary, Laura M. Thompson, Jason S. McLachlan, Marie A. Pereira, Scott E. Schlarbaum, and Jeanne Romero-Severson. 2010. Range-wide distribution of genetic diversity in the North American tree *Juglans cinerea*: A product of range shifts, not ecological marginality or recent population decline. Molecular Ecology 19: 4876–4891.

Hoban, Sean M., Tim S. McCleary, Scott E. Schlarbaum, Sandra L. Anagnostakis, and Jeanne Romero-Severson. 2012. Human-impacted landscapes facilitate hybridization between a native and an introduced tree. Evolutionary Applications 5: 720–731.

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

Indiana Nature. 2024. *Juglans cinerea* — Butternut. Species page on website by Indiana Nature LLC, dedicated to celebrating and protecting Indiana's natural heritage. Accessed April 22, 2024 at https://www.indiananature.net/pages/taxa/Plantae/j/Juglans_cinerea.php

ITIS (Integrated Taxonomic Information System). Accessed April 16, 2024 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.

Jantzen, Johanna R., Etienne Laliberté, Alexis Carteron, Rosalie Beauchamp-Rioux, Florence Blanchard, Anna L. Crofts, Alizée Girard, Paul W. Hacker, Juliana Pardo, Anna K. Schweiger, Sabrina Demers-Thibeault, Nicholas C. Coops, Margaret Kalacska, Mark Velland, and Anne Bruneau. 2023. Evolutionary history explains foliar spectral differences between arbuscular and ectomycorrhizal plant species. New Phytologist 238(6): 2651–2667.

Johnson, David L. 1998. New Jersey's Big Trees. N. J. Forest Service, Division Parks and Forestry, Department of Environmental Protection. 37 pp.

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)].

Manning, Wayne E. 1938. The morphology of the flowers of the Juglandaceae. I. The inflorescence. American Journal of Botany 25(6): 407–419.

Mauffette, Yves, Martin J. Lechowicz, and Luc Jobin. 1983. Host preferences of the Gypsy Moth, *Lymantria dispar* (L.), in southern Quebec. Canadian Journal of Forest Research 13: 53–60.

Michler, Charles H., Paula M. Pijut, Douglass F. Jacobs, Richard Meilan, Keith E. Woeste, and Michael E. Ostry. 2006. Improving disease resistance of butternut (*Juglans cinerea*), a threatened fine hardwood: A case for single-tree selection through genetic improvement and deployment. Tree Physiology 26: 121–128.

Moore, M. J. and M. E. Ostry. 2015. Influence of temperature and humidity on the viability of *Ophiognomonia clavigignenti-juglandacearum* conidia. Plant Disease 99(12): 1841–1846.

Moore, M. J., M. E. Ostry, A. D. Hegeman, and A. C. Martin. 2015. Inhibition of *Ophiognomonia clavigignenti-juglandacearum* by *Juglans* species bark extracts. Plant Disease 99: 401–408.

Morin, Randall S., Kurt W. Gottschalk, Michael E. Ostry, and Andrew M. Liebhold. 2018. Regional patterns of declining butternut (*Juglans cinerea* L.) suggest site characteristics for restoration. Ecology and Evolution 8: 546–559.

Mortier, Emma, Olivier Lamotte, Fabrice Martin-Laurent, and Ghislaine Recorbet. 2020. Forty years of study on interactions between walnut tree and arbuscular mycorrhizal fungi. A review. Agronomy for Sustainable Development 40(6): Article 43.

Murman, Kelly, Gregory P. Setliff, Cathryn V. Pugh, Michael J. Toolan, Isaiah Canlas, Stefani Cannon, Leslie Abreu, Miranda Fetchen, Longwa Zhang, Melissa L. Warden, Matthew Wallace, Jacob Wickham, Sven-Erik Spichiger, Emelie Swackhamer, Daniel Carrillo, Allison Cornell, Nathan T. Derstine, Lawrence Barringer, and Miriam F. Cooperband. 2020. Distribution, survival, and development of Spotted Lanternfly on host plants found in North America. Environmental Entomology 49(6): 1270–1281.

NatureServe. 2024. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed April 16, 2024 at https://explorer.natureserve.org/

NCCE (North Carolina Cooperative Extension). 2024. *Juglans cinerea*. North Carolina Extension Gardener Plant Toolbox, accessed April 22, 2024 at https://plants.ces.ncsu.edu/plants/juglans-cinerea/

Nesom, Guy. Undated. PLANTS profile for *Juglans cinerea.* U. S. Department of Agriculture, Natural Resources Conservation Service, The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed April 16, 2024 at http://plants.usda.gov

Niering, William A. 1953. The past and present vegetation of High Point State Park, New Jersey. Ecological Monographs 23(2): 127–148.

NJNHP (New Jersey Natural Heritage Program). 2001. List of Endangered Plant Species and Plant Species of Concern, September 2001. Biotics Database. NatureServe, Arlington, Virginia. Accessed September 18, 2003.

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). 2021. List of Endangered Plant Species and Plant Species of Concern. Biotics Database. NatureServe, Arlington, Virginia. Accessed January 2021.

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

Oliver, L. 2019. *Juglans cinerea* conservation status factors. NatureServe, Arlington, VA. Accessed April 16, 2024 at https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.154365/Juglans_cinerea

Ostry, Michael E. and Keith E. Woeste. 2004. Spread of Butternut canker in North America, host range, evidence of resistance within Butternut populations and conservation genetics. In C. H. Michler et al. (eds.), Black Walnut in a New Century, Proceedings of the 6th Walnut Council Research Symposium; July 25-28, Lafayette, IN. General Technical Report NC-243, USDA Forest Service, North Central Research Station, St. Paul, MN.

Parks, A., Michael A. Jenkins, Keith E. Woeste, and Michael E. Ostry. 2013. Conservation status of a threatened tree species: Establishing a baseline for restoration of *Juglans cinerea* L. in the southern Appalachian Mountains. Natural Areas Journal 33(4): 413–426.

Pijut, Paula M. and Melanie J. Moore. 2002. Early season softwood cuttings effective for vegetative propagation of *Juglans cinerea*. HortScience 37(4): 697–700.

Pike, Carolyn C., Martin Williams, Andrea Brennan, Keith Woeste, James Jacobs, Sean Hoban, Melanie Moore, and Jeanne Romero-Severson. 2021. Save our species: A blueprint for restoring Butternut (*Juglans cinerea*) across eastern North America. Journal of Forestry 119(2): 196–206.

Potzger, John E. and Ray C. Friesner. 1948. Forests of the past along the coast of southern Maine. Butler University Botanical Studies 8: 178–202.

POWO. 2024. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Accessed April 16, 2024 at http://www.plantsoftheworldonline.org/

Pringle, C. G. 1879. Dimorpho-dichogamy in *Juglans cinerea*, L. Botanical Gazette 4(12): 237.

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.

Rink, George. 1990. *Juglans cinerea* L., Butternut. In Russell M. Burns and Barbara H. Honkala (Technical Coordinators). Silvics of North America: Volume II, Hardwoods. Agriculture Handbook 654. U. S. Department of Agriculture, Forest Service, Washington, DC. 877 pp.

Ross-Davis, Amy, Zhonglian Huang, James McKenna, Michael Ostry, and Keith Woeste. 2008. Morphological and molecular methods to identify Butternut (*Juglans cinerea*) and Butternut hybrids: Relevance to Butternut conservation. Tree Physiology 28: 1127–1133.

Schumacher, Emily, Alissa Brown, Martin Williams, Jeanne Romero-Severson, Tannis Beardmore, and Sean Hoban. 2022. Range shifts in Butternut, a rare, endangered tree, in response to past climate and modern conditions. Journal of Biogeography 49(5): 866–878.

Stone, Witmer. 1911. The Plants of Southern New Jersey. Quarterman Publications, Boston, MA. 828 pp.

Stritch, L. and M. Barstow. 2019. *Juglans cinerea*. The IUCN Red List of Threatened Species 2019: e.T62019689A62019696. Accessed April 16, 2024 at https://www.iucnredlist.org/species/62019689/62019696

Taylor, Norman. 1910. Local flora notes - VI. Torreya 10(10): 224–228.

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.

Trelease, William. 1896. Juglandaceae of the United States. Missouri Botanical Garden Annual Report 1896: 25–46.

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 NISIC (U. S. Department of Agriculture, National Invasive Species Information Center). 2024. Butternut Canker. Accessed April 16, 2024 at https://www.invasivespeciesinfo.gov/terrestrial/pathogens-and-diseases/butternut-canker#cit

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2024a. *Juglans cinerea* 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). 2024b. PLANTS profile for *Juglans cinerea* (Butternut). The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed April 16, 2024 at http://plants.usda.gov

Van Dersal, William R. 1938. Native Woody Plants of the United States, Their Erosion-control and Wildlife Values. Miscellaneous Publication No. 303, U. S. Department of Agriculture, Washington, DC. 362 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.

Watts, W. A. 1979. Late Quaternary vegetation of central Appalachia and the New Jersey Coastal Plain. Ecological Monographs 49(4): 427–469.

Weakley, A. S. and Southeastern Flora Team. 2022. Flora of the Southeastern United States. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, NC. 2022 pp.

Whittemore, Alan T. and Donald E. Stone. Page updated November 6, 2020. *Juglans cinerea* 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 April 16, 2024 at http://floranorthamerica.org/Juglans_cinerea

Williams, Martin, Eric R. D. Moise, Kathleen Forbes, Charlene Williams, Ian DeMerchant, and Tannis Beardmore. 2020. Ecological status of *Juglans cinerea* in New Brunswick. Plant Disease 104: 860–867.

Willis, O. 1874. Catalogue of Plants Growing in the State of New Jersey. J. W. Schermerhorn, New York, NY. 92 pp.

Woeste, Keith, Lenny Farlee, Michael Ostry, James McKenna, and Sally Weeks. 2009. A forest manager's guide to Butternut. Northern Journal of Applied Forestry 26(1): 9–14.

Young, Bruce E., Elizabeth Byers, Geoff Hammerson, Anne Frances, Leah Oliver, and Amanda Treher. 2016. Guidelines for Using the NatureServe Climate Change Vulnerability Index, Release 3.02, 1 June 2016. NatureServe, Arlington, VA. 65 pp.