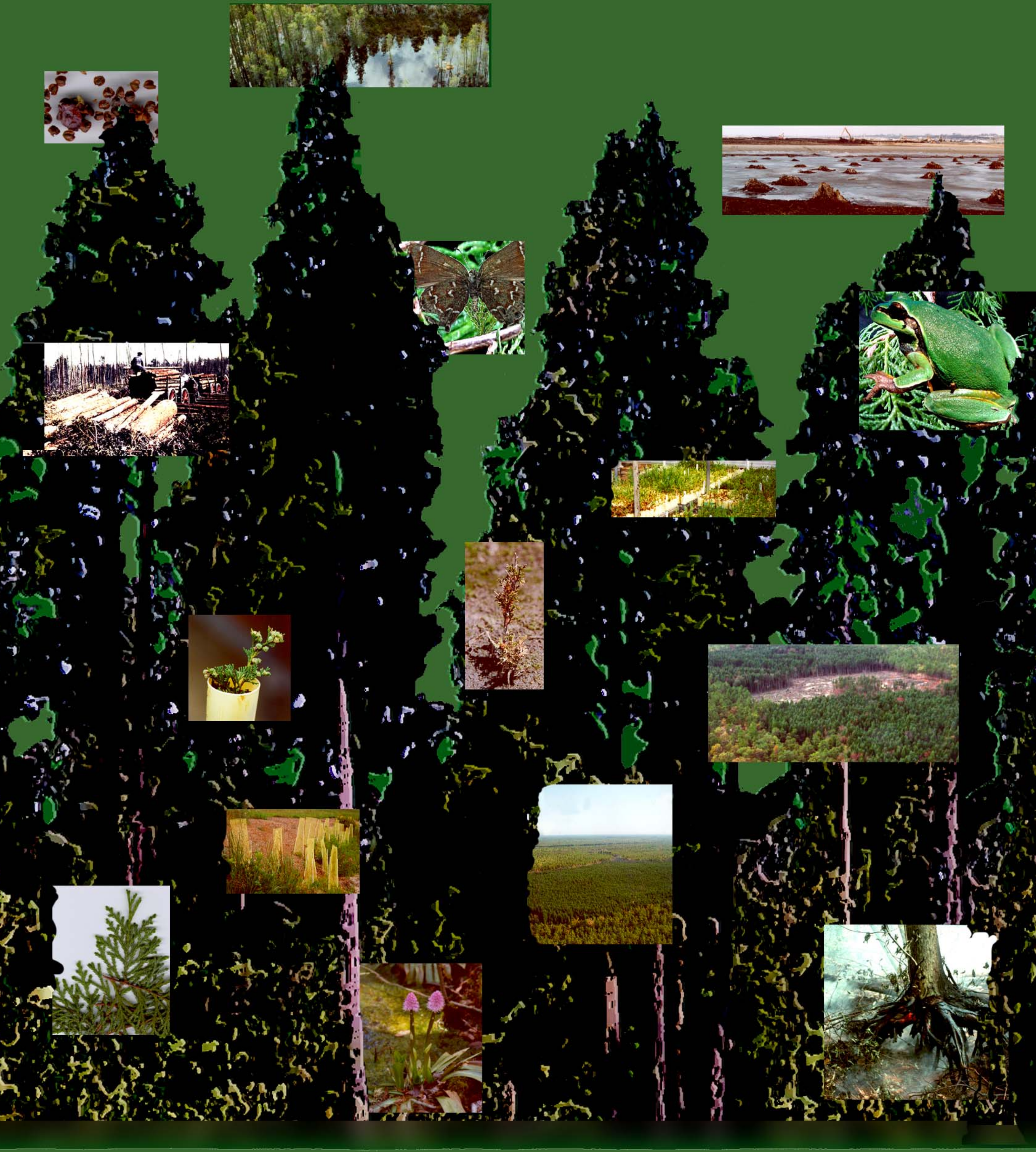

Atlantic white-cedar:

Ecology and Best Management Practices Manual

Atlantic white-cedar Ecology and Best Management Practices Manual

By: Kristin A. Mylecraine and George L. Zimmermann

Under the editorial guidance of the NJ Atlantic white-cedar Initiative Steering Committee

2000

New Jersey Atlantic white-cedar Initiative Steering Committee

New Jersey Forest Service

New Jersey Forestry Association

New Jersey Pinelands Commission

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I. Purpose of this Manual

Atlantic white-cedar (*Chamaecyparis thyoides* (L.)BSP) is found along the Atlantic and Gulf coasts of the United States, from Maine to Florida and west to Mississippi. Historically, this species has been a very valuable timber species, and remains so today. It is also very important ecologically and aesthetically. Over the last two centuries, the area occupied by Atlantic white-cedar has declined drastically. With knowledge, conservation, and the use of Best Management Practices, the long-term sustainability of this forest type may be ensured.

This manual was prepared under the editorial guidance of the New Jersey Atlantic white-cedar Initiative Committee, and focuses on issues concerning white-cedar in New Jersey, although much of the information is applicable throughout the entire range of Atlantic white-cedar. Specifically, this manual is intended to:

1. Provide general information to the landowner and resource manager about Atlantic white-cedar.

2. Increase public awareness about the importance of white-cedar, both ecologically and economically, and the necessity for active management of this species.

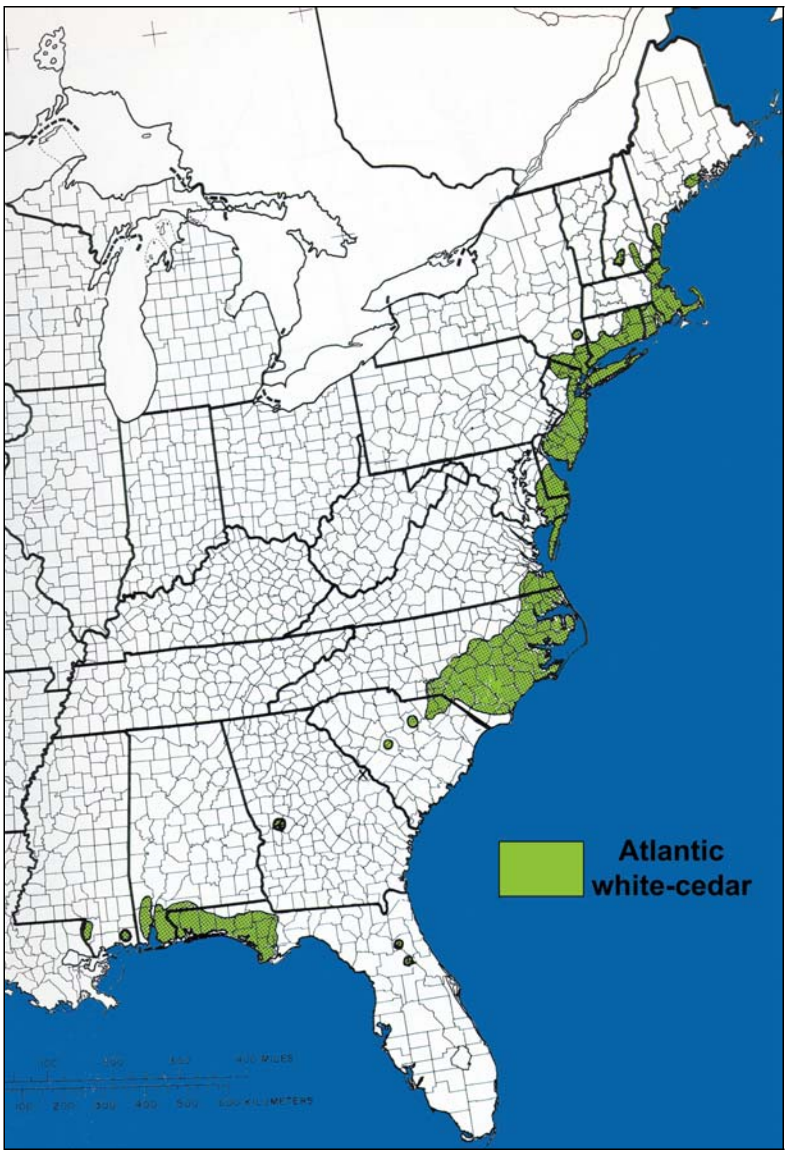
3. Provide Best Management Practices to be followed during all phases of Atlantic white-cedar management, including the regeneration, restoration, and management of this valuable resource.

Figure 1. *Aerial view of an Atlantic white-cedar stand. Photo by George Zimmermann.*

II. Introduction

Current and historic distribution

Rangewide distribution



- Atlantic white-cedar is found along the Atlantic and Gulf coasts, from southern Maine to central Florida, and westward to Mississippi, generally within a narrow coastal belt 50 to 100 miles wide (Harlow and Harrar 1937). Within this belt the distribution is very patchy, depending on the occurrence of suitable sites (Little 1950). The rangewide acreage of Atlantic white-cedar has declined significantly over the last two centuries.
  - At the time of European settlement, there may have been as many as 500,000 acres of Atlantic white-cedar throughout its range (Kuser and Zimmermann 1995).
  - According to one estimate, from foresters and conservationists surveyed in Spring 1995, the total rangewide acreage of Atlantic white-cedar forest (containing 5% or more of cedar) was estimated to be only 115,000 acres (Kuser and Zimmermann 1995).

Figure 2. Rangewide distribution of Atlantic white-cedar, adapted from Little (1971).

Distribution in New Jersey

- The majority of Atlantic white-cedar in New Jersey is found in the southern part of the state, although the species is also present in isolated areas in the northern portion.

- Prior to European settlement there may have been 115,000 acres of Atlantic white-cedar in New Jersey (New Jersey Forest Service 1997).

- In 1900, Vermeule estimated that there were 52,500 acres of Atlantic white-cedar in New Jersey, with an additional 85,100 acres of pine and hardwood swamps that contained some white-cedar (Vermeule 1900). Cottrell (1930) estimated that there were 100,000 acres of white-cedar at that time, although that estimate may be high (Little 1950).

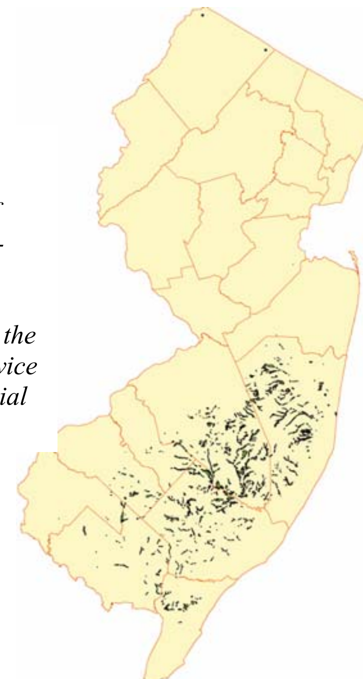


Figure 3. Approximate distribution of Atlantic white-cedar in New Jersey. Data interpreted by the NJ Forest Service from 1986 aerial photos.

- By 1974, there were fewer than 50,000 acres of white-cedar in New Jersey (Kantor and Pierson 1985). According to a NJ Forest Service estimate from 1986 aerial photographs, there are approximately 41,690 acres of Atlantic white-cedar in New Jersey today, with 26,136 acres containing greater than 50% cedar (NJ Forest Service unpublished data - see Figure 4).

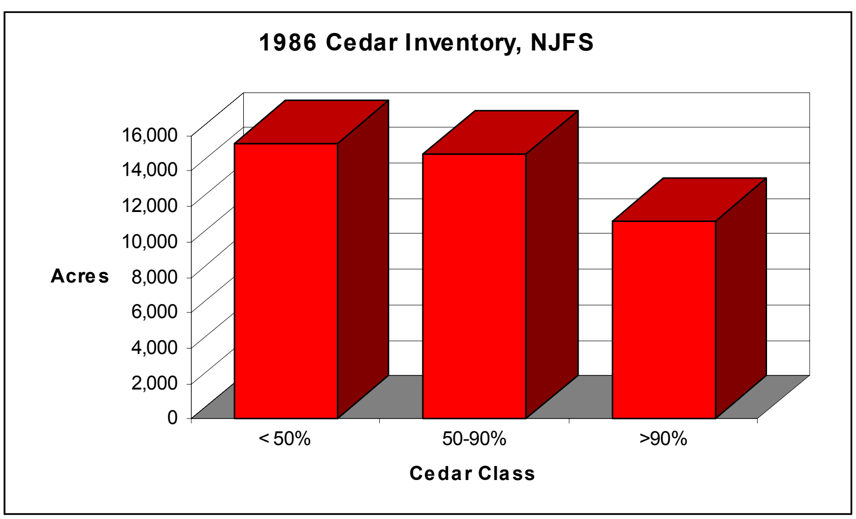


Figure 4. Inventory of Atlantic white-cedar in New Jersey. Data were interpreted by the NJ Forest Service based on 1986 aerial photo interpretation and subsequent ground truthing.

Southern New Jersey

- Roman and Good (1983) estimated that there were 21,450 acres (8680 ha) of Atlantic white-cedar (2% of the total land area) in the 1.1 million acre (445,000 ha) Pinelands National Reserve. This estimate, from New Jersey Pinelands Commission vegetation maps, does not include cedar that may be found in swamps dominated by hardwoods or pitch pine (*Pinus rigida*).

- In the Pinelands, cedar swamps occur mostly as narrow bands along streams. These bands are usually not more than 1,000 feet wide, some extending from the source of the stream to tide water (Cottrell 1929). Some cedar swamps are also found in broad lowlands. Pinelands Commission maps delineate a total of 626 discrete cedar swamp patches. 92% of the individual swamps are less than or equal to 100 acres (41 ha) and 84% are less than or equal to 50 acres (20 ha.) (Zampella 1987).

Figure 5. The dark band in this aerial photo delineates a typical Atlantic white-cedar stand along a stream in the NJ Pinelands. Photo by George Zimmermann.

Northern New Jersey

- Cedar stands in the northern portion of the state are few and isolated. Few sites in northern New Jersey contain more than a few individuals of Atlantic white-cedar. These sites include Wawayanda State Park and the Kuser Natural Area in High Point State Park, in Sussex County. The cedar swamp at High Point is found at an altitude of 457 m (1500 ft), the highest altitude recorded for this species rangewide (Laderman 1989).

- A number of additional sites in glaciated New Jersey previously contained cedar (Britton 1889, Vermeule 1896, Waksman et al. 1943, Heusser 1949a, 1949b, 1963). Historically, extensive cedar stands covered the Hackensack Meadowlands area and the Sandy Hook peninsula. The cedar stands of the Hackensack Meadowlands were described in detail by Torrey and others (1819). Peat deposits record increasing abundance of white-cedar from about the 14th century onward. By the time of European settlement in the 17th century, Atlantic white-cedar was the principal tree of the Hackensack swamp forests. The Hackensack forests contained trees of such size that are unknown today along the coast of New Jersey (Heusser 1949a). Today, white-cedar has been extirpated from the area (Schmid 1987).

Figure 6. Atlantic white-cedar stumps at the Mill Creek mitigation site in the Hackensack Meadowlands. This ancient cedar forest was uncovered in 1998 while excavating for this wetland mitigation project. These cedar trees may have been harvested in the 1860's. In the past, extensive cedar stands covered the Hackensack Meadowlands area, but today the species has been totally extirpated from the area. Photo by Robert R. Williams.

Figure 7. Jack Shuart of the New Jersey Forest Service after cutting sections from one of the larger Atlantic white-cedar stumps at the Mill Creek site. Initial dendrochronological analysis at Richard Stockton College of New Jersey indicates that this tree was at least 240 years old when it was cut. Photo by Kristin Mylecraine.

Value of Atlantic white-cedar

Ecological value

- Atlantic white-cedar ecosystems may provide many ecological benefits:
    - Cedar swamps may help to filter and purify water, by absorbing and filtering pollutants and sediment. These swamps also stabilize streamflows, by temporarily storing floodwaters and mitigating the effects of drought.
    - Cedar swamps provide a unique environment throughout the year and benefit a wide range of plant and animal species. In particular, they provide important winter habitat for deer and other wildlife.
    - Cedar swamps provide habitat for several threatened and endangered plant and animal species.
    - Cedar swamps frequently act as natural firebreaks (Little 1964); however this role varies considerably, depending on the wind orientation in relation to the stream, wind velocity, lowland width and lowland water table depth at the time of fire (Windisch 1987).

Economic value

Wood properties

- Atlantic white-cedar has been called the most important timber tree of the pine region of southern New Jersey (Moore and Waldron 1938). Several properties of Atlantic white-cedar wood make this species valuable for timber. The wood is durable, lightweight, aromatic, and usually has an even, straight grain. The heartwood is so durable that logs buried deep in the swamps for 50 years or longer furnish excellent lumber (Korstian and Brush 1931, Little 1950).

Uses

- Atlantic white-cedar wood is used for a wide variety of timber products. These include: boats, tanks, siding, fencing, decking, millwork, shingles, lawn furniture, poles, posts, stakes, channel markers, clam stakes, boxes and crates (Korstian and Brush 1931, Ward 1989). In the past, fishermen utilized the tough and fibrous bark to string their fish.

Value of associated species

- Although they have significant ecological value, the principal associates of cedar in New Jersey are of far less economic value. Red maple (*Acer rubrum*) has seldom been harvested, being suitable only for firewood, temporary corduroy roads, and other uses that will hardly, if at all, pay for the cost of removal. In general, blackgum (*Nyssa sylvatica*) is a species of low economic value, although it is harvested to some extent for specialized uses. This species is usually not cut in New Jersey because of the high cost of removal from swamps (Little 1950).

Historic utilization

17th and 18th centuries

- Exploitation of Atlantic white-cedar began with the arrival of European settlers to the Atlantic coast. In North Carolina, there was a significant period of exploitation between 1653 and 1750, following European settlement (Phillips et al. 1998). White-cedar was heavily cut in New Jersey as early as the 18th century. As early as 1749, Peter Kalm warned that heavy cutting in New Jersey might be extirpating white-cedar entirely from the state. He wrote that white-cedar was not only used for many purposes in New Jersey, but was also cut heavily for export (Benson 1937). During this time, most houses in Philadelphia and Wilmington were built with cedar shingles from southern New Jersey cedar swamps (Benson 1937, Kantor and Pierson 1985). Shingles and other products were exported to New York and the West Indies (Benson 1937). In 1758, white-cedar products formed about 20% of the exports from Cape May County (Cook 1857).

- During this time, Atlantic white-cedar was not only valued for the wood itself, but also for the land on which it existed. During the 17th and 18th centuries, many cedar swamps in New Jersey were cut, flooded and converted into cranberry bogs (Pierson and Zimmermann 1993). Beginning in the 18th century, large areas of cedar forest in North Carolina were also drained for agriculture (Frost 1995).

19th century

- Immense quantities of white-cedar were removed during the 19th century, much of which was second growth. Thousands of rails and sawed timber were being exported annually (Cook 1857). During this time, mining of cedar logs buried in swamp peat was a profitable industry in New Jersey (Cook 1868, Hall and Maxwell 1911, Korstian and Brush 1931). By 1857 many of the swamps of Cape May County had been cut over twice and some three times, and not a single acre of original growth was left (Little 1950).

- During this period, heavy cedar cutting also occurred in other regions. In North Carolina, cedar cutting during this period was facilitated by the advent of steam-powered trains and dredging equipment, to drain previously inaccessible cedar swamps (Earley 1987, Frost 1987). Frost (1987) speculates that 50% of all the existing white-cedar acreage in the state was cut between 1870 and 1890.

20th century

- Utilization of white-cedar has continued into the 20th century. At the turn of the century, New Jersey was the predominant source of Atlantic white-cedar lumber (Ward 1989). Vermeule (1900) estimated that cedar wood was valued at $90 per acre at that time. In 1911, over 669,000 board feet of cedar were cut in New Jersey. In addition, over 20 million cedar shingles were made (Bones 1973). By 1930, Cottrell observed that white-cedar had become less important in the state's annual cut than it had been 25 or 50 years earlier, largely because merchantable stands had been so heavily cut. In 1982, the annual cedar harvest was 250,000 board feet (Pierson and Zimmermann 1993). Today, many swamps in the Pine Barrens have been clearcut at least five times (Little 1979a). The amount of timber cut annually has now been reduced to a small amount, due to extensive cutting, conversion of cedar lands to other uses, and wetland protection (Ward 1989).

- In North Carolina, a decline in logging began in the 1920s to 1930s and continued into the 1970s to 1980s. This lull was followed by a third wave of exploitation. By this time, stands that had regenerated following earlier logging were 70 to 90 years old. New technology also became available during this period, including hydraulic equipment and wide, 6-foot tracks (Phillips et al. 1998). During this period, Atlantic Forest Products, a timber company, produced about 13 million board feet of white-cedar every year (Earley 1987).

- Atlantic white-cedar wood remains very valuable today. In 1989, North Carolina was the most important production area, with New Jersey and the Florida panhandle – southern Alabama region as secondary centers. In 1991, the retail price for finished lumber was at least $750 to $1000 per thousand board feet. In comparison, loblolly pine (*Pinus taeda*) retailed at $450 (Phillips et al. 1998).

Figure 8. Historic photo of Atlantic white-cedar harvest. Photo courtesy of George Pierson.

General site and stand characteristics

- In New Jersey, Atlantic white-cedar typically forms dense stands of trees all the same age (even-aged), or sometimes with mixed age classes (uneven-aged) (Harshberger 1916). According to Sheffield and others (1998) only 1/5 of the rangewide area of this species contains 50% or more Atlantic white-cedar. Nearly 2/3 of the total area contains proportions of less than 25% cedar. On more hydric sites, cedar commonly constitutes a greater proportion of the total stand.

- Because of their dense nature, cedar swamps are protective. The dense trees suppress movements of air, creating a calm, nearly windless environment within the swamp. Cedar swamps are cooler than the surrounding forest in the spring and summer, and warmer in the winter (Harshberger 1916).

- Atlantic white-cedar swamps are typically characterized by hummock-hollow topography. The bases of the cedar trees are typically surrounded by raised cushions of bog mosses (hummocks). Between the hummocks are depressions (hollows), which may contain standing water at certain times of year (Harshberger 1916).

- L.H. Reineke and C.F. Korstian (in Korstian and Brush 1931) developed several stand tables for Atlantic white-cedar based on field data collected in North Carolina, Virginia, and New Jersey, one of which is presented here (see Table 1.)

Table 1. Stand table from Korstian and Brush (1931). Total number of Atlantic white-cedar trees per acre, 1 inch or greater in diameter, by age and site index.

Age (years)	**Site Index**					
	20	**30**	**40**	**50**	**60**	**70**
	Number of trees per acre					
20	18,000	14,700	10,800	7,400	4,600	2,800
25	13,000	10,500	7,600	5,100	3,300	2,000
30	9,600	7,600	5,600	3,850	2,400	1,450
35	7,400	5,800	4,500	2,950	1,860	1,120
40	5,800	4,500	3,400	2,300	1,440	870
45	4,600	3,700	2,700	1,900	1,170	720
50	3,900	3,100	2,250	1,550	970	580
55	3,350	2,600	1,950	1,330	830	500
60	2,900	2,300	1,700	1,170	740	435
65	2,550	2,050	1,500	1,050	660	380
70	2,300	1,850	1,350	940	580	350
75	2,150	1,700	1,250	860	540	330
80	1,980	1,550	1,150	790	500	300
85	1,850	1,450	1,075	740	460	280
90	1,750	1,350	1,000	700	430	260
95	1,650	1,270	950	660	420	250
100	1,550	1,200	900	620	385	230

Figure 9. Typical Atlantic white-cedar stand in New Jersey. Note the dense, monospecific nature typical of these stands. Photo by George Zimmermann.

Figure 10. Forest floor of a typical Atlantic white-cedar stand in New Jersey, characterized by Sphagnum covered hummocks and hollows. Photo by Kristin Mylecraine.

Flora associated with Atlantic white-cedar

Tree species

- **Northern New Jersey:** In northern New Jersey, red maple is the predominant hardwood associate. Other associates include blackgum, black spruce (*Picea mariana*), tamarack (*Larix laricina*), and Eastern hemlock (*Tsuga canadensis*) (Little 1950).

- **Southern New Jersey:** Red maple is also the predominant hardwood associate in the Pinelands of southern New Jersey. Other common associates include blackgum, sweetbay magnolia (*Magnolia virginiana*), pitch pine and gray birch (*Betula populifolia*). In some areas of central New Jersey and Cape May County, white-cedar may be found with sweetgum (*Liquidambar styraciflua*), and rarely with tulip poplar (*Liriodendron tulipifera*) (Little 1950).

Shrub species

- In some cedar swamps, the dense overstory may prevent the development of a dense understory. In swamps that are more open, or along swamp edges, several shrub species can be found. One study found 25 species of shrubs associated with Atlantic white-cedar in southern New Jersey (Little 1951). Table 2 lists some of the most common shrub associates in this portion of New Jersey. In northern New Jersey cedar swamps, great rhododendron (*Rhododendron maximum*) is also very common (Collins and Anderson 1994).

<u>*Table 2.*</u> *Some shrub species occurring with Atlantic white-cedar in southern New Jersey, compiled from Harshberger (1916), Little (1951), Collins and Anderson (1994), Roman et al. (1987), Stoltzfus and Good (1998), and Laidig and Zampella (1999).*

Common Name	Scientific Name	Common Name	Scientific Name
Shadbush	*Amelanchier spp.*	Staggerbush	*Lyonia mariana*
Red chokeberry	*Aronia arbutifolia*	Bayberry	*Myrica pennsylvanica*
Leatherleaf	*Chamaedaphne calyculata*	Virginia creeper	*Parthenocissus quinquefolia*
Sweet pepperbush	*Clethra alnifolia*	Swamp azalea	*Rhododendron viscosum*
Fetterbush	*Eubotrys racemosa*	Swamp dewberry	*Rubus hispidus*
Black Huckleberry	*Gaylussacia baccata*	Sassafras	*Sassafras albidum*
Dwarf Huckleberry	*Gaylussacia dumosa*	Laurel-leaved greenbrier	*Smilax laurifolia*
Dangleberry	*Gaylussacia frondosa*	Common greenbrier	*Smilax rotundifolia*
Inkberry	*Ilex glabra*	Poison ivy	*Toxicodendron radicans*
Smooth winterberry	*Ilex laevigata*	Poison sumac	*Toxicodendron vernix*
Winterberry holly	*Ilex verticillata*	Highbush blueberry	*Vaccinium corymbosum*
Sheep laurel	*Kalmia angustifolia*	Cranberry	*Vaccinium macrocarpon*
Mountain laurel	*Kalmia latifolia*	Lowbush blueberry	*Vaccinium pallidum*
Spicebush	*Lindera benzoin*	Southern arrowwood	*Viburnum dentatum*
Maleberry	*Lyonia ligustrina*	Southern wild-raisin	*Viburnum nudum*

Herbaceous plants

- Herbaceous plants found in cedar swamps include insectivorous sundews (*Drosera* spp) and pitcher plants (*Sarracenia purpurea*), although these are more common in open, sunny locations (Collins and Anderson 1994). Other species include bladderworts (*Utricularia* spp), golden club (*Orontium aquaticum*), starflower (*Trientalis borealis*), and Arethusa (*Arethusa bulbosa*) (Collins and Anderson 1994). Several species of orchids are confined almost exclusively to cedar swamps (Harshberger 1916). Cedar swamps also provide habitat for the federally endangered swamp pink (*Helonias bullata)*.

- Several species of ferns can be found, including the rare curly grass fern (*Schizaea pusilla*), which can be found growing at the base of the cedar trees (Harshberger 1916, Collins and Anderson 1994). Other common fern species include cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*) and chain ferns (*Woodwardia* spp) (Collins and Anderson 1994).

- Clumps of sedges may be common, including long sedge (*Carex folliculata*) and Collins' sedge (*Carex collinsii*) (Collins and Anderson 1994).

- The ground and bases of trees are typically covered with several species of sphagnum mosses and liverworts (Collins and Anderson 1994).

Note: The plant species listed above are only some of the more common species found in New Jersey Atlantic white-cedar swamps. For a more extensive list of plant species found throughout the entire range of cedar, see Laderman (1989) and Laderman and Ward (1987).

Fauna associated with Atlantic white-cedar

- The information on animals associated with Atlantic white-cedar communities is limited. Laderman (1989) has collected much of the information that is available.

Bird species

- There have only been a few detailed studies of bird species associated with Atlantic white-cedar. Terwilliger (1987) found that cedar stands in the Great Dismal National Wildlife Refuge held nearly twice as many birds per unit area as a surrounding hardwood forest.

- In southern New Jersey, Brady (1980) found that mature cedar swamps support the lowest breeding bird species diversity of any habitat type. However, Wander (1980-1981) found that one species, the black-throated green warbler (*Dendroica virens*), was entirely restricted to cedar swamps for breeding. Two other species, the brown creeper (*Certhia familiaris*) and sharp-shinned hawk (*Accipiter striatus*), were largely restricted to cedar swamps for breeding.

- The ecotones between cedar swamps and surrounding habitats are also utilized by a great variety of bird species (Wander 1980-1981).

Mammal species

- Cedar swamps provide important winter habitat (Burke 1979) and food supply (Little et al. 1958, Little and Somes 1965) for the white-tailed deer (*Odocoileus virginianus*). The cottontail rabbit (*Sylvilagus floridanus*) and meadow mouse (*Microtus pennsylvanicus*) also feed on cedar seedlings. Ward and Clewell (1989) report trees with black bear (*Ursus americanus*) markings in Florida cedar wetlands. Nineteen species of mammals are reported to be currently associated with cedar swamps in the NJ Pinelands (NJ Pinelands Commission 1980):

Common Name	Scientific Name	Common Name	Scientific Name
Beaver	*Castor canadensis*	Mink	*Mustela vison*
Southern red-backed vole	*Clethrionomys gapperi*	Little brown bat	*Myotis lucifugus*
Star-nosed mole	*Condylura cristata*	White-tailed deer	*Odocoileus virginianus*
Virginia opossum	*Didelphis virginiana*	Muskrat	*Ondatra zibethicus*
Big brown bat	*Eptesicus fuscus*	Eastern pipistrelle	*Pipistrellus subflavus*
River otter	*Lutra canadensis*	Pine vole	*Pitymys pinetorum*
Striped skunk	*Mephitis mephitis*	Raccoon	*Procyon lotor*
Meadow vole	*Microtus pennsylvanicus*	Eastern cottontail	*Sylvilagus floridanus*
Long-tailed weasel	*Mustela frenata*	Southern bog lemming	*Synaptomys cooperi*

Amphibian and reptile species

- Several species of herptiles can be found in association with Atlantic white-cedar, many of which are considered threatened, endangered or rare. The following amphibian and reptile species can be found in the NJ Pinelands (NJ Pinelands Commission 1980):

Common Name	Scientific Name	Common Name	Scientific Name
Northern Cricket Frog	*Acris c. crepitans*	Spotted turtle	*Clemmys guttata*
Four-toed salamander	*Hemidactylium scutatum*	Bog turtle	*Clemmys muhlenbergii*
Pine Barrens treefrog	*Hyla andersoni*	Nothern black racer	*Coluber c. constrictor*
Eastern mud salamander	*Pseudotriton m. montanus*	Eastern king snake	*Lampropeltis g. getulus*
Northern red salamander	*Pseudotriton r. ruber*	Northern pine snake	*Pituophis m. melanoleucus*
Carpenter frog	*Rana virgatipes*	Red-bellied turtle	*Pseudemys rubriventris*
		Northern red-bellied snake	*Storeria o. occipitomaculata*

Fish species

- There are a number of fish species which are considered characteristic of acid Pinelands streams (NJ Pinelands Commission 1980), which may be associated with Atlantic white-cedar. Mud minnows (*Umbra pygmaea*) have been observed in small temporary ponds in Atlantic white-cedar clearcuts (Rudolf Arndt 1999, personal communication). For additional information about the fish species of the Pinelands, see Hastings (1979, 1984) and Zampella and Bunnell (1998).

Insect species

- Numerous insect species can be found within Atlantic white-cedar swamps, including the rare butterfly, Hessel's hairstreak (*Mitoura hesseli*), which has been found in bogs from Connecticut to North Carolina (Laderman 1989). The larva of this species feed exclusively on Atlantic white-cedar (Cryan 1985).

Figure 11. *Hessel's hairstreak adult. Photo by George Zimmermann.*

Figure 12. *Pine Barrens treefrog. Photo by Rudolf Arndt.*

Figure 13. *Timber rattlesnake. Photo by Rudolf Arndt.*

Figure 14. *Mud minnow. Photo by Rudolf Arndt.*

III. Silvics

Seed production, distribution and viability

Production

- At intermediate latitudes, flowers usually appear in March or April. Male and female flowers are produced separately, although on the same tree (Korstian and Brush 1931).

- Atlantic white-cedar cones, approximately 1/4 inch in diameter, mature in one year and contain about 5 to 15 winged seeds. The seeds are about 1/8 inch long, and there are about 420,000 to 500,000 seeds per pound (Korstian and Brush 1931).

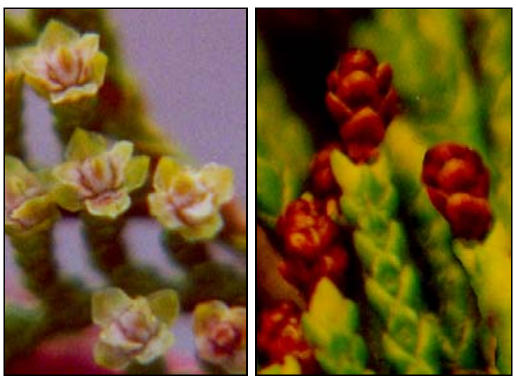


Figure 15. Close up view of Atlantic white-cedar female (left) and male (right) flowers.

Figure 16. Mature cones of Atlantic white-cedar.

- Seed production begins at a young age. In open stands, trees may produce cones at 4 or 5 years, and at 10 to 20 years in dense stands (Korstian and Brush 1931). Seedlings grown in a nursery and planted in the field tend to begin seed production at a younger age than natural reproduction (Little 1950).

- The number of cones produced may depend on the size and location of the tree. Large trees tend to produce more cones than smaller trees. Trees in the open tend to produce more cones than those in dense clumps, although dominant trees in clumps may be as prolific as open grown trees of the same size (Little 1950).

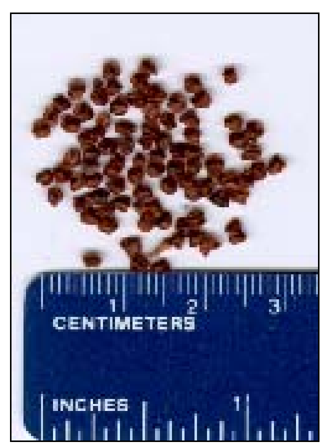


Figure 17. Atlantic white-cedar seeds.

Distribution

- In New Jersey, cones ripen during September and October (Harris 1974) and seed fall begins in early autumn. Seed is distributed mainly by wind and to a lesser degree by floating in streams and swamps (Korstian and Brush 1931). The tiny seeds can also be blown along the crust of snow (Eckert 1999, personal communication).

- In dense stands of white-cedar, most of the seed falls directly under the stand. Under a mature stand, seed may be distributed at a rate of 8 to 9 million seeds per acre (Little 1950).

- The extent to which seed is carried beyond these stands depends greatly on the density and height of surrounding vegetation. The amount of seed fall per unit area greatly decreases with increasing distance from the seed source. In New Jersey, prevailing winds are from the west during the time of seed fall. Therefore, the bulk of seed is distributed to the east side of the source (Little 1950).

- Most seed is released by the end of the winter, but distribution may continue throughout the year. According to Little (1950), peak seed distribution occurs between October 23 and November 2.

- Seed dispersal may also be affected by weather conditions. Rain showers may cause partial or complete cone closure (Little and Garrett 1990).

Viability

- Korstian and Brush (1931) reported germination rates between 70 and 90 percent. However seed viability is highly variable, and may depend on the age, genetics, general health and nutrition of the parent tree, as well as weather and climatic conditions (Laderman 1989). Viability also varies among seedlots from different swamps (Boyle and Kuser 1994).

- Much of the viable white-cedar seed will germinate fairly promptly if stored in a cool, moist medium (swamp peat) for some time and if germination conditions are suitable. However, delayed germination is common. Even under ideal conditions, some seeds will not germinate before the second spring (Little 1950).

- Cedar seed may remain viable in a sphagnum substrate for an unknown length of time (Little 1950), possibly for as long as 14 years (Little 1990, personal communication).

Soil and moisture requirements

Soil

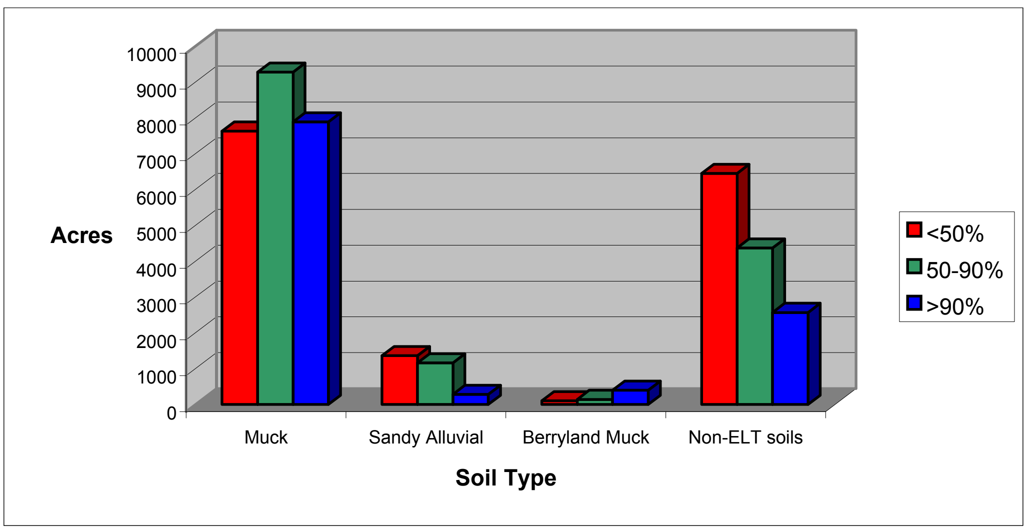
- As found today, Atlantic white-cedar is largely confined to areas of organic peat overlying a sandy subsoil. These soils are generally acidic, with a pH between 3.5 and 5.5 (Little 1950). In the Great Dismal Swamp in North Carolina, Korstian and Brush (1931) found that the proportion of hardwoods in a stand increases with the amount of clay in the subsoil.

- Cedar can also be found on poorly drained mineral soils. In the more inland parts of its range, cedar can be found along sandy streambeds (Korstian and Brush 1931). Haas and Kuser (1999) have found that it is possible to introduce seedlings and stecklings (rooted cuttings) into extremely barren sand location, although long term survival and sustainability on such sites is yet to be seen.

- Suitable seedbeds for Atlantic white-cedar germination include rotten wood, peat, sphagnum moss, and moist mineral soil (Little 1959). Greenhouse experiments have found earlier and more complete germination on peat moss than on sand (Greenwood 1994, Zimmermann 1993). The reason for this is not known, although it cannot be attributed to pH alone (Boyle and Kuser 1994) or moisture holding capacity (Zimmermann 1993). Seeds may also germinate in mineral soil, but at lower percentages (Laderman 1989).

- In New Jersey, Atlantic white-cedar is found on a variety of soil types. The NJ Forest Service is currently mapping potential Ecological Land Types (ELTs) of New Jersey, as part of the US Forest Service Ecomap project. The cedar-maple-gum ELT includes muck, sandy alluvial, and Berryland muck soil types. However, a significant percentage of the current Atlantic white-cedar acreage is found on non-ELT Atsion soils (see Figure 15).

Figure 18. Existing Atlantic white-cedar stands by percent cedar composition and soil type. Cedar stands were identified from 1986 aerial photography, and classified as <50% cedar, 50-90% cedar, and >90% cedar. Data collected by NJ Forest Service.



Moisture

- Atlantic white-cedar is often considered an obligate wetland species, and is considered New Jersey's only obligate wetland tree species (Reed 1988). However, Moore and Waldron (1940) suggest that it may have occupied a considerable portion of the intermediate zones between upland and lowland sites, characterized by poorly drained sands, in the past but "the combination of cutting and frequent fires that have occurred since settlement has tended to reduce the area in cedar to the wetter portions which it now occupies."

- In a typical cedar stand, standing water is often present in depressions for several months, although the water table may fall as much as 2-3 feet below the surface in very dry autumns (Korstian 1924). Golet and Lowry (1987) characterized the hydrology of several cedar swamps in Rhode Island. The mean annual water level ranged from 13 cm above to 11cm below the ground, and the duration of surface flooding ranged from 18-76% of the growing season. Water levels varied significantly between years, primarily in response to variations in annual precipitation.

- Moisture is considered one of the critical factors for cedar regeneration (Little 1950, Zimmermann 1997). Both too much and too little water can be detrimental. Pinchot (1899) observed that there is generally more complete reproduction in dry swamps than in wet swamps with standing water, possibly because the standing water prevents the germination of Atlantic white-cedar seeds (Harshberger 1916). On the other hand, relatively dry swamps may provide too little moisture for adequate germination of white-cedar seed and growth of seedlings (Little 1950), making reproduction on such sites problematic (Zimmermann 1997).

- Best growth is achieved in swamps with a relatively dry surface, but with the water table at a depth no greater than 4 to 5 inches (Little 1950). In a greenhouse study, Allison and Ehrenfeld (1999) found that seedlings experienced greatest growth in moist, well-drained conditions. Growth was least in inundated soil conditions and intermediate in saturated soil. Observations suggest that growth is slower on upland soils (Korstian and Brush 1931).

- In order to have wetland conditions, a surplus in the water budget is required. There are six hydrogeologic freshwater wetlands types found in the New Jersey Pinelands, classified based on the cause of their surplus. These have been described by Epstein (1995, 1997):

    - **(1) Ponded and (2) Perched wetlands** may occur at high elevations, away from floodplains. Ponded wetlands result from the existence of a topographic basin, with an impervious layer at the surface. In perched wetlands, the impervious layer is below the surface, yet above the water table.

    - **(3) Stream and (4) Tidal flood wetlands**: Stream flood wetlands occur when flood water flows out and away from a stream channel onto the floodplain due to excessive upstream channel flows. Tidally induced flood wetlands occur when a stream floods due to high tides, which prevent the stream from discharging. This water "backs up" and floods over stream banks.

    - **(5) Unconfined and (6) Confined groundwater discharge wetlands** are the most common wetland types in the Pinelands, and occur at the upper margins of floodplains. Unconfined groundwater discharge wetlands occur when the water table decreases in elevation and comes closer to the surface from the wetland to the associated streams. Confined groundwater discharge wetlands occur when there is an impervious layer at or below the surface, preventing groundwater from rising to the surface. Where there is an opening in the layer, pressurized water will rise above the layer and probably discharge at the surface.

- Atlantic white-cedar can be found on all six wetland types (Epstein 1998). Each of these wetland types has different characteristics and susceptibilities (Epstein 1993). Hydrologic conditions vary significantly among different cedar swamps. A single wetland may be a combination of different wetland types. Before white-cedar management decisions are made, the hydrology of a particular swamp must be considered.

Microtopography

- Microtopography, as it affects moisture availability, is also an important factor. Seedlings that germinate on the top of hummocks may die from lack of moisture during dry periods. On the other hand, seedlings in depressions may die if subject to prolonged flooding (Akerman 1923, Korstian and Brush 1931, Little 1959). Akerman (1923) concluded that seedlings originating midway between the top and base of stumps had the best survival. The presence of *Sphagnum* may be as important as elevation in determining the habitat quality of microsites (Ehrenfeld 1995a). In general, the younger and smaller seedlings are more susceptible to drowning and drought (Little 1959).

- Microtopography may also affect the degree of mycorrhizal infection in Atlantic white-cedar. Cantelmo and Ehrenfeld (1999) found that mycorrhizal infection varies strongly with the hydrology of the sediments and that this variation is expressed over microtopographic gradients.

- A recent study found that cedar, as well as its associated species tend to avoid the lower microsites (Ehrenfeld 1995b). However, field surveys by Allison and Ehrenfeld (1999) show that seedlings do not differ in their occurrence on hummocks or bottoms. They also found no significant difference in occurrence with respect to presence or absence of *Sphagnum* within the microhabitat. These conflicting results illustrate that there are still unknowns present in our understanding of cedar germination and seedling requirements, and there may be several interacting factors involved.

Light requirements

- There have been many conflicting statements concerning the shade tolerance of Atlantic white-cedar. Some authors consider this species intolerant of shade, while others consider it shade tolerant (Baker 1922, Akerman 1923, Noyes 1939, Moore 1939).

    - Little (1950) describes white-cedar as more tolerant of shade than pitch pine and gray birch, but not as tolerant as red maple and other associated hardwoods.

    - Korstian and Brush (1931) suggest that white-cedar is very tolerant of shade in early youth, becoming less tolerant with age.

    - From their observations, Hickman and Neuhauser (1978) reported that cedar is able to become established (although slowly) under a dense canopy of maple, but maples fail to become established under any closed canopy, and therefore considered white-cedar to be more tolerant than red maple.

- A fair amount of light, probably to provide heat, is necessary for optimal germination and survival. Pinchot (1899) observed that a certain amount of light is necessary for the germination of white-cedar and no new seedlings begin after the crowns of a young stand closed. However, Little (1950) observed that seedlings often occur in large numbers under older stands. Seedlings may also become established under the shade of shrubs (Korstian and Brush 1931). According to one study, light intensities have to be less than 16% of full sunlight before germination is greatly reduced (Little 1950). Recent shading experiments have shown that light reduction does not affect new recruitment of Atlantic white-cedar (Moore 1996). However, growth under shade is greatly reduced and survival is limited to short periods. Seedlings that germinate under closed canopies may survive only 1-3 years (Little 1950).

Form

- In dense, closed stands, Atlantic white-cedar develops a long, clear straight bole. Crowding causes the bole to assume a nearly cylindrical form below the crown and a very rapid taper within the crown. The crown is usually very short, narrow and conical (Korstian and Brush 1931). Open grown trees typically have greater taper and longer crowns. Open grown trees also tend to have more limbs and a rougher bole (Korstian and Brush 1931).

Figure 19. Typical Atlantic white-cedar form. In dense stands, cedar tends to have a long, cylindrical bole. Photo by George Zimmermann

Root system

- Atlantic white-cedar has a very shallow root system, confined to the upper 1 to 2 feet of peat in swamps where the lower soil layers are saturated with water. A small taproot is formed during the first year, but is subsequently lost in the development of numerous lateral roots (Little and Garrett 1990). On sites with a lower water table and more deeply aerated soils, the roots may penetrate deeper (Korstian and Brush 1931, Laderman 1989).

Growth

Growth rate

- The growth rate of white-cedar is primarily influenced by site quality, stocking, and condition of the stand (Korstian and Brush 1931). In general, growth is slower on excessively wet sites and on very dry, sandy sites. Higher growth rates are achieved on organic soils with little standing water, but with a water table usually within 6 inches from the surface (Little 1950).

- On better sites in New Jersey, white-cedar averages an annual increase of 1 to 1.5 feet in height and 0.1 to 0.15 inches in diameter at breast height (DBH) for the first 40 to 50 years. At about 50 years of age, height growth gradually declines, ceasing completely at about 100 years. Diameter growth reaches a maximum at about 50 years, but continues at a significant rate for the next 50 years (Korstian and Brush 1931).

- Atlantic white-cedar exhibits maximum growth in the southern portions of its range. In the South, saplings can reach three meters (9.8 ft) in seven or eight years. In southern New Jersey this size is reached in about ten years. However, on unfavorable substrates, growth in 15 years may only be 1.2 m (3.9 ft) (Laderman 1989).

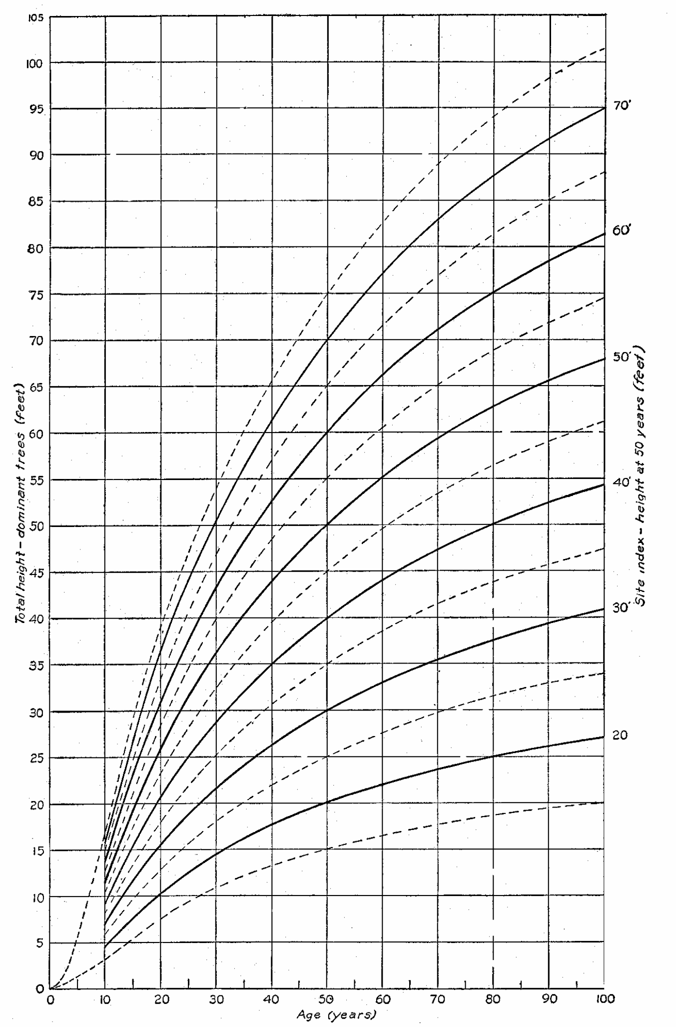
Maximum size and age

- Atlantic white-cedar attains its maximum size in the southern portions of its range (Laderman 1989). Historical records suggest that Atlantic white-cedar in the original forest may have lived up to 1,000 years (Cook 1857, Gifford 1900). The average diameter is believed to have been 2-3 feet, rarely reaching 4-7 feet. In New Jersey, trees in the original forest probably lived to about 200 years, with an average diameter of 2-3 feet (Little 1950).

- Throughout its current range, mature cedar stands (75 to 100 years old) with normal density average 80-85 feet tall and 10-14 inches in DBH on good sites (Korstian and Brush 1931). Rangewide, the largest living Atlantic white-cedar reported is 88 feet tall, with a circumference of 15 ft. 6 in., and is located in Brewton, Alabama (Rooney 1992). In New Jersey, the largest cedar is located in Bass River State Forest, Burlington County and has a circumference of 9 ft. 2 in. (Johnson 1998).

Figure 20. Former New Jersey record Atlantic white-cedar. This tree is located at Nixon Branch, Cumberland County. Photo by John Kuser.

Site index



- For white-cedar, the height at 50 years is used as the basis for site classification. Figure 20 shows the site index curve for Atlantic white-cedar taken Korstian and Brush (1931).

- In the southern parts of its range, sites typically produce trees 50-70 feet tall in 50 years (site index of 50 to 70). From New Jersey northward, sites produce trees 20-50 feet tall in the same time (Korstian and Brush 1931). In southern New Jersey, the height of Atlantic white-cedar does not exceed 50 feet in 50 years (site index of 50), with many stands in the 40 foot class (Moore and Waldron 1940).

Figure 21. Site Index curve for Atlantic white-cedar, from Korstian and Brush (1931). Height growth at age 50 is generally used as the basis for site classification.

Yield of Atlantic white-cedar

- The yield of Atlantic white-cedar varies greatly with stand age, site quality, and the number and volume of the individual trees. For example, the yield of stands 100 years old may be as much as 54,200 board feet per acre (International log rule, 1/8" saw kerf) on good sites (site index of 60) or as low as 6,550 board feet on poor sites (Korstian and Brush 1931).

- Korstian and Brush (1931) developed several yield tables for Atlantic white-cedar. Yield tables of basal area per acre (Table 3), board feet per acre (Table 4) and cords per acre (Table 5) are presented here.

<u>Table 3</u>. Yield table developed by Korstian and Brush (1931). Basal area per acre of all Atlantic white-cedar trees 5 inches or more in diameter, by age and site index. Basal area is measured at breast height (4.5 feet above ground).

	Site Index					
	20	**30**	**40**	**50**	**60**	**70**
Age (years)	**Basal area – square feet per acre**					
20	-	-	-	-	6.7	29.0
25	-	-	-	11.4	44.4	94.5
30	-	-	11.6	41.9	104.0	160.0
35	-	7.2	28.1	88.2	158.4	201.4
40	-	23.3	65.2	134.2	199.5	229.0
45	9.6	40.1	104.0	174.8	226.1	248.2
50	20.3	68.1	139.7	206.6	245.2	263.8
55	33.9	90.2	166.4	227.6	258.1	273.4
60	48.0	109.9	189.5	241.9	267.1	281.6
65	63.3	128.3	205.5	251.1	275.7	289.1
70	75.3	145.2	214.9	259.0	281.4	294.4
75	86.1	160.9	223.9	266.1	287.3	299.4
80	96.8	172.5	232.2	272.6	292.5	303.7
85	106.7	183.0	238.6	275.7	295.8	307.7
90	115.8	190.5	244.2	279.7	298.8	310.7
95	121.0	196.2	248.6	283.8	301.1	313.7
100	125.6	201.4	252.1	287.1	303.4	316.7

<u>Table 4</u>. Yield table developed by Korstian and Brush (1931). Yield of well-stocked, even-aged stands of Atlantic white-cedar trees 8 inches or greater in diameter, in board feet, International (1/8 inch) log rule, by age and site index. Stump height = 1 foot. Top diameter inside bark = 6 inches.
For ¼-inch saw kerf, deduct 9.5 percent.

	Site Index					
	20	**30**	**40**	**50**	**60**	**70**
Age (years)	**<u>Yield - Board Feet per acre</u>**					
20	-	-	-	-	-	120
25	-	-	-	-	255	1,000
30	-	-	-	205	1,060	3,440
35	-	-	105	710	2,660	8,320
40	-	40	405	1,540	5,910	15,300
45	-	165	910	3,000	10,700	23,000
50	25	350	1,620	5,500	16,600	30,300
55	105	650	2,530	8,800	22,300	37,000
60	200	1,000	3,900	12,100	27,500	42,900
65	305	1,400	5,450	15,300	31,900	48,200
70	420	1,950	7,050	18,400	35,700	53,100
75	545	2,550	8,750	21,500	39,300	57,300
80	685	3,250	10,500	24,300	42,700	60,800
85	840	4,050	12,300	27,000	46,000	63,900
90	1,000	4,850	14,100	29,500	49,000	66,700
95	1,170	5,700	15,900	32,000	51,700	69,300
100	1,350	6,550	17,800	34,400	54,200	71,500

Table 5. *Yield table developed by Korstian and Brush (1931). Yield of well-stocked, even-aged stands of Atlantic white-cedar trees 5 inches or greater in diameter, in cords per acre. Volume includes stem and bark between 1 foot stump and an inside bark top diameter of 4 inches.*

Age (years)	**Site Index**					
	20	**30**	**40**	**50**	**60**	**70**
	Yield of wood and bark - cords per acre					
20	-	-	-	-	1.4	5.9
25	-	-	-	2.8	8.9	18.7
30	-	-	2.4	8.9	19.2	33.2
35	-	1.2	6.7	16.0	31.0	48.0
40	-	3.9	11.8	24.0	43.5	61.8
45	1.0	6.9	17.5	32.7	55.3	73.2
50	2.6	10.2	23.6	41.8	65.1	82.7
55	4.1	13.9	29.4	50.5	73.0	90.7
60	5.6	17.3	34.9	58.1	79.5	97.5
65	7.1	20.6	40.0	64.4	85.2	103.8
70	8.5	23.7	44.6	69.5	90.2	109.5
75	9.8	26.7	48.8	73.8	94.5	114.4
80	11.0	29.5	52.8	77.4	98.5	118.7
85	12.2	32.2	56.1	80.5	101.9	122.4
90	13.3	34.4	59.1	83.2	105.0	125.6
95	14.3	36.5	61.6	85.6	108.0	128.7
100	15.1	38.2	63.8	87.8	110.7	131.5

Susceptibility to injury

Fire

- White-cedar is very susceptible to fire at all ages. Even a light fire is sufficient to kill the cambium, girdling and killing the trees. Fire scars on living trees are uncommon because most trees subjected to fire are killed (Korstian and Brush 1931).

- Fire can have either a beneficial or detrimental effect on Atlantic white-cedar stand dynamics. The type of effect depends on several factors (Little 1964), including:

    - composition of the original stand
    - amounts of viable seed of each species stored in the forest floor
    - composition of adjacent stand
    - depth to which the fire burns in the forest floor
    - position of the water table relative to the substrate after the burn

- In most swamps, the peat is so wet and the air within the forest so humid that fires seldom sweep through except during unusually dry seasons or when an unusually hot fire is driven by a strong wind. However, cedar trees on the edges of stands are very susceptible to fire, and are frequently killed by fires that originate in the surrounding uplands (Gifford 1896, Vermeule 1900). In dry years, when the peat becomes thoroughly dry, fires sometimes spread to cedar swamps and cause severe damage (Korstian and Brush 1931). Windisch (1987) found that the majority of fires recorded in the Pine Plains of New Jersey over the last 50 years have breached the lowlands they encountered. This is particularly true of narrow lowlands impacted by headfires oriented nearly perpendicular to them.

- If a large percentage of hardwoods and shrubs were present before the fire, and their dormant buds below the forest floor were not killed, hardwood and shrubs may dominate the resulting stand (Little 1964). In recent years, animal damage from deer and rabbits has frequently prevented white-cedar from becoming reestablished on sites following wildfire (Little 1964).

- Although relatively rare, wildfires in very dry periods may consume sufficient amounts of peat, destroying the hummocks and leaving no substrate above the water table suitable for Atlantic white-cedar germination. Such sites are commonly replaced by leatherleaf (*Chamaedaphne calyculata*). The invasion of white-cedar or hardwood into these areas depend on the accumulation of sufficient sphagnum so that seedling survival is possible (Little 1964).

- The most disastrous fires may be those which burn in slash a few years after logging, killing large areas of young growth (Korstian and Brush 1931).

Figure 22. (left) A fire burned the soil and root systems in this Atlantic white-cedar stand. This type of fire can greatly reduce the ability of cedar to regenerate. Photo by George Pierson.

Figure 23. (right) A 1999 wildfire killed a significant portion of cedar at this regenerating site in Bass River State Forest. Photo by George Zimmermann.

Wind

- Atlantic white-cedar has a shallow root system and a weak hold in the swamp peat. Therefore, mature white-cedars are susceptible to windthrow from severe winds. Trees grown in dense stands never become windfirm and are especially susceptible when the stand is opened for some reason. Trees that have grown in exposed areas along swamp margins are usually more windfirm (Korstian and Brush 1931).

Insects and disease

- Atlantic white-cedar has very few serious insect enemies (Korstian and Brush 1931).

- There are also few fungi that attack white-cedar, and their damage is not usually serious (Little 1959). According to the U.S. National Fungal Database maintained by the USDA, there are over 80 fungi specifically associated with Atlantic white-cedar (Farr et al. 1989). Some of the more important fungi are discussed below:

  - White-cedar seedlings are not particularly prone to damping-off. Juniper blight, *Phomopsis spp.*, is common in nurseries but not on natural regeneration (Hepting 1971).

  - A foliage disease common in southern New Jersey is caused by *Didymascella chamaecyparidis*. The disease causes the lower leaves to turn brown then gray. Korstian and Brush (1931) considered this disease to be "extremely parasitic" and "extremely destructive" to foliage of seedlings and young trees.

  - Rust galls on leaves of cedar from Maine to Georgia are caused by *Gymnosporangium fraternum*.

  - Throughout cedar's range, spindle shaped stem and branch swellings are caused by *Gymnosporangium biseptatum*.

  - A witches broom effect caused by *Gymnosporangium ellisii* can be found on cedar throughout its natural range.

  - The heartwood of white-cedar, though highly resistant to decay, can be compromised by *Fomitopsis cajanderi* (also referred to as *Fomes cajanderi, Fomes subroseus*, or *Trametes subrosea*). This fungus is usually found on trees older than 40 years of age and in the southern part of cedar's range.

Animal Damage

- Atlantic white-cedar is a preferred winter browse of the white-tailed deer (Little et al. 1958, Little and Somes 1965). During the winter months, deer are concentrated on a small percentage of their range (Burke 1998, personal communication). In southern New Jersey, wintering area surveys indicated that lowland sites are utilized by deer during periods of severe winter weather, with Atlantic white-cedar swamps the preferred habitat (Burke 1979). Therefore, even low populations can have a significant impact on young Atlantic white-cedar during these times.

- Other animals, such as rabbits and small rodents, may also cause localized browse damage to white-cedar seedlings (Little 1950), depending on local populations.

- Beaver dams downstream from cedar stands may flood and kill the cedars (Little 1950).

Freshwater inundation

- Observations in New Jersey suggest that brief periods of flooding, where water levels are raised about 1 foot, as when the impounded water in an upstream cranberry bog is released, do not cause any apparent damage to white-cedar and hardwood stands. However, prolonged flooding may cause mortality. Flood damage to Atlantic white-cedar reproduction may be heavy, especially those trees with their crowns partially or completely submerged (Little 1950).

Figure 24. (left) This cedar tree is infected with a parasitic fungus Gymnosporangium sp., causing a large burl to form on the trunk.

Figure 25. (right) Planted Atlantic white-cedar rooted cutting, showing the effects of deer browsing.

Photos by Kristin Mylecraine

Figure 26. (Left) Aerial view of a flooded stand of Atlantic white-cedar. Photo by George Zimmermann.

Figure 27. (right) Submerged Atlantic white-cedar planted rooted cutting. Photo by Kristin Mylecraine.

Salt water

- Atlantic white-cedar is not tolerant of salt water. Major storms may drive saltwater inland as either spray carried by the wind or inundation by storm waves or tides. Salt water can kill white-cedar stands, although the damage to forests may vary with the duration of the flooding. In addition, rising sea level may threaten many coastal cedar stands (Little 1950).

Vegetative reproduction

- When seedlings or saplings are injured, Atlantic white-cedar may develop shoots from lateral branches or dormant buds (Little 1950), although the growth of these shoots is slow (Little 1959). Seedlings that survive repeated browsing by deer may develop into multiple stems through layering (Little 1950). However, mature cedar does not stump sprout after it has been cut.

- Atlantic white-cedar propagates well from cuttings. High rooting success rates have been achieved using rooting hormones, mist and bottom heat (Boyle and Kuser 1994, Hinesley et al. 1994). It is also possible to root cuttings in containers outdoors (Hinesley and Snelling 1997).

The role of disturbance

Successional stage

- The successional stage of Atlantic white-cedar has been the subject of debate (Buell and Cain 1943, Little 1950, Hickman and Neuhauser 1978, Motzkin et al. 1993, Zampella and Lathrop 1997, Zampella et al. 1999).

- White-cedar has often been considered a subclimax species that will gradually be replaced by hardwoods in the absence of disturbance. One of many scenarios described by Little (1950) is the gradual replacement of dying overstory cedar trees by the more shade tolerant hardwood understory. This type of hardwood replacement of cedar may take centuries. In one stand in North Carolina, Buell and Cain (1943) found that the establishment of hardwoods was apparently favored by the maturation of the overstory, and suggested that without fire or other clearing agent the "…cedar forest will give way to the natural course of succession to the bog climax…"

    - This view indicates that some type of disturbance, either natural or through harvesting, may be necessary to perpetuate the white-cedar forest type.

    - To dispute this, Stoltzfus (1990) examined 18 cedar stands in the Pinelands, and concluded that seedling and sapling densities were not great enough to suggest a transition from cedar to red maple in these stands. Zampella and Lathrop (1997) examined aerial photos and found that hardwood invasion of undisturbed swamps has not been as common in the Mullica River basin over the last 61 years. In a related field study, Zampella and others (1999) examined size-class structure of mature cedar stands. Although they found an increasing contribution of red maple in relation to increasing cedar size-class structure, they concluded that "hardwood replacement of cedar in swamps is not a certain outcome of cedar swamp succession". However, the time scale examined may not be sufficient to observe the gradual replacement described by Little.

- Another view is that neither cedar nor red maple successfully become established under mature cedar stands and only after a disturbance is a mature stand replaced by either another stand of cedar or hardwoods. This view indicates that existing cedar swamps are not in danger of domination by red maple, or other hardwoods, unless some type of disturbance (blowdown, fire, etc.) occurs. Such a disturbance would create conditions favorable to both cedar and red maple. The end result may be the replacement of cedar by either maple or another cedar stand.

    - In a cedar swamp on Cape Cod, Massachusetts, Motzkin and others (1993) found that the establishment of both cedar and red maple is episodic rather than continuous. Neither cedar nor maple were found to successfully establish beneath closed canopies. In addition, maple was not found in all-aged populations as would be expected from Little's gradual replacement explanation.

    - Similarly, Hickman and Neuhauser (1978) found neither cedar nor maples to be successfully reproducing under mature cedar stands in Lebanon State Forest, New Jersey. Stoltzfus and Good (1998) suggest that either cedar or maple may become established within gaps and eventually replace the dominant individuals as they die. The development of community structure within the gap would be determined by a combination of factors, including cedar and maple seed sources, shrub layer thickness, water table level, deer browsing, and gap size.

- The dynamics of cedar stands and their successional role may encompass all views and be a complex matter involving the interaction of a number of factors.

Types of disturbance

Fire

- Fire has been an important disturbance controlling cedar stand dynamics. Under the right conditions, fire can help perpetuate white-cedar. A fire that burns through the crowns, but consumes little of the forest floor, will kill the mature cedar trees, but may provide the conditions needed for cedar regeneration, if adequate cedar seed was stored in the soil (Little 1959). Frost (1995) suggests that only fire could be "expected to remove enough biomass to expose the open seed bed required for the dense monospecific regeneration characteristic of white cedar, and only fire can clear additional area for expansion of a cedar stand into adjacent communities of other types."

- Although there are no quantitative data on the role of fire in southern white-cedar stands, Frost (1995) suggests that the lower extreme of the fire-return interval gradient may have been 250-300 years in the Carolinas, more commonly with a return interval of 25 to 100 years. In a cedar swamp on Cape

Cod, fires occurred at 100 - 200 year intervals prior to European settlement. These fires were usually followed by regeneration of a new stand (Motzkin et al. 1993). Fire has been especially important within the Pine Barrens region. In this region, the combination of dry soils, periodic droughts, high winds, and fuel conditions favor the occurrence of fire (Little 1979b, Forman and Boerner 1981). Zimmermann and others (1999) found charcoal in a majority of peat core sections from Penn Swamp, in Wharton State Forest, New Jersey.

❖ In recent years, the importance of fire has declined due to changing fire frequencies, and an increase in development and fire suppression.

Harvesting

❖ Historically, timber harvesting has been an important disturbance in New Jersey. In recent decades, timber harvesting may have replaced fire as the dominant disturbance. Within the Mullica River basin, timber harvesting has been the major disturbance over the past 61 years. In this area, cutting was most intense prior to 1930, declined during the following decade, and increased from 1941-1961. Signs of harvesting, visible on aerial photographs of the area, have declined dramatically after 1961 (Zampella and Lathrop 1997).

Windthrow

❖ Windthrow, from high winds and storms, often creates gaps within Atlantic white-cedar stands. Atlantic white-cedar trees are especially susceptible to windthrow when a stand is opened up from a disturbance.

Figure 28. Extensive windthrow within an Atlantic white-cedar stand. Photo by George Pierson.

Flooding

- In the past, extensive windthrow may have clogged drainage channels and raised water levels, killing all vegetation and the open sites subsequently created after flooding subsided may have been favorable for the establishment of pure white-cedar stands. Similar conditions may be created following beaver flooding and subsequent abandonment (Little 1950).

Genetic variation

- The western Florida (panhandle) population of Atlantic white-cedar has been considered a separate species, *Chamaecyparis henryae* (Li 1962), but is usually referred to as a subspecies of Atlantic white-cedar, *Chamaecyparis thyoides* var. *henryae* (Little 1966, 1979, Ward and Clewell 1989).

- Haas and Kuser (1999) have found that North Carolina cedar cuttings can survive in the climate of New Jersey, and conclude that there may "not be a large origin-dependent component to the field performance of Atlantic white-cedar". However, Summerville and others (in press) examined height growth and survival among different parent trees, stands and broad soil/site types in eastern North Carolina, and found significant variation, indicating the possibility for selection opportunity.

- Eckert (1998) and Kuser et al. (1997) have examined allozyme variation (a measure of genetic diversity) within and among population of Atlantic white-cedar in New Hampshire, southern Maine (Eckert 1998), New Jersey, and North Carolina (Kuser et al. 1997). Kuser et al. (1997) found the majority of allozyme variation within populations, with only nine percent of the total variation among populations. The largest values for heterozygosity were found in Lebanon State Forest, New Jersey. The isolated stand at High Point, New Jersey was genetically depauperate. This may indicate that the High Point stand was formed from one or a small number of cedar individuals that reached this isolated site. They also found a lack of correlation between geographic and genetic distances among New Jersey and North Carolina populations, indicating that Atlantic white-cedar may have had a means of long distance dispersal following the last ice age to reach its current range.

IV. Current Situation

Reasons for Atlantic white-cedar decline

- Several factors, as well as interactions among them, have led to the decline of Atlantic white-cedar. Some of the most important factors are described below, although the relative contributions of these factors to the decline are not known.

White-tailed deer population

- In New Jersey, the population of white-tailed deer was reduced to only a few family groups in 1902, due to the lack of hunting restrictions and ineffective law enforcement. This was followed by a period of restocking, during which new deer were introduced into the state. By 1935, the deer population in southern New Jersey had reached carrying capacity, due to these restocking efforts, effective legislation, and law enforcement. By 1972, the entire state supported a deer herd either at or in excess of carrying capacity (Howard 1972).

- This increase in deer population has had a significant impact on Atlantic white-cedar. In many areas, cedar fails to regenerate and form new stands following a disturbance because of excessive deer browsing (Little and Somes 1965, Zimmermann 1997). Kuser and Zimmermann (1995) suggest that this is the prime reason cedar fails to regenerate in New Jersey today. Several plantings in North Carolina have also failed because of deer browsing (Phillips et al*.* 1998).

Wildfire

- Frost (1987) identifies fire suppression as a factor in the decline of cedar, by eliminating the opportunity for cedar to invade patches occupied by other species. Forman and Boerner (1981) suggest that the recent decline in point fire frequency (the frequency at which an average point burns) in the NJ Pine Barrens will lead to the replacement of cedar swamps by hardwoods.

- However, in many cases, wildfires have caused the succession from white-cedar to hardwoods or shrubs. In recent years, animal damage from deer and rabbits has often prevented the reestablishment of Atlantic white-cedar following wildfire (Little 1964). For example, a large fire in 1977 burned 59.8 ha. of cedar patches within one of the largest cedar complexes in the Pinelands. Portions of this area were subsequently harvested as part of a salvage cut. By 1991, most of this area was dominated by shrub and emergent cover. Cedar regenerated only in one 4.5 ha. patch (Zampella and Lathrop 1997).

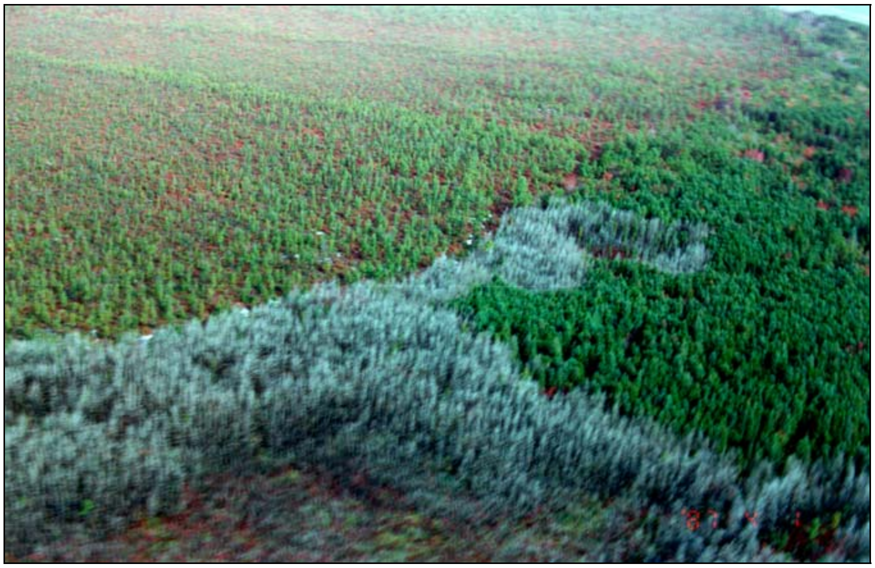


Figure 29. *Atlantic white-cedar stand in Ocean County, New Jersey partially killed by wildfire. Photo by Robert R. Williams.*

Harvesting procedures

- If a harvest is conducted properly and proper post-harvest management techniques are employed, harvesting can help to perpetuate the Atlantic white-cedar forest type. However, the primary objective of most harvesting operations in the past has been related to economic gain, rather than regeneration of the stand. As a result, past management techniques have often led to the conversion to other wetland types.

    - **Selective logging:** In most cases, selective logging of only white-cedar was employed, leaving many larger stems of undesirable species, and occasional cedars of low value and low genetic potential. The undesirable trees not only provide a source of undesirable seed, but also provide shade that may favor hardwood reproduction over white-cedar (Little 1950). In many cases, the result has been the replacement of cedar by hardwoods (Harshberger 1916, Little 1950).

    - **Failure to regenerate:** The failure of stands to regenerate following a harvest has become an increasing problem in recent years. In the Mullica River basin, the majority of sites harvested prior to 1930 show a comparatively strong and vigorous recovery. However, harvests conducted after 1930 have generally resulted in a net loss of cedar, possibly because of an increase in deer pressure during this time (Zampella and Lathrop 1997).

    - **Lack of post-harvest management:** The lack of post-harvest management in the past has also promoted the conversion of white-cedar stands to other wetland types.

    - **Lack of competition control:** After a harvest, the rapid growth of hardwood sprouts may enable them to gain an initial advantage over cedar seedlings beginning from seed (Little 1950). Therefore, the lack of subsequent vegetation control has often led to the conversion to hardwoods. Alternatively, an association of tall shrubs may develop and prevent the formation of another white-cedar stand (Little 1950).

- **Lack of artificial regeneration:** Historically, if Atlantic white-cedar failed to regenerate naturally, artificial methods were not employed, resulting in the conversion to other stand types.

- **Lack of deer protection:** In recent times, severe deer browsing and the lack of protection from deer have prevented the regeneration of cedar following harvesting.

Conversion to agriculture

Figure 30. Standing dead Atlantic white-cedar in area flooded for cranberry production. Photo by George Zimmermann.

- A number of cedar swamps in New Jersey and Massachusetts have been converted to cranberry production. Some swamps have been converted to other agricultural uses, including blueberry production. In New Jersey, a number of attempts to clear, drain, and farm cedar swamps for other crops have been unsuccessful (Korstian and Brush 1931). Cedar swamps in other areas have also been drained for agriculture. Beginning in the 18th century, much of the Great Dismal Swamp and the land along the Alligator River in North Carolina was drained for agriculture (Frost 1995).

Development

- Cedar swamps have been filled for development and/or cleared and converted to lagoon developments.

- Suburbanization adjacent to Atlantic white-cedar swamps may have substantial impacts on the plant community and physical environment of Atlantic white-cedar swamps in the New Jersey Pinelands. A large influx of non-native and upland Pinelands species was found in runoff sites, located at stormwater sewer outfalls within suburban developments. Suburbanization was also associated with changes in vegetation structure, water chemistry and quantity, and was found to affect reproduction (Schneider and Ehrenfeld 1987, Ehrenfeld and Schneider 1990, 1991).

- Cedar swamps located more distant from suburbanization and agricultural land use disturbances appear to be buffered from the impact of these disturbances (Laidig and Zampella 1999).

Hydrologic change

- In the Great Dismal Swamp of North Carolina, ditches have lowered the water table, adversely affected the establishment and growth of white-cedar seedlings, and increased the fire risk (Akerman 1923). After 1856, the steam dredge was widely used in North Carolina to drain wetlands for logging. Legislation facilitating the use of public funds for drainage of privately owned wetlands initiated major wetland exploitation in this state (Frost 1987). Drainage systems have also affected cedar swamps in other parts of the species range (Karlin 1997).

- In the Mullica River basin, mortality due to flooding has been observed near tidal portions of the Mullica River (Zampella and Lathrop 1997).

Beaver

- Some cedar stands have been lost due to excessive flooding from beaver dams. Beaver had been extirpated in the Pinelands during the 19th century, but was reintroduced and became reestablished in the region in the 1930's (Applegate, et al. 1979). Some areas of Bass River and Lebanon State Forests have suffered mortality due to beaver activity. Zampella and Lathrop (1997) noticed flooding in several abandoned cranberry bog areas, at which beaver activity was also noted.

Roads

- Throughout cedar's range, extensive stands have been flooded or drained by the creation of roads. On the other hand, increased light and heat immediately adjacent to road cuts may favor the germination and rapid growth of cedar seedlings (Laderman 1989).

Lakes

- There are few natural lakes in southern New Jersey. Most lakes in this area are man-made and occupy the site of former wetlands. Many of these lakes were built to provide a head of water for industry, particularly the iron industry that flourished in south Jersey from 1700-1860 (Collins and Anderson 1994).

Theft

- Because of its high value, Atlantic white-cedar has been the target of illegal harvesting and theft. Typically, only the very biggest and best cedars are removed, and the site is not properly prepared for regeneration. Therefore, cedar usually fails to regenerate the area, hardwoods and shrubs are encouraged, and there is an increased risk of blowdown of the remaining trees (NJ Forest Service 1998).

Natural successional trends

- Little (1950) considers Atlantic white-cedar a subclimax species that will eventually be replaced by climax hardwood species. Therefore, some cedar stands may have been lost due to natural successional trends in the absence of disturbance.

Salt water

- Rising sea level over time may account for the loss of some coastal stands of Atlantic white-cedar. Salt water carried inland by storms may also cause mortality (Little 1950). Salinity may have been a factor in the elimination of cedar from a Secaucus marsh within the Hackensack tidal marsh area (Heusser 1949a).

Current concerns and issues

Protection of Atlantic white-cedar

- The increased public awareness of the ecological importance of wetlands, as well as the desire for cedar products, has led to increased protection of Atlantic white-cedar. Atlantic white-cedar wetlands are protected under federal and state wetland laws, including, but not limited to the following:

    - **Clean Water Act (1977): Section** 404 of the federal Clean Water Act prohibits the discharge of dredge or fill material into "navigable waters" without an Army Corps of Engineers permit.

    - **New Jersey Freshwater Wetlands Protection Act (1987) (NJSA 13:9B-1 et seq.):** New Jersey state law with the intent to "…preserve the purity and integrity of freshwater wetlands from random, unnecessary or undesirable alteration or disturbance…" (NJSA 13:9B-2).

- There are several additional programs and regulations in New Jersey that provide for the protection and sustainability of cedar wetlands.

    - The Comprehensive Management Plan developed by the New Jersey Pinelands Commission (1980), protects wetlands in this region through a regional land allocation program, a land acquisition program, and a wetlands management plan. Under the wetlands management plan, most development within wetland boundaries is prohibited and an upland buffer to the wetland is required (Zampella and Roman 1983). The Comprehensive Management Plan also presents guidelines for the harvesting and management of Atlantic white-cedar (NJ Pinelands Commission 1980, 1996).

    - The New Jersey Forest Service also reviews forest management and harvesting plans to ensure that proper management practices are employed.

    - In 1995, the New Jersey Forest Service formed an Atlantic white-cedar steering committee, known as the Atlantic white-cedar Initiative, with several goals and objectives related to cedar management, restoration, research, and sustainability (NJ Forest Service 1997). There is also a rangewide Atlantic white-cedar Alliance which intends to protect, manage and restore cedar throughout its entire range, with special emphasis on southern US stands.

Benefits of management

- Atlantic white-cedar represents a declining forest cover type important to maintaining biodiversity across the landscape. After a disturbance, several factors interact to shape vegetation development to cedar, hardwood, mixed hardwood-cedar, or open shrub/herbaceous wetlands (Roman et al. 1987). Disturbance may be required to perpetuate Atlantic white-cedar, yet disturbance often results in the conversion to other vegetation types. The general trend since European settlement has been toward conversion of cedar to other wetland types following disturbance (Roman et al. 1987). An Atlantic white-cedar management program can help to ensure the sustainability of Atlantic white-cedar following disturbance. Using proper management techniques, cedar can be utilized and successfully regenerated, ensuring the long-term sustainability of this species.

- Protection and proper management of Atlantic white-cedar will provide several benefits, including:

    - a sustainable source of Atlantic white-cedar timber for a variety of wood products
    - habitat for plant and animal species associated with Atlantic white-cedar wetlands, including threatened and endangered species
    - areas for recreation and aesthetic quality
    - maintenance of diversity across the regional landscape

Management issues

- In order to provide the benefits listed above, the following management issues should be considered:

    1. Ensure the long-term maintenance of existing Atlantic white-cedar stands through the regeneration of harvested or disturbed stands.

    2. Prevent further fragmentation of present stands through the use of proper management techniques.

    3. Increase the current acreage occupied by Atlantic white-cedar.

        - Restore Atlantic white-cedar to areas that are capable of supporting cedar and may have contained cedar in the past.
        - Where stands have become fragmented, promote the development of larger stands by merging adjacent stands.
        - Encourage peripheral expansion of existing stands.
        - Increase the percentage of cedar in existing stands.

    4. Manage for stands of diverse age and size classes to provide a variety of habitat types.

    5. Through research, increase the current knowledge about the requirements of Atlantic white-cedar and determine the best techniques for regenerating and restoring cedar.

V. Management Plan Development

Use of professional help

- A management plan for Atlantic white-cedar should be developed with the help of a professional forestry consultant. A forester should be consulted during all phases of Atlantic white-cedar management. When planning a harvest, a forester can provide the necessary expertise to guide a landowner through the permit and harvest process. A list of approved foresters is maintained by the New Jersey Forest Service, and is available upon request.

Management objectives

- The objectives of all cedar management plans should be discussed by the landowner and a professional forester, and should be clearly stated in the management plan. When harvesting cedar, these objectives may include one or more of the following:

    - **Regeneration of the stand**: Harvests should be done in a manner to ensure adequate reproduction of Atlantic white-cedar.

    - **Sustainability**: If conducted properly, a harvesting plan can help to ensure the perpetuation of the Atlantic white-cedar forest type.

    - **Economics and the production of wood products:** Individual stands may be managed specifically for the production of desired products.

    - **Wildlife habitat:** Cedar stands may be managed for specific wildlife species. Foe example, a diverse mixture of old growth, mature, intermediate "pole" size and regeneration areas will maximize wildlife habitat (Laderman 1989). This vertical stratification is especially beneficial to avifauna (Anderson 1979).

    - **Maintenance of diversity across the landscape:** Atlantic white-cedar swamps are a unique environment, and help to maintain diversity across the regional landscape.

    - **Restoration:** Stands containing a low percentage of Atlantic white-cedar can be harvested with the intent to increase the proportion of cedar in the next stand through proper regeneration methods.

    - **Conversion:** On sites that are capable of supporting cedar, other wetland forest types (swamp hardwoods, pitch pine lowlands) may be harvested with the intent to convert the stand to Atlantic white-cedar. This requires the introduction of cedar through artificial methods and will be discussed in a later section.

- **Salvage:** Salvage operations, following damage from fire, flooding, or wind not only provide economic benefit, but may create conditions favorable for regeneration, depending on the degree of damage to the site.

Required permits

- **Local permits (Municipality):** All forestry activities may be subject to local permitting procedures specific to each municipality. This is true for all municipalities within the Pinelands and may or not be true outside of this region.

- **NJ Pinelands Commission:** The majority of Atlantic white-cedar in New Jersey is located within the New Jersey Pinelands. Forestry activities in this area require the filing of an application to the NJ Pinelands Commission. Application requirements can be found in the New Jersey Pinelands Comprehensive Management Plan and its supplements (NJ Pinelands Commission 1980, 1996). Land that has an approved New Jersey Forest Stewardship plan under the current regulations does not require the filing of an application to the Commission, but remains subject to local permitting procedures.

- **Freshwater Wetlands Protection Act (1987):** The Freshwater Wetlands Protection Act regulates all forestry activities within forested wetlands and transitional areas. Woodland owners implementing normal harvesting of forest products, in accordance with a forest management plan approved by the State Forester (NJDEP, Division of Parks and Forestry, New Jersey Forest Service) are not required to obtain a wetland permit to work in forested wetlands. The management plan and/or harvest plan must be submitted to a Regional Forester of the NJ Forest Service and a site inspection is made. (NJ Bureau of Forest Management 1995).

VI. Silviculture & Best Management Practices

The harvest

General harvest guidelines

- **Harvest method:** Atlantic white-cedar requires relatively open conditions for adequate establishment. Therefore, stands should be managed in even-aged tracts by clearcutting (Korstian and Brush 1931, Little 1950, Pinelands Commission 1980). This is usually done either in patches or strips, the size of which depends on the swamp size, existing vegetation and adjacent stand composition.

Figure 31. Atlantic white-cedar clearcut in progress at Penn Swamp, Wharton State Forest, New Jersey, 1990. Photo by George Zimmermann.

- **Management Unit:** When developing a management strategy, the entire swamp should be considered as part of the larger landscape whenever possible. Each swamp may consist of many individual stands of different size and age classes, and may be under different ownership.

- **Regeneration:** The primary objective of any harvesting operation should be the regeneration of the stand. Successful regeneration of an existing stand is influenced by several factors, including the following (Zampella 1987, Laderman 1989):

    - size, shape and orientation of the cut
    - size, shape, age, condition, and species composition of the previous stand
    - hydrology of the site
    - adjacent forest type
    - white-tailed deer population

  If natural regeneration is not successful following a harvest, artificial regeneration methods should be employed. Regeneration is discussed in greater detail in the next section.

Figure 32. Atlantic white-cedar harvest in Atlantic county, New Jersey. Photo by Robert R. Williams.

Harvest size

- There have been many conflicting statements regarding the appropriate harvest size for Atlantic white-cedar. The size of any harvest should be discussed with a professional forester, and should promote regeneration of the stand. The final decision should be made jointly by the landowner and forester and must be clearly stated in the management and/or harvesting plan. The harvesting plan is reviewed by the NJ Forest Service to ensure the harvest size chosen is appropriate. Factors that should be considered in determining harvest size include the following:

    - Landowner objectives
    - Economics
    - Size, shape, age, condition, and species composition of the previous stand
    - Adjacent forest type
    - Susceptibility of adjacent stand to windthrow
    - Soil type and hydrology of the site
    - Equipment available
    - Access

Design of harvest

- The design of an individual harvest should help to promote regeneration of the stand, and depends on the same factors stated above for harvest size. The harvest design should be clearly stated in the management plan and is reviewed by the NJ Forest Service to ensure feasibility. Several suggestions have been made by various authors, some of which are presented in this section. Because of the large amount of variability among different cedar stands, these harvest designs may not be applicable for every stand, and the variety of possible harvest designs are not limited to those described here. The design of an individual harvest should be discussed and determined by a professional forester.

Complete Clearcuts

- For relatively small properties, particularly less than 5 or 6 acres, Little (1950) suggests a complete clearcut of the property, as long as pole or mature white-cedars form the adjacent stand or appropriate measures are taken to ensure regeneration.

- Larger areas may also be harvested using a complete clearcut, if determined feasible by a consulting forester and appropriate measures are taken to ensure adequate regeneration.

- Complete clearcuts result in a temporary modification of habitat, which will benefit some species of flora and fauna and may have detrimental effects on others.

Strip clearcuts

- For larger areas, one method that has been recommended is a system of strip cuttings (Korstian and Brush 1931, Little 1950).

- **Strip length:** In general, the length of the strips should be as short as possible because exposure and windthrow frequently cause losses in the surrounding stand.

- **Orientation:** To allow adequate seed dispersal into the cut, the strips should be oriented at approximately right angles to the direction of the wind (Korstian and Brush 1931). Because of the prevailing westerly winds during seed dispersal, strips should be oriented from north to south and progress from east to west, or southeast to northwest (Little 1950).

- **Strip width:** Korstian and Brush (1931) suggest that strips should be no more than 1,000 feet wide, leaving strips of uncut timber between the strips. Little (1950) suggests that the design of the strip cuts should depend on the percentage of cedar in the existing stand. He recommends the following:

Pure cedar stands

- For pure cedar stands and stands composed of 50% cedar or greater, strips should be ideally only 100-150 feet wide, although most strips 300-400 feet wide reproduce satisfactorily. Wider strips may be understocked in the center. The amount of seed stored in the peat, supplemented by outside seed sources, should allow the resulting stand to be formed largely of white-cedar.

- Adjoining seed sources to the west should not be removed until adequate reproduction one to three feet tall is established.

Mixed stands

- For swamps containing 25% to 50% cedar, clearcut strips should be only 100-200 feet wide and the edge should be composed of as many white-cedars as possible.

- For swamps containing less than 25% cedar, at least 10-20 white-cedars with healthy crowns should be left per acre because of the small amount of seed stored in the peat. Some of the residual trees may be overthrown by wind, but sufficient numbers should survive for a long enough period to furnish the desired seed. If seed trees are to be removed, it should be done after the cedar reproduction reaches one to three feet tall. This type of stand may be considered a case for restoration, which is covered under the next section.

- During the harvest, all hardwoods should be removed along with the white-cedar. Additional cleaning of hardwood sprouts may be necessary.

Special Considerations

Timing of Harvest

Time of year

- Whenever possible, harvesting of cedar and cedar/hardwood stands should occur either during dry periods of the year or when the ground is frozen (NJ Pinelands Commission 1980, 1996).

Rotation length

- There are several factors to be considered in determining the rotation length (the number of years between the establishment of the stand and the time it is harvested). These include:

  - **Size and kind of material desired:** According to Laderman (1989) Atlantic white-cedar reaches merchantable age in 50-70 years. Korstian and Brush (1931) suggest a rotation of 40 -50 years for the production of cordwood, and 60 - 80 years for sawtimber. For other products, such as poles, the stand may be harvested earlier.

  - **Regeneration of the stand:** The amount of reproduction may be significantly affected for stands harvested at 30 years or younger (Little 1950). If younger stands are cut, additional methods (artificial regeneration) may be required to supplement natural regeneration.

  - **Other management objectives:** Wildlife habitat for specific species, etc.

- The Atlantic white-cedar Steering Committee outlines three general rotation options, depending on the management objectives (modified from NJ Forest Service 1998):

  - **Standard Rotation:** This option should be used when managing for a specific product. Stands are maintained for a predefined rotation. The rotation length will depend on the product size desired, regeneration potential, and stand integrity.

  - **Extended Rotation:** Under this option, stands should be managed beyond normal harvesting rotation, perhaps up to 100 years. This option should be used if wood products of larger diameter are desired, or when managing for particular wildlife species.

  - **Old Growth:** Old growth stands should be managed beyond 100 years. The production of wood products would be a secondary objective. This option may be desirable if managing for wildlife species requiring larger trees or more complex stand composition or stratification. These stands should be monitored for deterioration and the loss of regeneration potential.

Threatened and endangered species

- Atlantic white-cedar stands provide habitat for several threatened and endangered species. All forestry activities should be conducted to avoid irreversible adverse impacts on the survival of any populations of threatened or endangered species or their habitat. If a threatened or endangered species is found, the management plan should address the protection and enhancement of the species. Maintenance of the Atlantic white-cedar forest type will continue to provide habitat for threatened and endangered species that rely on this forest type.

- For current listings of federal and state threatened and endangered species, contact your local NJ Division of Fish, Game and Wildlife, Natural Lands Management, and the US Fish and Wildlife Service.

Condition of existing stand

- A dense canopy in the pre-harvest stand is preferable to an open canopy. A dense canopy suppresses the growth of a heavy shrub layer, which may interfere with white-cedar regeneration after the harvest thus requiring additional management (Zampella 1987, Laderman 1989).

Adjacent stand

- A cedar stand adjacent to a harvested area is preferable to any other forest type. This decreases the chance for invasion of competing species (Laderman 1989), and provides a source of cedar seed to supplement seed already stored in the soil. An adjacent stand of cedar to the West of the cut is especially beneficial because of the prevailing westerly winds at the time of seedfall (Little 1950).

- If the adjacent stand is not composed of white-cedar, one possible practice is to leave a band of cedar between the harvested area and adjacent forest type. This may help provide the necessary seed and prevent hardwood invasion. This band could later be removed when the regenerating cedar reaches 6ft. (Zampella 1987). Another alternative to this strategy is the use of seed trees.

Access roads

- During a harvest operation, roads that are not properly constructed can be a major source of erosion and degrade fish and wildlife habitats (NJ Bureau of Forest Management 1995). Permanent roads may be constructed to provide year round access to an area and facilitate fire protection. Temporary access roads can also be constructed for a specific harvesting operation. Some Best Management Practices for access roads are listed below. For additional information about access roads see Weist (1998), Environmental Protection Agency (1993), and NJ Bureau of Forest Management (1995).

    - Existing roads and trails should be followed whenever possible.

    - Roads should be as direct as possible.

    - The total number of roads, the miles or acres used in their construction, the size and number of landings, and the number of skid trail miles should be minimized.

- Roads should not affect the reach or flow of wetlands, and the number of watercourse crossings should be minimized.

- Fill roads should be avoided whenever possible in wetlands, and should be used only when no other practical alternative exists. An effective alternative is the use of corduroy roads. Whenever possible, corduroy roads should incorporate logging debris and slash from the site rather than sawmill waste. However, additional material may be brought to the site if needed.

- At the conclusion of any harvesting operation, all temporary access roads should be closed.

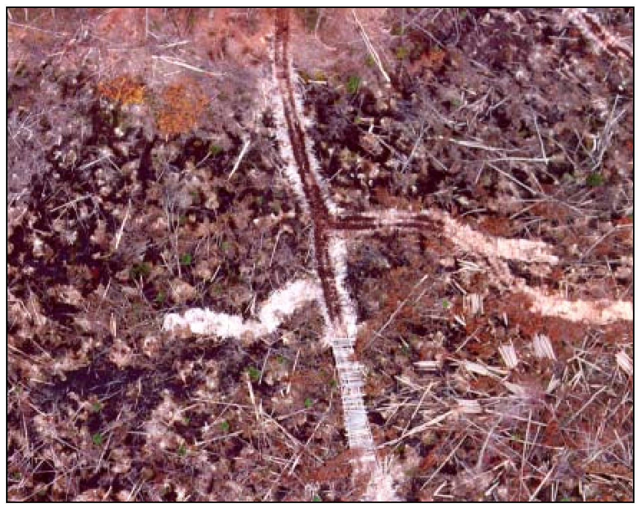


Figure 33. Aerial view of the Penn Swamp harvest in Wharton State Forest, New Jersey (1990), showing corduroy roads. Photo by George Zimmermann.

Figure 34. Close up view of a corduroy road. Photo by Robert R. Williams.

Protection of water resources

- Harvests should be conducted in a manner to protect water resources, including water recharge, discharge, and quality. All activities should be carried out so as to:

    - Minimize changes to surface and ground water hydrology
    - Minimize changes to temperature, water quality and surface water conditions
    - Prevent unnecessary soil erosion, siltation, and sedimentation
    - Minimize unnecessary disturbances to aquatic habitats.

Stream crossings

- A stream crossing is a point at which a forest road or skid trail comes in contact with a body of water. If not properly constructed stream crossings have the potential to adversely affect the quality of water resources through erosion. Whenever possible, cedar swamps should be harvested on one side of a stream at a time to avoid unnecessary stream crossings. However, if stream crossings are needed, the following best management practices should be followed (NJ Bureau of Forest Management 1995):

    - Stream crossings should be constructed at the narrowest section of the watercourse and should be perpendicular to the stream.

    - To minimize streambank erosion, an area with a gentle slope should be chosen. Stream banks should be stabilized at crossings. Seeding, hay or straw, riprap, filter fabric, or mulching can be used for this purpose.

    - Stream crossings should provide a stable bottom or surface that allows for equipment to cross intermittent or perennial streams without increasing stream sedimentation. Use culverts or bridges where an unstable stream bottom would be damaged. All temporary culverts and log crossings should be removed at the completion of the operation.

    - Stream crossings should not impede the flow of water.

    - Stream crossings should not disturb the spawning or migration movements of aquatic species.

Recommended harvesting equipment

- The type of equipment used for a particular harvest will depend on the size and design of the harvest, accessibility, age of the stand, soil type, hydrology of the site, and the cost and availability of the equipment. Equipment options should be discussed with a professional consulting forester.

- When harvesting in wetlands, low-ground pressure track machines should be used (NJ Bureau of Forest Management 1995). In New Jersey, the Pinelands Commission suggests utilizing "the least intrusive harvesting techniques", including the use of winches and helicopters when practical (NJ Pinelands Commission 1996).

- In North Carolina, where the majority of cedar is cut, an amphibious feller-buncher is commonly used. This machine is made specifically for harvesting cedar in wetlands. The standing tree is seized by the machine's tractor-mounted articulated arms, which shear it at the base and place the cut trees in parallel rows. Using a feller-buncher, a single operator can cut and lay 400 to 500 trees per day in stands of normal density, and as many as 800 trees per day in the densest stands. A skidder can then be used to seize six to eight trees and pull the trunks to the roadway (Laderman 1989). If available, this type of machine would be acceptable for use in New Jersey.

<u>Figure 35.</u> (Above left) Cedar harvest in Atlantic County, New Jersey.

<u>Figure 36.</u> (Above right) Tractor with flotation tires, used for logging wet cedar stands.

<u>Figure 37.</u> (Right) Traditional small tractor used for logging.

Photos by Robert R. Williams.

Regeneration

- Regeneration of Atlantic white-cedar should be the primary objective of any harvesting operation. Regeneration of Atlantic white-cedar following a harvest, or other disturbance, can be achieved through either:

  1. **Natural Regeneration:** from seed stored in the soil or from adjacent stands

  OR

  2. **Artificial Regeneration:** through either direct seeding or supplemental planting

- Whenever possible, natural regeneration is preferred over artificial methods. Artificial methods must be employed when the amount of natural regeneration is not sufficient, or if natural regeneration fails for some reason.

Natural regeneration

- Atlantic white-cedar seed for natural regeneration may come from a variety of sources:

  - **Seedbank**: Seed stored in the soil beneath a mature stand. The top inch of soil underneath a mature cedar stand usually contains one to four million viable white-cedar seeds per acre (Korstian and Brush 1931, Little 1950), which may be sufficient to restock the site.

  - **Adjacent stands**: Effective seeding from outside sources should be adequate to stock an area with several thousand seedlings per acre within 5 years. The distances at which large amounts of seed fall on a unit of area from an adjacent stand are not great. Natural regeneration from outside seed sources should be relied upon only within a distance equal to the height of the adjacent cedars when the cut is on the west side of a seed source. A distance equal to three times that height is needed when the cut is on the east side (Little 1950).

  - **Seed trees:** The use of seed trees is not usually preferred (Korstian and Brush 1931) because any seed trees left are very susceptible to windthrow. However, Little (1950) suggests that sufficient trees may survive for a long enough period to furnish the desired seed.

  - Given adequate seed source, natural regeneration can be successful on appropriate sites. However, most sites will require protection from deer and control of competing vegetation. Refer to later sections for more information on these topics.

Figure 38. *(left) First year Atlantic white-cedar natural regeneration. Photo by George Zimmermann.*

Figure 39. *(right) Natural regeneration of Atlantic white-cedar at a research site in Lebanon State Forest, New Jersey. Photo by John Kuser.*

Advantages of natural regeneration

1. Natural regeneration is comparatively inexpensive.
2. Technology (for greenhouse propagation) is not required.
3. Intrinsic genetic diversity of the stand is maintained.

Optimal conditions for natural regeneration (high probability sites)

- High probability sites are those with adequate moisture (hummock topography present), adequate viable buried seed, control of competing hardwoods, and adequate deer protection (Zimmermann 1997).

- The most likely sites are those with a large percentage of cedar present before the harvest or an adequate outside seed source.

- A continuous supply of moisture is critical for germination of white-cedar seed. The water supply cannot be too much or too little for seedling survival (Kuser and Zimmermann 1995). There is generally better reproduction in fairly dry swamps than in extremely wet ones (Pinchot 1899). However, drier sites can also be problematic (Little 1950, Zimmermann 1997). There is also a critical interaction between moisture and substrate for successful germination (Kuser and Zimmermann 1995).

Logging residues

- The effect of logging slash on the natural regeneration of Atlantic white-cedar has economic importance. The cost and time associated with site preparation may be reduced if adequate stocking can be achieved in the presence of slash.

- Several researchers have noted a negative effect of dense logging slash on the establishment of Atlantic white-cedar (Korstian 1924, Little 1950, Laderman 1989) and have suggested slash removal:

    1. Korstian and Brush (1931) suggest burning of slash the first winter following logging.

    2. Logging slash can also be incorporated into corduroy roads. This is preferable to transporting sawmill wastes to the site for access roads, which will only compound the slash problem (Zampella 1987).

    3. Little (1950) suggests that slash removal will not only benefit cedar regeneration, but will also decrease the risk of damaging fires.

- On the other hand, Cottrell (1929) reported that slash did not interfere with reproducing cedar in New Jersey. A recent study conducted by Zimmermann (1997) found a decrease in initial cedar germination as a result of slash, but for the second year and older cohorts no statistical difference in cedar density was found between slash and no slash treatments. Even under double slash, cedar densities may be adequate to stock the site, provided adequate protection from deer. These results indicate that slash removal may not be necessary to provide adequate regeneration.

- The effect of slash may be dependent on the size and species composition of the slash material, as well as its density. For this reason, Zimmermann (1997) suggests that another study of white-cedar response to slash loads is necessary.

Artificial regeneration

- If there is a lack of seed stored in the soil and an adequate seed source is not available, natural regeneration may not be sufficient to stock the site. If this is the case, or if natural regeneration fails for some reason, artificial methods should be employed. These methods include direct seeding or supplemental planting of seedlings or rooted cuttings.

Direct seeding

- Little (1965) suggested that white-cedar can be directly seeded with good initial success, using either collected seed or forest floor debris:

  1. **Collected seed**

     - Cones should be collected in the fall (October - December) during good seed crop years.
     - Seed can be extracted from the cones by drying, soaking overnight, and redrying (Harris 1974). Most seed can be removed after heating in an oven at 35-37°C until the cones open. The remaining seed may require soaking overnight and reheating (Boyle and Kuser 1994).
     - Seed can be sown either in the fall of the same year or the following spring. If the seed is not sown until the spring, it should be stored in a cool, moist medium to induce germination. A 30-day stratification on sphagnum at 4°C is recommended (Boyle and Kuser 1994).

  2. **Forest floor debris**

     - The storage of viable seed in the forest floor can be advantageous for direct seeding. The debris and moss from the upper portion of the forest floor under a mature cedar stand can be removed and used as a source of seed (Little 1965).

- Laderman (1989) suggests that seeding is preferred over planting in most circumstances. However, recent seeding success in New Jersey has been very variable, especially on dry sites (Zimmermann 1997). For this reason, Kuser and Zimmermann (1995) do not recommend direct seeding.

Advantages of direct seeding

1. Direct seeding is relatively inexpensive.
2. Technology is not required.
3. Genetic diversity is maintained.

Disadvantages of direct seeding

1. Seed viability is highly variable.
2. Seed crops vary among seedlots from different swamps and years.
3. Atlantic white-cedar seed commonly exhibits delayed germination.
4. Cone collection is often difficult and time consuming.

Supplemental planting

- Plantings can be either Atlantic white-cedar seedlings (germinated from seed), or stecklings (rooted cuttings). One advantage of planting over direct seeding is that seedlings may be planted successfully on drier sites, provided they are large and their roots dipped in an antidessicant before outplanting. Plantings also seem to be more reliable for cedar establishment on moderately moist sites (Zimmermann 1997).

- In New Jersey, the optimal planting season is thought to be April/May (Kuser and Zimmermann 1995). Seedlings or cuttings can also be planted in the fall with good survival rates.

Figure 40. Three year old planted Atlantic white-cedar rooted cutting. Photo by John Kuser.

Figure 41. Atlantic white-cedar rooted cuttings planted at a mitigation site in Lebanon State Forest, New Jersey. Photo by Robert R. Williams.

Seedlings versus cuttings

Advantages

Seedlings
- relatively inexpensive
- requires little technology
- promotes genetic diversity

Cuttings
- allows for the selection of desirable individuals
- can be produced quickly
- does not rely on variable seed crops and viability
- easy to collect

Disadvantages

Seedlings
- seed viability is highly variable
- delayed germination is common
- production is relatively slow

Cuttings
- may be more expensive to produce
- often requires additional technology (mistbed, bottom heat, etc.)
- genetic diversity may be reduced (if only a few trees are used to produce numerous cuttings)

- Both seedlings and cuttings appear to have potential for artificial regeneration (Phillips et al. 1998, Haas and Kuser, 1999), although seedlings may perform slightly better under field conditions (Phillips, et al. 1993, 1998). In one study, first year survival of both cuttings and seedlings under field conditions exceeded 95% in virtually all cases (Haas and Kuser 1999).

- Today, commercial production of Atlantic white-cedar is mostly through rooted cuttings. At one time, Weyerhaeuser Company, located in North Carolina, produced 280,000 rooted cuttings for commercial sale, in response to the high demand for use in wetland mitigation and restoration (Phillips et al. 1998). The New Jersey state nursery, located at the Forest Resource Education Center, in Jackson, produces rooted cuttings for use on state lands and for commercial sale.

Figure 42. (left) Atlantic white-cedar seedling.

Figure 43. (right) Atlantic white-cedar rooted cutting.

<u>Figure 44.</u> Atlantic white-cedar cuttings rooting in a mistbed at Rutgers University. Photo by John Kuser.

Fertilization

- A recent study has shown that fertilizer (Osmocote) and mulch treatments may greatly increase the growth of planted seedlings (Haas and Kuser 1999). This may be beneficial to managers because it will shorten the amount of time that the seedlings have to be actively managed, particularly with regard to protection from deer.

- More information is needed before the use of fertilizer becomes widespread for Atlantic white-cedar regeneration. One major concern is the effect the fertilizer may have on competing vegetation, as well as the intended cedar seedlings. The intended effect of fertilization may be countered by the negative effect of competition. The combined treatment of vegetative control and fertilization may further increase the growth of the intended species (Colbert, et al. 1990, Tiarks and Haywood 1986). However, if the costs and effort associated with additional vegetative control become excessive, the application of fertilizer may not be cost effective.

- Another concern is the effect of fertilization on water quality. The use of fertilization should be restricted to sites where surface or running water is not present, to reduce contamination risks.

Protection from deer

- In most areas, protection from deer is necessary for successful regeneration, both natural and artificial. In one study, no cedar grew to 1.3 m. without deer protection (Zimmermann, et al. 1999). Protection can be accomplished using electric or woven fences, chemical repellents, plastic mesh collars, or other retardants. Atlantic white-cedar must be protected until the regeneration reaches a height above the level of deer browsing.

- **Plastic mesh collars** have been effective for small plantations or for areas where rabbit clippings may be a problem (Kuser and Zimmermann 1995). However, they do not offer protection from small rodents which browsed collared cedar at one research site (Zimmermann 1997). One study in North Carolina found that tree shelters may cause physical injury and/or stunted growth in some cases (Phillips et al. 1998).

Figure 45. Plastic mesh deer collar used to protect Atlantic white-cedar plantings from browse. Photo by John Kuser.

- **Chemical deer repellents:** Hinder, a chemical deer repellent, has been used in some instances. However, this method requires frequent application during the growing season and after rains and therefore requires a lot of time and is expensive. This method was not found to be as effective as an electric fence (Zimmermann 1997). There may be other chemical deer repellents that are commercially available.

- **Food patches:** The use of food patches as a method to minimize deer browsing has not been employed widely in white-cedar management. Using this method, areas with an abundant food supply adjacent to cedar regeneration areas would be created to divert deer browsing away from the cedar. The effectiveness of this method for Atlantic white-cedar is not currently known. However, the NJ Division of Fish, Game, and Wildlife had a "diversionary food patch program" in the 1950's and 1960's, which was not successful in diverting deer from agricultural crops on experimental areas in the Pinelands (Burke 1998, personal communication).

- **Fencing:** Both woven and electric fences have been successful in minimizing the effect of deer browsing. Electric fences seem to be very successful and are more economically feasible (Zimmermann 1997). A five strand, solar powered electric fence is commonly used. When installing this type of fence, the following procedures should be followed:

  - Clear fence line of vegetation before installation.
  - Use five rows (minimum) of single strand high tensile wire.
  - Support corners with sunken poles.
  - On long lines, use spider poles or insulated stakes to provide support.
  - To maximize the effectiveness of the fence, use peanut butter or peanut oil on the wires in the late fall, to attract and train the deer. In addition, the charge may initially be put on fast cycle for several weeks.
  - Fence maintenance should include periodic monitoring of fence voltage and maintaining fence lines clear of vegetation.
  - The fence should not be removed until cedar saplings reach a height above the level of deer browsing (approx. 6 to 8 feet).

Figure 46. Five strand electric fence at Colletti research site, in Lebanon State Forest, New Jersey. Photo by George Zimmermann.

Figure 47. (left). *Woven fence at Penn Swamp, in Wharton State Forest, New Jersey. Photo by George Zimmermann.*

Figure 48. (right). *Aerial view of a research site in Lebanon State Forest, New Jersey, showing the effect of deer browsing and the importance of deer protection. The top portion shown in this photo is enclosed by an electric fence, while the bottom portion (control) is not. Photo by George Zimmermann.*

Control of competing vegetation

- Atlantic white-cedar regeneration, whether natural or artificial, can be hindered by competing vegetation (Korstian and Brush 1931, Moore 1996). Therefore some type of vegetation control is often necessary (Moore 1996). Initial vegetation control can be accomplished using one of the following techniques:

  - **Manual removal**: Manual removal of competing vegetation using hand tools is time consuming and therefore not practical in most cases.

  - **Mechanical site preparation:** Competing vegetation can be removed by mechanical means, such as drum chopping or brush hogging the site.

<u>Figure 49.</u> Drum chopper, used for mechanical site preparation. Photo by New Jersey Forest Service.

- **Burning:** Korstian and Brush (1931) suggest that slash fires, conducted under wet conditions following a harvest, reduce the dense growth of shrubs and hardwood competition. Moore (1996) also found that a light, surface burn applied in the winter following the harvest is a practical method for controlling the sprouting of competing vegetation and promoting white-cedar regeneration.

- **Herbicide**: Herbicide can be applied from the ground using backpack sprayers or aerially from a helicopter. Backpack sprayers are sufficient for relatively small areas. This method can be time consuming, but has the advantage of being able to target the spray. For larger areas aerially spraying may be more practical. Label instructions and application rates should be strictly adhered to at all times. Some examples of wetlands approved herbicides that may be used in New Jersey are Arsenal Applicators Concentrate, Rodeo, and Accord.

    - Arsenal Applicators Concentrate, a wetlands approved herbicide, is commonly used because it provides adequate control over competing species such as red maple, with little or no obvious negative effects on cedar populations (Kuser and Zimmermann 1995, Moore 1996, Zimmermann 1997). Arsenal is not labeled for use when standing water is present. For Atlantic white-cedar release, 12 to 16 oz. per acre should be applied after July 15 and before hardwood defoliation in the fall (American Cyanamid Company 1995).

- Rodeo is labeled for use when standing water is present (Monsanto Company 1997a). In the past, Rodeo has resulted in cedar seedling browning and/or mortality, therefore much care should be taken. This herbicide may not be as effective in controlling red maple.

- Accord is labeled for forestry site preparation, and forestry conifer and hardwood release, and can be used in and around standing water (Monsanto Company 1997b).

- **Burning + Herbicide:** The combination of burning (during the winter following the harvest) and herbicide (applied at the end of the summer following the harvest and burn) may further reduce vegetative cover (Moore 1996).

Table 6. Comparison of wetlands approved herbicides that may be used for Atlantic white-cedar site preparation and release.

Herbicide	**Manufacturer**	**Use with Standing Water**	**Suggested Application Rate**	**Notes**
Arsenal herbicide Applicators Concentrate	American Cyanimid	No	12 to 16 oz. per acre	Has been shown to provide control over competing species with little or no obvious negative effect on Atlantic white-cedar.
Rodeo	Monsanto	Yes	Varies depending on target species – see label instructions	Should be used with caution. Has resulted in cedar seedling browning and / or mortality. May not be as effective in controlling red maple.
Accord	Monsanto	Yes	See label instructions	Accord has not been widely used for Atlantic white-cedar in New Jersey, therefore data are not available.

Intermediate Treatments

Cleanings

- The hardwood associates of cedar sprout readily after being cut, and therefore subsequent removal is often necessary. The cost and need for additional cleanings vary depending on the composition of the harvested stand and adjacent stands (Little 1950).
    - Harvested stands that are pure white-cedar may require no subsequent cleanings in order to obtain a new stand of similar composition.
    - Cleanings become increasingly more important as the proportion of hardwoods increases (Little 1950). Cleanings may also be important on areas where a heavy understory of shrubs and small hardwoods was established prior to removal of the overstory (Little 1950). One or two additional cleanings may be desirable, made at intervals of about five years (Korstian and Brush 1931).
- Along with removing undesirable species, Korstian and Brush (1931) suggest the removal of poorly formed and diseased cedar trees from a stand.

Herbicide

- Because of the time and effort required, manual cleanings are not expected to be extensively employed as a management technique in the New Jersey Pinelands (Zampella 1987). An effective alternative for controlling hardwood species is the use of herbicide such as Arsenal Applicators Concentrate.

Thinnings

- There are several problems which often discourage the use of thinning as a management practice for Atlantic white-cedar.
    - By opening up the canopy, thinning may stimulate the growth of hardwood species. This may require additional cleaning and make regeneration of cedar after the final cut much more difficult. For this reason alone, several researchers do not advise thinning (Little 1959, Bamford and Little 1960).
    - The profit from thinning may not meet the cost of the thinning itself, as well as the cost of additional cleanings and the disposal of underbrush at the time of harvest that may be necessary (Little 1950).
    - By opening up the stand, thinning may increase the stand’s susceptibility to windthrow (Little 1950). Moore and Waldron (1938) suggest leaving a narrow, lightly thinned strip along the margins of the stand for protection.
- Despite these problems, many early foresters strongly recommended thinning of Atlantic white-cedar.

Akerman (1923) thought that thinnings would save 20% of the necessary time for growing trees for sawtimber, as well as improve the quality of the wood. Korstian and Brush (1931) recommended thinnings in order to prevent loss and stagnation in the stand and to promote rapid growth in just enough trees to occupy the full crown area.

- The smallest individuals in a cedar stand are typically removed as the result of density dependent mortality (self thinning) (Korstian and Brush 1931, Gibson and Good 1986). Therefore, a commercial thinning of these small individuals has been recommended.

Figure 50. Atlantic white-cedar thinning operation in Gloucester County, New Jersey. Photo by Robert R. Williams.

- Some thinnings of Atlantic white-cedar were conducted during the 1920s. These were mostly commercial thinnings in stands about 45 years old made from below the crown. The growth of the larger "crop" trees was not markedly or consistently increased, therefore the production of merchantable timber was not significantly increased (Bamford and Little 1960).

- Bamford and Little (1960) suggest that crown thinnings in reproduction stands may be effective if conducted when the trees are about 10 feet tall and favor dominance of about 700 stems per acre.

- Korstian and Brush (1931) suggest that only one moderately heavy thinning during the life of a stand will provide an economic advantage. Such a thinning should remove overtopped, intermediate, and some of the codominant trees and leave 700 to 1,000 trees per acre (Korstian and Brush 1931).

- Moore and Waldron (1940) suggest that thinnings are only justified on "45-foot sites" and in stands where the stocking is at least 200 square feet per acre. They suggest that thinnings should be light, removing not more than about 35% of the basal area. Stands may benefit from thinnings between 30-40 years, but beyond that the benefit is questionable (Moore and Waldron 1938).

Protection

Wildfire

- Atlantic white-cedar is susceptible to fire damage at all ages; therefore protection from wildfire may be beneficial. Little (1950) suggests the elimination of the large, intense fires in selected areas. This may be accomplished by:

  - maintaining small amounts of fuel on the forest floor and in areas surrounding the selected stands
  - disposal of slash after logging (Korstian and Brush 1931)
  - prescribed burning in surrounding areas (Zampella 1987, Laderman 1989)
  - providing access roads for fire protection (Little 1950)

- Regenerating areas where slash has not been removed should be rigorously protected from fire for 5 to 10 years following logging because of the increased fire risk associated with slash (Korstian and Brush 1931).

Animal damage

- Protection from deer should continue until cedar regeneration reaches above the level of deer browse.

- Flooding caused by beaver dams may kill white-cedar stands (Little 1950). Cedar of all ages and sizes can be adversely affected. This type of beaver problem could be mitigated through trapping and relocation in cooperation with the NJ Division of Fish and Wildlife.

Figure 51. Beaver trapped at Lebanon State Forest, in cooperation with NJ Division of Fish and Wildlife. This beaver was removed and relocated away from an area where the dam was flooding a regenerating stand of Atlantic white-cedar. Photo by New Jersey Forest Service.

Insects and fungi

- There are relatively few fungi that attack white-cedar and their damage is not usually serious. In addition, white-cedar has no serious insect enemies. Those problems that do appear are usually scattered and not very problematic, therefore control measures are not usually necessary (Little 1950).

VII. Restoration

Goal

- The loss of Atlantic white-cedar forest has been documented over the last two centuries. Many areas that supported cedar in the past have been converted to other vegetation types or other land uses. The goal of restoration projects is to increase the overall acreage of this species by restoring cedar to portions of its former range. This can be done by establishing cedar on sites that do not currently contain cedar, but which have the potential to support cedar and may have supported cedar in the past.

High probability sites

- The establishment of Atlantic white-cedar where none currently exists will be costly. Choosing a good site for restoration is very important in order to minimize costs, and maximize the potential for success. The following factors should be taken into account when choosing a site:

  - **Site history:** Sites that have supported cedar in the past, especially the recent past have a higher probability for successful restoration. These sites can be identified using historical knowledge of the area, or may show signs that cedar was present (stumps, hummock-hollow microtopography, etc.)

  - **Soil:** Restoration projects should be restricted to areas with soils favorable to Atlantic white-cedar. In the New Jersey Pinelands these include Muck, Berryland, and Alluvial soils.

  - **Hydrology:** High probability sites include those that currently contain a hydrology that will support Atlantic white-cedar, and where this hydrology is sustainable over time. The most favorable sites are those that are not too dry, but also not excessively wet. On some sites, where wetland hydrology has been lost due to past drainage, wetland conditions can be recreated, although this process is very costly and time consuming.

  - **Site preparation & subsequent management:** Sites that require minimal site preparation and subsequent management will be the most cost effective overall and will produce favorable results in the shortest amount of time.

  - **Seed source:** Sites with the highest probability for success are those with an adjacent stand of Atlantic white-cedar or an intact, viable seedbank to provide a source of seed for natural regeneration. This may minimize the need for the introduction of artificial regeneration, and may decrease the overall cost of the restoration project.

  - **New Jersey Ecomap:** Sites identified as potential sites for Atlantic white-cedar by the NJ Ecomap program may have a higher probability for success.

Types of restoration sites

Shrub dominated sites

- In the Mullica River basin, the conversion of mature Atlantic white-cedar to shrub dominated wetlands has been a dominant trend over the past 61 years (Zampella and Lathrop 1997). Many of these sites may be disturbed cedar stands (harvested, fire, etc.) that have not regenerated back to cedar. There has been a lot of recent interest in restoring these shrub/scrub dominated sites back to Atlantic white-cedar. Because there are no large trees to be removed, this type of restoration may be more cost effective than hardwood or pitch pine conversion sites.

- Restoration on shrub dominated sites requires:

    - **Control of shrub vegetation:** If there is low shrub coverage, vegetation may be controlled initially using an herbicide. If the shrub vegetation is larger and denser, other methods, such as drum chopping, brush hogging, or mechanical removal may be necessary.

    - **Site preparation:** In some cases, additional site preparation may be needed. This may be true if a thick root mat is present. Drum chopping should sufficiently break up the root mat. If an herbicide or brush hog is used to remove vegetation, additional techniques, such as root raking, may be required to break up the root mat.

    - **Introduction of Atlantic white-cedar**: The introduction of Atlantic white-cedar may be through either natural seeding or artificial introduction (direct seeding of outside seed or planting).

        - **Natural seeding:** The use of natural seeding to extend the area of white-cedar into areas that do not presently contained cedar is limited to areas near a parent white-cedar stand.

        - **Artificial regeneration:** In areas where a seed source is not available, the use of artificial methods is necessary. Laderman (1989) suggests that direct seeding is preferable to planting in most circumstances. However, planted seedlings may have an advantage because they are larger and are able to overtop the hardwood sprouts or outgrow the period of susceptibility to animal damage in a shorter period than seedlings started from seed (Little 1950).

        - A combination of natural and artificial regeneration methods may also be used.

    - **Protection from deer**: Protection from deer (as described on page 56) will be necessary to ensure survival in most areas.

    - **Subsequent control of competing vegetation:** Shrub species sprout readily. Therefore, additional manual cleanings or herbicide application may be necessary.

Agricultural sites

- Little (1950) suggests that white-cedar is a logical tree to use for reforestation of abandoned fields or pastures on wet sites on the edge of the pine region and in the Delaware Valley section of southern New Jersey. Problems associated with this type of site include competing vegetation, unsuitable moisture conditions and animal damage. This type of restoration should be restricted to agricultural sites with a hydrology suitable for cedar.

- In the pine region of New Jersey, abandoned cranberry bogs may have the potential for Atlantic white-cedar restoration. Many of these areas were probably white-cedar swamps prior to cultivation. Gifford (1900) wrote that white-cedar is constantly invading cranberry bogs. Atlantic white-cedar, as well as red maple and other species have invaded the abandoned bogs at the Cranberry Bog County Preserve in Long Island (Mylecraine and Zimmermann unpublished field notes). The establishment of white-cedar, red maple, gray birch and pitch pine on abandoned bogs depends on relative amounts of seed and competing vegetation (Little 1950). These sites must be chosen carefully, as some cranberry bogs may be prone to excessive flooding. Some may also provide important wading bird, aquatic animal and botanical habitat in their current state. Abandoned blueberry fields or other agricultural sites in wet areas may also be possible restoration sites.

- Restoration on agricultural sites will require similar techniques to those mentioned for shrub dominated sites above:

  - **Control of competing vegetation:** If a site has been recently abandoned, minimal competition control (herbicide) may be required. Other techniques, such as drum chopping may be needed if larger shrub or hardwood vegetation is present.

  - **Site preparation:** Additional site preparation (drum chopping or root raking) may be required if a thick root mat is present. Areas that have been tilled will be relatively level and damage from standing water may occur. Therefore, creation of hummocks may be necessary (Little 1950) to create optimal hydrologic conditions. Cantelmo and Ehrenfeld (1999) also suggest the creation of microtopographic structures 30-40 cm high, with the trees planted on their tops, to ensure that the trees become infected with mycorrhizae.

  - **Introduction of Atlantic white-cedar:** If there is an adjacent stand of white-cedar, natural seeding may be used to introduce cedar. If this is not true, or if the area is too large to seed in naturally, artificial methods must be used. One study on abandoned farmland found planting to be more successful than seeding. Planting of large, vigorous stock may give the best results (Little 1950).

  - **Protection from deer:** As with other sites, protection from deer is usually necessary. Protection from rabbits and rodents may also be required on these sites.

  - **Subsequent control of competing vegetation:** If shrub or hardwood species become a problem, subsequent control of competing vegetation may be required.

Figure 52. Aerial photo of cedar restoration site on an abandoned blueberry field and cranberry bog in Lebanon State Forest, New Jersey. Photo by Kristin Mylecraine.

Wildfire sites

- The effect of fire on Atlantic white-cedar depends on many factors. The potential for regeneration following a wildfire depends on the severity of fire, the composition of the original stand, the amount of seed stored in the peat, the degree to which the fire burns the forest floor, and the water table depth relative to the forest surface after the burn.

- On some sites, where the peat has not been severely burned and there is sufficient seed in the soil, conditions may be favorable for Atlantic white-cedar regeneration. However, cedar regeneration may fail because of excessive deer browsing and/or competing vegetation. This scenario may only require the following:

  - **Protection from deer:** Protection from deer, usually in the form of an electric or woven wire fence, is necessary in most areas.

  - **Control of competing vegetation:** In many cases, competing vegetation may develop rapidly following a wildfire and control may be necessary. If an area is fenced soon after the fire has occurred, there may not have been sufficient time for competing vegetation to become established. In this case, vegetative control may not be necessary.

- On other sites, where the peat and seedbank have been severely burned, the effect may be a rise in water table and the resulting conditions may not be favorable for Atlantic white-cedar regeneration. Sufficient time for the reestablishment of an organic layer may be required before the site again becomes suitable for cedar.

Mixed hardwood / pine / cedar stands

- A disturbance within a pure cedar stand may increase the percentage of hardwoods in the stand. A mixed stand may also develop in older cedar stands as hardwoods (Little 1950) replace dying mature cedar trees. As early as 1900, Gifford suggested converting mixed hardwood/cedar stands to pure cedar (Gifford 1900). Silvicultural practices to favor white-cedar in mixed stands of pitch pine and white-cedar are often more problematic than on wetter hardwood sites (Little 1950).

- This type of restoration would require:

  - **Removal of vegetation:** All hardwoods and pines should be harvested from the stand and removed. Individual Atlantic white-cedars can also be harvested, but a sufficient number should be left as seed trees.

  - **Site preparation:** Depending on the density of shrub vegetation and thickness of the root mat, additional site preparation may be needed.

  - **Regeneration:** Seed trees left during the harvest may provide for adequate regeneration to restock the site. However, Gifford (1900) suggested that a stand produced in this way might be "irregular and uncertain". If the number of seed trees is not sufficient, or natural regeneration fails, artificial methods may be required (direct seeding and/or planting).

  - **Control of competing vegetation:** Hardwood and pine sprouts following the harvest may need to be removed to ensure successful regeneration.

  - **Protection from deer:** In most areas, deer protection will be necessary.

- Brown and Atkinson (1999) examined the success of this type of restoration in the Great Dismal Swamp National Wildlife Refuge in North Carolina. A 2.4 ha cut was made within a mixed hardwood/cedar stand. Seed trees were left for natural regeneration, but extensive flooding later killed the natural regeneration. The site was then planted with cedar and the first year data show high survival rates.

Hardwood swamp sites

- Hardwood sites that have the required conditions for cedar may be potential sites for conversion. These hardwood swamps are usually of low economic value because of the high cost of operating in a swamp, the low value of the wood itself, and the rot generally present in the larger trees, particularly red maple. (Little 1950). Favored sites should be those that show signs of past cedar presence. Some research has been done on such sites (Zimmermann 1997), although more information is needed to determine the best methodology to use.

- Hardwood conversion requires:

  - **Killing and removal of hardwood trees:** All existing vegetation must be removed (clearcut) to provide open conditions required by Atlantic white-cedar. Because of the low value of swamp hardwoods, their removal may be problematic. This can be done using a variety of methods:

- Individual trees can be felled manually, girdled, poisoned, or killed using a selective herbicide. Using these methods, initial costs may be excessively high.

- Removal costs may be reduced by using a method requiring little effort to treat a larger area, such as burning or flooding swamps, or the use of salt or other killing agents (Little 1950). Another possibility is the aerial application of a selective herbicide. These methods have not been widely used for hardwood conversions and research will be needed to determine the success of such methods.

- **Site preparation:** If a dense understory layer or a thick root mat is present, additional site preparation may be needed. This may include drum chopping, root raking, or other methods.

- **Introduction of Atlantic white-cedar:** Introduction of Atlantic white-cedar on hardwood conversion sites will probably require artificial methods, such as direct seeding or planting. Some natural seeding may be used if there is a nearby white-cedar stand.

- **Protection from deer:** Protection from deer, using an electric or woven wire fence or other method is necessary in most areas.

- **Control of hardwood sprouts:** Hardwoods sprout readily after being cut. Therefore these sprouts must be controlled, by either manual cleanings or herbicide application in order to promote successful cedar regeneration.

Figure 53. Example of hardwood conversion site. This hardwood swamp at the Forest Resource Education Center, in Jackson, New Jersey, has been converted to Atlantic white-cedar. Photo by George Zimmermann, 1992.

Pitch pine lowlands

- Little (1950) suggests that the moister sites of hardwood swamps favor the establishment and growth of white-cedar seedlings more than do the relatively dry, sandy sites of pine swamps. Pitch pine swamps may have fewer favorable seedbeds, because of the thick litter of pine needles and leaves of shrubs and hardwoods. Removal of this layer increased the germination rates, but germination was still less than occurred on the moister sites of a nearby hardwood swamp. On these sites, pine possibly should be favored rather than cedar (Little 1950).

- However, if this type of restoration is desirable, the following procedures would be required:

  - **Clearcut existing vegetation:** All existing pines and other vegetation must be removed to create conditions adequate for Atlantic white-cedar. Pine generally has a greater economic value than hardwoods; therefore removal may not be as problematic and may pay for the cost of removal and aid in cedar restoration costs.

  - **Site preparation:** Little (1950) suggests that seedbed preparation may be necessary, possibly through a broadcast burn. Other possibilities include drum chopping or root raking.

  - **Introduction of Atlantic white-cedar:** As stated above for hardwood conversion, Atlantic white-cedar may be through natural seeding or artificial methods, depending on the location and availability of seed sources.

  - **Protection from deer:** As with hardwood conversions, protection from deer will be necessary in most areas.

  - **Control of competing vegetation:** Like the hardwood species, pitch pine has the ability to sprout from the stump and roots after it has been cut and therefore may present a problem. In this case, vegetation can be controlled by mechanical means or by using a selective herbicide that will kill the pine without harming the white-cedar regeneration.

Barren sites

- A recent study has found that it is possible to introduce Atlantic white-cedar onto extremely barren, sand locations, such as mined locations in the Pine Barrens (Haas and Kuser 1999, Kuser 1999). However, long-term survival and sustainability is yet to be seen. This type of site can only be successful if hydrologic conditions are adequate for white-cedar.

- This type of restoration would require:

  - **Introduction of Atlantic white-cedar:** Introduction of Atlantic white-cedar on such sites should be through planting. Direct seeding should not be used on such sites, because the harsh conditions may prevent germination and establishment of seedlings. Planted seedlings or cuttings that are larger in size will probably have a better chance of surviving and becoming established.

- **Fertilization and soil amendments:** In one study, a combination of fertilizer and mulch treatments greatly increased first year growth on a barren site (Haas and Kuser 1999).

- **Protection from deer:** Protection from deer may be necessary if local deer populations are high.

Figure 54. Atlantic white-cedar rooted cutting planted on bare sand soil, at Clayton Sand, Jackson, New Jersey. Photo by John Kuser.

Restoration on sites where wetland hydrology has been lost

- Atlantic white-cedar restoration may be possible on former wetland areas where wetland hydrology has been lost. These sites include previous wetland sites that have been drained or filled for agriculture or other uses. This type of restoration is very costly and time consuming.

- This type of restoration requires:

  - **Restoration of wetland hydrology:** In order to restore wetland hydrology, site excavation and construction of water control structures may be necessary. This process is very expensive. The hydrology created must be suitable for Atlantic white-cedar, and must be sustainable through time.

  - **Introduction of Atlantic white-cedar:** On such sites, artificial introduction of Atlantic white-cedar will be necessary.

  - **Protection from deer:** If local deer populations are high, deer protection may be necessary.

  - **Control of competing vegetation:** If competing vegetation becomes a problem, control measures may be necessary.

- In North Carolina, the U.S. Fish and Wildlife Service, Pocosin Lakes National Wildlife Refuge, and North Carolina State University are currently working to restore an 18,000 acre Atlantic white-cedar/Baldcypress (*Taxodium distichum*) bog. Researchers are attempting restoration of wetland hydrology and vegetation to a 640 acre research area within the bog, which was previously drained and cleared for farming. Plans include the installation of 14 water control structures on canals that drain the area (Wicker and Hinesley 1998, Hinesley and Wicker 1999).

Assessment of stocking levels for restoration and regeneration of white-cedar

- The determination of stocking levels for natural or artificial regeneration of most forest species is a complex matter with multiple variables involved (Roe et al., 1970, Daniel et al., 1979). White-cedar is no exception and therefore the number of trees to plant for a cedar stand are hinged on many factors including: desired percent composition of cedar and associate trees, site index, rotation age, propagule type and survival, whether thinnings will be done, herbivory, costs, and product(s) desired.

- There are no data in the literature to date that give minimum cedar seedling numbers in the first year needed to obtain fully stocked pure cedar stands; Korstian and Brush's stand tables (1931) start at age 20. An early assessment of success in reaching a fully stocked mature cedar stand must take into account self-thinning. This is particularly true for stands naturally regenerating from on-site seedbanks, where initial cedar seedling densities could vary from few to millions per acre (Korstian and Brush 1931, Little 1950, Zimmermann 1995). Gibson and Good's assessment (1986) of self-thinning is based on the Korstian and Brush stand tables thus limited again to stands 20 years or older.

- If a pure or nearly pure, 'normal' or fully stocked stand is desired, Korstian and Brush's stand tables (1931), based on site index and final rotation age, could be used as a stocking guide. Below are samples from a few of their tables for an average range of site indices. Refer to Korstian and Brush's original work if more information or more complete tables are required.

Table 7. Portions of stand tables from Korstian and Brush (1931) for fully stocked Atlantic white-cedar stands by age and site index.

	Site Index					
Age (years)	**20**	**30**	**40**	**50**	**60**	**70**
	Number of trees per acre ≥ 1 in. DBH					
20	18,000	14,700	10,800	7400	4600	2800
40	5800	4500	3400	2300	1440	870
50	3900	3100	2250	1550	970	580
60	2900	2300	1700	1170	740	435
70	2300	1850	1350	940	580	350
80	1980	1550	1150	790	500	300
	Number of trees per acre ≥ 5 in. DBH					
20	0	0	0	0	58	213
40	0	185	442	759	900	705
50	161	465	788	946	795	545
60	355	666	935	906	663	427
70	506	803	910	802	555	343
80	620	850	862	725	477	292
	Number of trees per acre ≥ 8 in. DBH					
25	0	0	0	0	0	12
40	0	0	0	27	165	310
50	0	0	34	162	359	388
60	0	17	119	310	430	349
70	7	54	213	382	414	308
80	16	112	288	411	390	278

- If a pole size product is desired, then depending on site index, survival rate, and rotation age, more trees may need to be planted than if a timber-sized product is desired. To correctly assess planting densities or adequacy of natural regeneration, a professional forester should be consulted, who will take into account all variables mentioned in this section.

- All managed stands should be monitored continually through their life, especially during the critical regeneration phase.

VIII. Summary

- Atlantic white-cedar (*Chamaecyparis thyoides*) is found within suitable habitats along the Atlantic and Gulf coasts of the United States. White-cedar is a valuable species for several reasons. It is important economically, as a valued timber species. Cedar stands also provide several ecological benefits, and provide areas for aesthetics and recreation.

- Since European settlement, the acreage of Atlantic white-cedar in New Jersey, as well as rangewide, has declined drastically for a variety of reasons including; wildfire, past harvesting procedures, white-tailed deer, conversion to agriculture, development, hydrologic change, beaver activity, timber theft and natural successional trends. Atlantic white-cedar requires disturbance to regenerate; yet disturbance often results in the conversion to other wetland types. The general trend has been toward conversion of cedar to other wetland types (shrubs, hardwoods) following disturbance. Without proper management, the failure of cedar to regenerate following a disturbance may lead to a continued net loss of cedar.

- Proper management of Atlantic white-cedar will help to ensure regeneration and long-term sustainability of this species. Using proper techniques, cedar can be utilized for timber products and successfully regenerated. There is a great deal of variation among individual Atlantic white-cedar stands. Therefore, management strategies will depend on several factors, including landowner objectives, economics, composition of the previous stand, soil type and hydrology of the site, equipment available, and accessibility. General best management practices for harvesting cedar include the following:

    - discuss management objectives and possible management strategies with a professional consulting forester
    - follow all local, state, and other guidelines, and obtain all necessary permits
    - harvest by clearcutting (i.e. complete clearcut or clearcut strips)
    - conduct harvests to avoid impacting populations of threatened and endangered species, and protect water resources
    - ensure regeneration of the stand through either natural or artificial methods
    - provide adequate post harvest management (i.e. control of competing vegetation, protection from deer) and intermediate treatments (i.e. cleanings, thinnings, protection)

- In addition to maintaining existing cedar stands, there has been a lot of interest in restoring Atlantic white-cedar to areas of its former range that have converted to other wetland types. High probability sites for restoration will be those that have soil and hydrology conditions suitable for cedar, require minimal site preparation and subsequent management, and have an outside seed source nearby or an intact viable cedar seedbank on site. Restoration may be accomplished by conversion of hardwood swamps, pitch pine lowlands, mixed hardwood / pine / cedar stands, shrub dominated wetlands, or agricultural wetlands that previously supported cedar. Highly disturbed sites, such as following mining activity or wildfire, may also be possible candidates for restoration.

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