Atlantic White Cedar Wetland Ecosystem Restoration Strategy

September 25, 2020

State of New Jersey
Department of Environmental Protection
NJ Forest Service

CEDAR RESTORATION PARTNERS

New Jersey Conservation Foundation

New Jersey Audubon

Pinelands Preservation Alliance

Pine Creek Forestry LLC

Conserve Wildlife Foundation of New Jersey

The Allegheny Society of American Foresters New Jersey Division

Stockton University

FoHVOS New Jersey Invasive Species Strike Team

NWTF Conserve. Hunt. Share.

The Nature Conservancy New Jersey

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New Jersey Department of Environmental Protection

State of New Jersey Pinelands Commission

Forest Service Div. of Parks & Forestry NJ

New Jersey Division of Fish and Wildlife

State Park Service Division of Parks and Forestry N. J.

New Jersey Forest Fire Service Since 1906

Executive Summary

Atlantic white cedar is a characteristic wetland forest tree species of the New Jersey Pinelands. Its distribution today is mainly restricted to freshwater wetlands, where it shades streams and swamps that discharge groundwater from the Kirkwood-Cohansey aquifer. Centuries of exploitation and development have greatly diminished the abundance of this species both in New Jersey and across its range, and threaten the resiliency of Atlantic white cedar ecosystems. Forest management has been successfully used to return cedar to sites where it had been lost on both public and private land, and New Jersey Forest Service intends to scale up the prior efforts of cedar site restoration to a landscape level. This strategy will initiate 1,000 acres of cedar restoration per year for 10 years; the goal of this strategy is that cedar forest area will be increased by 10,000 acres by 2030. This effort will strengthen connectivity of this ecosystem, increase the area of high-value wetlands for water quality maintenance, and begin to restore the grandeur of south Jersey's wetland forests.

Why is this document called a 'Restoration Strategy'?

Increasing the acreage of Atlantic white cedar forest is a strategy that draws on collaborative forest management. This document illustrates the input of many stakeholders for cedar restoration and provides the context for what will be an assemblage of individual forest management projects. Each project will comprise a series of actions to benefit the Atlantic white cedar forest resource.

This document is not intended as a permitting vehicle - each individual activity will be reviewed and permitted in either the:

1) New Jersey Department of Environmental Protection Natural and Historic Resources Land Management Review Process, or
2) a Natural Resource Stewardship Plan written by the New Jersey Forest Service.

Further, all activities that fall under the jurisdiction of the Pinelands Commission's Comprehensive Management Plan will go through that permitting process.

1. About the Problem

1.1 - Value of Cedar

Atlantic white cedar (Figure 1) has long been recognized as the most valuable forest tree species in southern New Jersey (1) (2) (3). Long before the days of cranberry cultivation, and even before the era of charcoaling, iron forges, and widespread lumbering, Atlantic white cedar was being harvested for local use and export outside of the pine region. Its wood qualities and their wide desirability made it a sought-after species, leading to widespread cutting of this species for centuries (4; 5; 6; 7; 1).

Figure 1: Mature Atlantic white cedar stand, Wharton State Forest. Source: NJFS

Beyond these immediate economic uses of cedar, it is and has been regarded for its ecological significance. In 1819, John Torrey, for whom the oldest botanical society in the United States was named, remarked that, "The cedar swamp, near New-Durham, is particularly deserving of notice... Many of our most rare and interesting plants were obtained in this place (8)." Today, New Jersey's Atlantic white cedar swamps are habitat for swamp pink (*Helonias bullata*), a federally-threatened and state-endangered flower of the lily family (9) (10), as well as many other plant species distinct to the pinelands (Figure 2). In addition to plants, cedar swamps are a valuable habitat for the fauna of the Pinelands. At least one member of the butterfly and moth family, Hessel's hairstreak (*Mitoura hesseli*), is exclusively dependent on Atlantic white cedar swamps, and is a species of special concern in New Jersey (11). Cedar swamps provide winter hibernation habitat for the state-endangered Timber Rattlesnake (*Crotalus horridus*) (12), and provide a moderated environment for many others to cool off in the summer and find cover in the winter.

The microsite conditions that make cedar swamps valuable to wildlife also make these sites valuable in their provision of ecosystem services, like water quality. Wetlands in general, and cedar swamps in particular are moderated environments in comparison to the surrounding

Figure 2: Swamp Pink. Source: USFWS, https://www.fws.gov/northeast/njfieldoffice/images/_SP_19_APR_2005_.jpg

landscape. Cedar swamps provide continuous cover throughout the year, creating a cool, shaded environment in the summer, and radiative cover in the winter (13). Streams in the Pinelands are supplied by groundwater almost exclusively (14) (15) which discharges through lowlands; these ecosystems help to moderate base flow and act as a filter for nutrients in water (16). Roman and Good's (16) land capabilities descriptions for water quality maintenance value of different wetlands assign the highest value to AWC swamps. Cedar swamps meet all three of their criteria for wetlands capable of high nutrient removal capacity: cedar swamps are usually connected to a stream or other river course, their soils are generally muck with a high organic content, and they have very dense tree cover. Peat formed in the muck soils of cedar swamps represents a long-term reservoir for removal and storage of nutrients and pollutants from water (16), as well as an extensive, stable pool of sequestered carbon. Cedar and muck soils contribute largely to the Pinelands region's characteristic red-brown water color (17). The contribution of cedar swamps to the character of the Pinelands and its water cannot be overstated.

1.2 - Scarcity

Like the Pinelands landscape it calls home in NJ, Atlantic white cedar is vulnerable to the activities of humans. Of the sixteen states that comprise its range, Atlantic white cedar is considered vulnerable in six, imperiled in four, and presumed extirpated in one (18). From Maine to Mississippi, there are 531,000 acres of timberland on which cedar occurs, but only in 109,000 acres of those does it comprise more than half of the canopy (19). New Jersey is considered one of the strongholds of the species, yet the acreage of cedar in our state is vastly reduced from its historic levels (20).

Cedar-dominated swamps are believed to have occupied more than 100,000 acres in New Jersey at the time of European settlement (21), but current estimates place the number between 25,000 and 42,000 acres (see the map titled *Atlantic White Cedar Extent: Contrasting Assessments* on page 35). Older estimates vary as to the extent of cedar in New Jersey (Table 1), but it is widely recognized as being vanishingly scarce, and in decline. Even if one only reaches back to the last century, decline is apparent: from 1956 to 1979, there was an overall reduction in the area of cedar swamps (22). In comparison to a recent areal estimate of AWC, pitch pine lowlands occupied an order of magnitude more area, estimated to be well over 100,000 acres in the Pinelands region (16).

Table 1: Estimates of extent of Atlantic white cedar forests in New Jersey.

Author/Instution	Acreage	Year of Estimate	Method
Roman and Good, Rutgers University	*21,450	1978-1979	Aerial Photo Interpretation, 1:24,000
New Jersey Forest Service	*26,136	1979	Aerial Photo Interpretation, unknown scale
United States Forest Service	49,800	1974	Aerial Photo Interpretation, unknown scale
New Jersey Forest Service	50,000	1952	unknown
Vermuele, New Jersey Geological Survey	52,500 (85,100 additional acres with cedar component)	1899	unknown

**Containing 50% or more AWC*

1.3 - Causes

The causes of cedar's diminished presence in New Jersey are manifold and have differed over time as to their relative impact. The forces that have driven the decline in forest area occupied by cedar include agricultural wetland modification, inundation by man and beavers, uncontrolled herbivory, changes in wildfire behavior, saltwater expansion, fragmentation, and the interaction of non-silvicultural logging with these other factors.

1.3.a - Agriculture

Thousands of acres of cedar swamps were converted to cranberry bogs or diked to support the unique hydrologic needs of cranberry cultivation (16). In 2015, the New Jersey Department of Agriculture stated that 3,000 acres were still in production for cranberries (23), but in 1895, there were 5,000 acres in production (24), with untold more area of former cedar forest inundated upstream of the cranberry dikes to support the farming operations. The legacy of productive land use followed by abandonment can still be seen in aerial images of the Pinelands (Figure 3), where abandoned cranberry bogs and dikes mince up drainages, separating by miles patches of formerly connected forest.

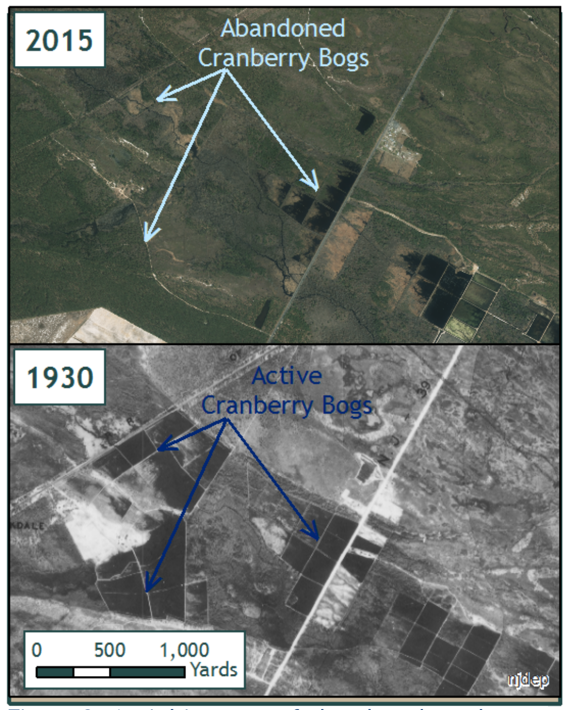


Figure 3: Aerial imagery of abandoned cranberry bogs, 1930 and 2015. Source: NJDEP, Forest Service and Bureau of GIS.

1.3.b - Wildlife

The skeletal remains of the region's agricultural and industrial heritage make easy work for beavers, who take advantage of sluices and flood gates to minimize the work needed to make dams. Prior to European settlement, beavers may have provided a disturbance to hardwood sites that would allow cedar to establish; today, they make dams at roads and dikes, inundating and killing cedar forests (25) (26) (21). Man-made alterations to hydrology through built infrastructure, as well as an increase in the population of beavers resulting from less trapping, allow beavers to easily impact cedar wetlands (Figure 4).

Figure 4: Standing dead cedar recently killed by inundation from beaver activity, Brendan T. Byrne State Forest. Source: B Isaacson, NJFS

Another mammal, the white-tailed deer (*Odocoileus virginianus*), is responsible for dramatically reducing the ability of cedar to regenerate on its own. Deer herbivory can be the main determinant for the establishment of young cedars (27) (28), as cedar is the favorite browse of deer in lowlands of the Pinelands (29). While the deer population in New Jersey may now be below its historic peak from the 1990s (30), it is still high enough in some drainages of south Jersey to impact cedar regeneration.

1.3.c - Fire

The Lenape indirectly mitigated the impact of wildfire on cedar through their use of frequent annual burning in their management of New Jersey's forests. Many of these fires were set to drive deer with the flames for ease in hunting (31); (25); (2); (24) to ease travel (32) (33), or both. Low intensity fires set during the winter and spring had the potential to kill fire-sensitive AWC, but were less likely to burn the muck soils underlying the swamps, as this portion of the year represents the seasonal high water table (34). Fires that 'turf,' or consume the organic soil can make a site inhospitable to cedar for the foreseeable future (Figure 5) (21).

Figure 5: Swamp forest roots exposed by combustion of peat soil. Great Swamp National Wildlife Refuge burned in the Lateral West Fire, near Suffolk, VA, August 2011. Many such acres of lost peat have been permanently converted to open water and emergent marsh. Source: https://www.flickr.com/photos/usfwsnortheast/6098305612/in/album-72157627462458136/

Figure 6: 'Stump Forest' at Mill Creek site in Hackensack Meadowlands. Some of these ancient Atlantic white cedar trees witnessed the landing of the Dutch in New York harbor; their remains were exposed as a result of a wetlands mitigation project. Source: R. Williams, Pine Creek Forestry.

Little (25) (35) made note that after such a fire the hydrology of a site becomes much more wet, in some cases tipping the site away from cedar cover for long periods.

1.3.d - Hydrology

The delicate balance of hydrology that permits cedar to survive on a site also played a role in landscape changes to cedar populations. In the Hackensack meadowlands, harvesting, ditching, and damming caused the demise of a cedar forest that may have covered several thousand acres (Figure 6) (36). Changes to hydrology can cause cedar mortality by altering the balance of tidal flushing, bringing periodic salty water to areas previously occupied by freshwater.

1.3.e - Climate Change

Coastal saltwater inundation has long been identified as a cause of cedar acreage losses (7). Soils that have been brined with salt are toxic to the trees, killing overstory and preventing regeneration (25). Until recently, coastal submergence was progressing slowly up the coastal elevational gradient (Figure 7). With increasing rates of sea-level rise due to global climate change, losses due to submergence and salt are expected to increase (37). Coastal losses are

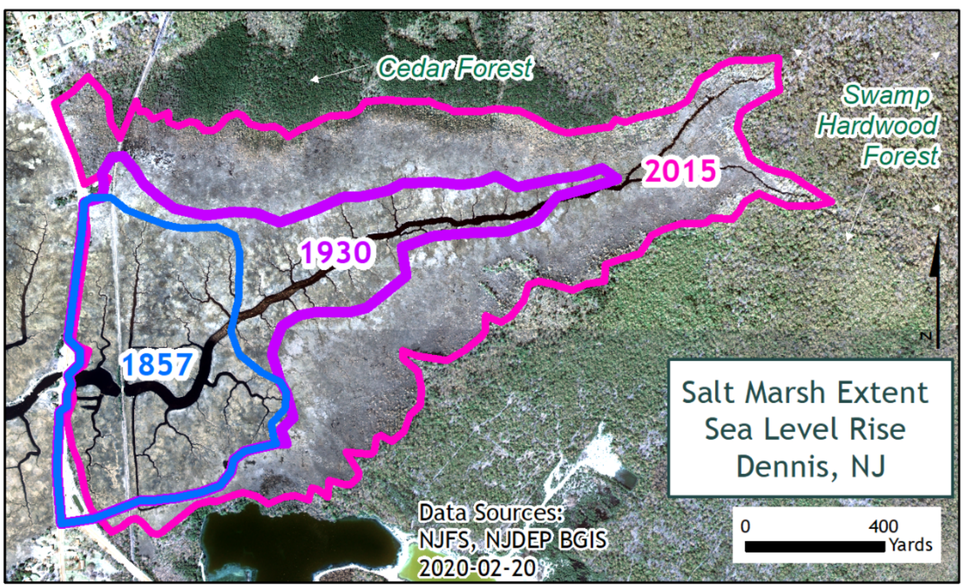


Figure 7: Example of coastal forest losses over time in Cape May County, New Jersey. In 1857, GH Cook mapped today's hardwood swamp to the east of the marsh as the "Great Cedar Swamp," a continuous swamp of Atlantic white cedar. The salt marsh's expansion since then has come at cost to the cedar forest. Cook also pointed out that unmitigated logging caused extensive losses of cedar acreage, the likely explanation for the swamp hardwood forest above.

Aerial image above is a true-color image captured by NJDEP in 2015. Marsh extent in 1857 reconstructed from a georeferenced version of Cook's map (7), and extent in 1930 from photo interpretation of 1930s aerial images.

currently of significant concern because they represent a readily apparent effect of climate change, and because land lost to salt cannot be quickly replaced.

1.3.f - Non-Silvicultural Logging

By this means many cedar swamps are already quite destitute of cedars…
- Pehr Kalm, 1748

Cedar decline attributed to overharvesting is a complicated story, with improper harvesting procedures through careless exploitation driving decline. Starting with European settlement, its desirability led to extensive harvesting without regard to its reestablishment. Pehr Kalm, a Swedish professor visiting southern New Jersey in 1748 & 1749, remarked that "Swamps and Morasses formerly were full of them [cedar], but at present these trees are for the greatest part cut down, and no attempts has as yet been made to plant new ones." (38). Soon thereafter, Samuel Smith, a member of the provincial council and historian, remarked that "the people subsisting in great part by…. cutting down the cedars," which he described as being "now much work'd out." (39).

Figure 8: Cedar swamp being logged, early 1900s. Source: NJFS

This pattern of cedar exploitation was widespread and opportunistic. After the virgin-growth timber was cut over in the 1700's, second-growth cedar was historically cut at a young age, with a harvest return interval of as little as 50 years (7). In the first half of the 20th century, 70 to 80 years was considered a normal rotation length (40) (25) (Figure 8). Wacker (41) attributes the repeated declines of the lumber industry in the Pinelands to a lack of saw-log sized trees; when the informal rotation age was reached for an area, the industry would spring back, and repeat a cycle of total harvest. Muntz (2) noted the same descriptions, and summarized the net effect of cedar decline, stating that "cutting of immature stands, the replacement of white cedars in some swamps by deciduous species, and burning of swamps in prolonged dry periods all tended to reduce the importance of the cedar industry and, by the end of the 1800's, it had declined to a position of relatively minor significance."

The timber which originally covered these swamps has now all been cut off, and there is no first growth to be found
- George H Cook, 1857

With widespread cutting, that any cedar forests still exist today is a testament to the robust constitution of the tree itself. Like many of the other successful Pinelands-dwelling species, cedar has persisted on the landscape and survived the era of over-exploitation due to its biology. It can occupy soils that are so low in nutrients and acidic that other species have difficulty thriving (42). It naturally forms pure, even-aged communities due to its ability to rapidly and overwhelmingly respond to disturbance (40) (25) (43). It can handle levels of competition that would strangle other species to death: cedar swamps support greater volumes of wood and a thicker, more closed canopy than any other species in the Pinelands (43) (21). It naturally grows in even-age, monoculture stands and is a fruitful bearer of seeds, making it naturally adapted to stand-replacing disturbances.

It can also be long-lived: Cook (7) made note of two ancient survivors, aged 700 and 1,080 years old. Cedar growth rates are rapid for the first 50-100 years of growth, but substantially taper off above this age (44); the outer annual rings of the ancient trees observed above were described as being "not thicker than paper" (7). These older individuals as well as the abundant cedar timber available to the colonists speaks volumes about the ability of cedar to survive and thrive under the management regimes leading up to European settlement.

For thousands of years prior to European settlement cedar could successfully colonize available habitat due to its life history. In a landscape dominated by repeated low-intensity fire, cedar's copious, long-lived, wind-blown seeds germinated well out of the wet, fire-resistant muck of the Pinelands drainages. Once established, many years-worth of seed crops were present in the sphagnum and muck of the lowlands; disturbance that opened the overstory would allow those seeds to germinate, regenerating cedar. Low-intensity fire, set annually by the Lenape and their forebears (31) (2), provided the disturbance needed; sometimes hot enough to kill much or all of the overstory, but cool enough to spare seeds that lay dormant in protective sphagnum and muck.

For cedar to colonize a site and exclude hardwoods, a constant and heavy shower of seed rain is needed. Such a dense covering of seed is best achieved when the areas affected by or adjacent to the disturbance are providing

Figure 9: Non-silvicultural harvest of cedar swamp in southern New Jersey, 1922. Only cedar has been cut, with swamp hardwoods left because they were undesirable. This functions as a 'seed-tree' cut that will regenerate red maple and blackgum at the expense of Atlantic white cedar. By this exact method, much of New Jersey's Atlantic white cedar forests were decimated and converted into hardwood swamps. Source: NJFS

seed. Continuity of the cedar forest created the conditions necessary to regenerate cedar following disturbance. Without a wider context of a landscape with lots of surrounding cedar, insufficient seed supply was likely a factor in the failure of cutover sites to regenerate as cedar (22). Silvicultural methods like the provision of cedar seed trees on a harvest site to provide an insurance policy for seedlings were likely not considered in harvests of years' past. When harvested in centuries past, cedar forests were usually 'high-graded:' only the valuable cedar was harvested, leaving the economically-worthless deciduous trees in place. Those same residual

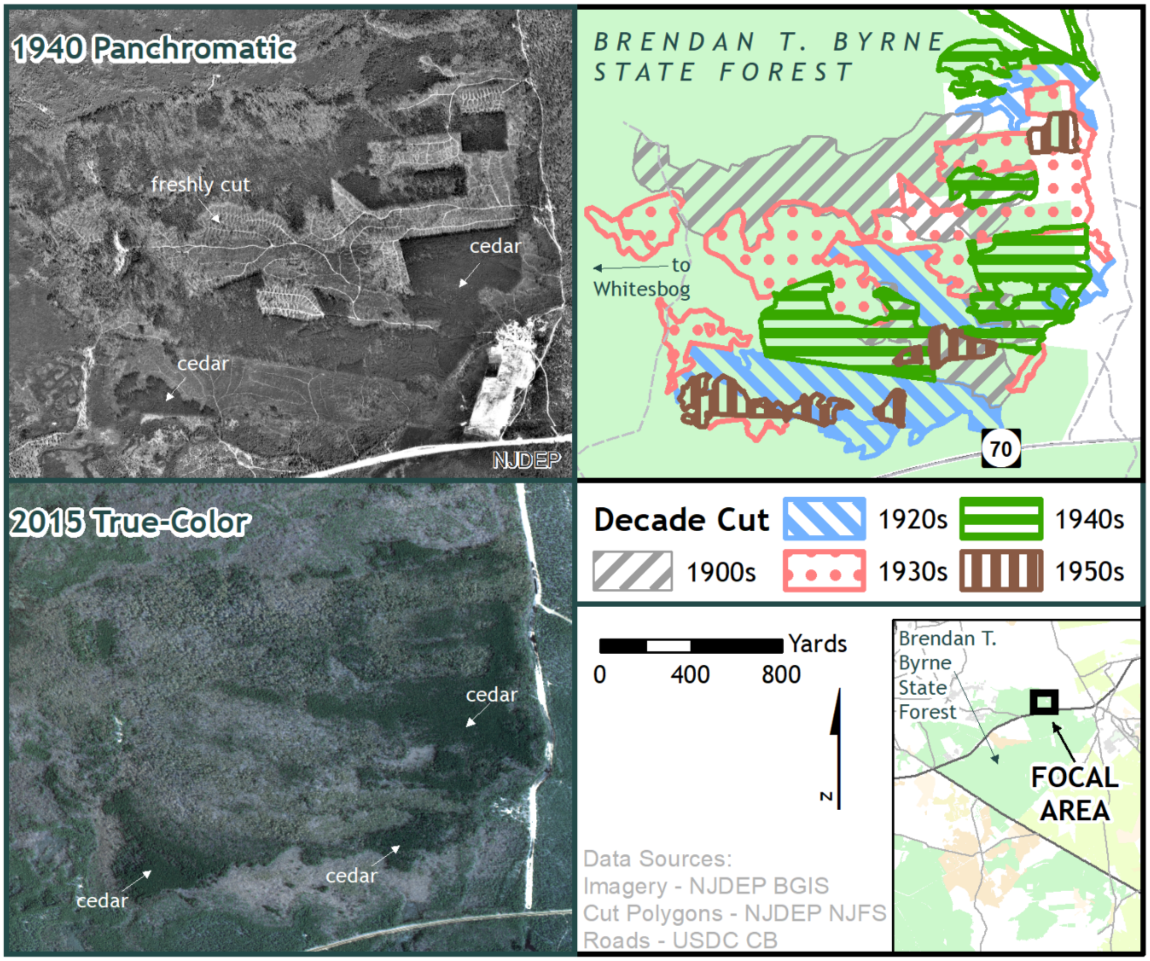


Figure 10: Example of the effects of repeated non-silvicultural logging. Portions of some cut areas were able to successfully regenerate into solid cedar forests. For most of the acreage, remnants of cedar forest have been left scattered across the hardwood swamp that sprang up, the vestigial remains of an ecosystem wracked by exploitative cutting. Most of the area was purchased in 1969 by the New Jersey Department of Conservation and Economic Development. Cuts prior to 1900 are not shown.

hardwoods rained seeds down on the disturbed site, contributing ample non-cedar seeds to begin the new forest that sprang up in response (Figure 9) (25) (21).

Cutting cedars at a younger age, as was the practice up to recent decades, increased the frequency with which the sites had to be re-colonized. Neighboring stands were less able to provide needed seed rain for a site because of fragmentation within drainages. Lack of seed rain was the result of both failing to ensure cedar regeneration after harvest, as well as from wetland modification for agriculture. To make matters worse, suppressed hardwood seedlings and stems were retained after logging through neglect, giving hardwoods a head start on some sites (13) (25). Our society "rolled the dice" with each non-silvicultural cedar harvest, risking that the site would not come back as cedar. With every extractive cut, there was a chance that hardwoods or other plants would take over a forested site, with a loss of overall cedar acreage (Figure 10).

By fragmenting our wetland landscape through the changes described above, there was a shrinking likelihood of natural cedar regeneration on a disturbed, formerly-cedar stand. In centuries past, neglect only indirectly affected total cedar acreage: an individual site might not come back as cedar after a disturbance, but there was a sufficient mass of the species to enable it to persist on its own in the landscape. As our society has fragmented the cedar wetlands for centuries through cutting and wetland modification, and indirectly through the deer herd, we have inhibited the natural ability of cedar to persist on the landscape. This explains in part why cedar sites and gaps within cedar forests have been episodically and gradually replaced by hardwoods.

1.4 - Purpose of Strategy

Today, our cedar resource is at a tipping point. Estimates over the past decades have produced fewer and fewer total acres of majority-cedar forest in New Jersey. From Maine to the Gulf Coast, New Jersey is one of the last remaining strongholds of this coastally-restricted ecosystem (18) (19) (Figure 11). The natural ecological processes that led to the formation of cedar forests have been interrupted for hundreds of years, threatening its existence. Rather than let this unique and valuable ecosystem be whittled away to meaninglessness through neglect disguised as preservation, we can achieve ecosystem restoration through attention and active forest management. We must allow the ecological processes that sustained cedar through the millennia back on the landscape – continuous stands of cedar along drainages, and encouragement of self-sustaining natural regeneration following disturbance.

The goal of this strategy is to reinforce the integrity of the Atlantic white-cedar forest type in the landscape of the Pinelands. This is best achieved by restoring the continuity and connectivity of cedar forests through forest management. Techniques such as seed tree harvests, herbicide application, fencing, and

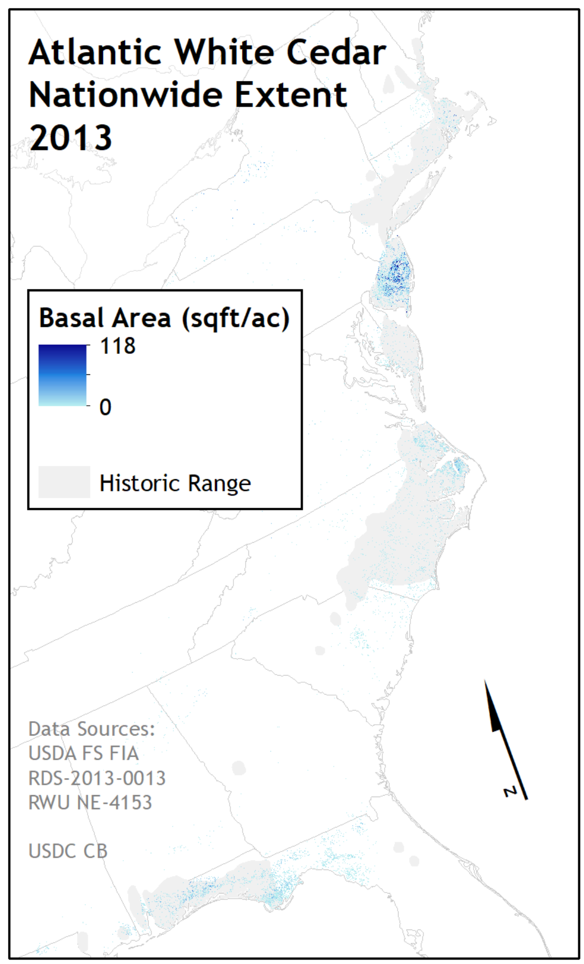


Figure 11: Current distribution of Atlantic white cedar. Vestiges of the species remain in New Jersey, North Carolina, Florida, and Massachusetts.

Figure 12: Example of successful Atlantic white cedar restoration in Bass River State Forest, photo taken in 2013. Source: B. Isaacson, NJFS

supplemental planting are capable of recruiting new age classes of cedar within lowlands whose cedar stands have been fragmented from centuries of exploitative land use. Prior activities have restored or regenerated several hundred acres (Figure 12). Through this strategy, NJFS seeks to conduct 1,000 acres of restoration per year for 10 years, for a total of 10,000 acres.

The concept of cedar restoration at the stand and local level has been successfully demonstrated on both public and private lands in New Jersey, albeit at a smaller extent than called for in this strategy. These projects, along with abundant research about cedar regeneration in the state, have served to develop significant knowledge of the silviculture of this species. These research efforts led to the development of a Best Management Practices manual (21), and significant knowledge about propagating cedar at the New Jersey Forest Service Nursery. It is worth noting that much of the research to expand knowledge about cedar restoration was conducted to support future landscape-scale restoration, a need for which was acknowledged by many parties (38) (45) (46). The institutional depth of knowledge developed because of this long-term effort provides the foundation to support our restoration objective.

It should be stated that this strategy is not intended to get loggers into the woods or to reincarnate a bygone wood products industry. However, the involvement of industry is necessary as a tool to make restoration possible: industry is the only constituency within the forest community with the ability to apply the extensive and heavy disturbance required. We expect each management action to have a modest impact on the forest industry as a side effect because the strategy's intent is to rebound the population of this species on the landscape and restore an ecosystem, not identify areas for harvest. There is no rotation length being advocated or suggested. Ideally, these forests will be allowed to grow for centuries, like those ancient trees witnessed by GH Cook's contemporaries (7).

It must be stated that it would not be wise to attempt to return cedar to all forested wetlands in the Pinelands, nor would it be currently reasonable to return it to all sites which formerly supported it. While successional trajectories can be shaped using forest management, sites that have undergone significant changes as a direct result of deliberate hydrologic manipulation are beyond the purview of this strategy. Such sites require significant engineering inputs to make the changes needed for habitability for cedar. While their restoration is a laudable goal, the intent of this strategy is to bolster the cedar population through stand management, as this represents the most practical use of state resources at this time. Efforts should be carried out to restore cedar to abandoned agricultural sites at a later date. Below, we describe a hierarchy of sites by ease of cedar restoration activities.

Unless we act, our cedar resource will stagnate or decline. Without active steps towards ecosystem restoration, we continue our society's abuse of this wetland ecosystem in the form of neglect rather than exploitation.

2. Hierarchy of Sites

For the purposes of this strategy an inventory of different site types was used to establish priorities for restoration. The forest types described below are by no means a full accounting of the wetland forests in the Pinelands. Rather, this section describes the site types where cedar restoration work has been investigated in the past. Non-forested wetlands, excluding former agricultural sites, are not discussed here as they do not currently support a tree canopy. Similarly, extant cedar stands are not discussed, as the purpose of this strategy is to increase acreage of cedar, rather than call for management within healthy stands. Not all the site types described here are appropriate for cedar restoration at this time.

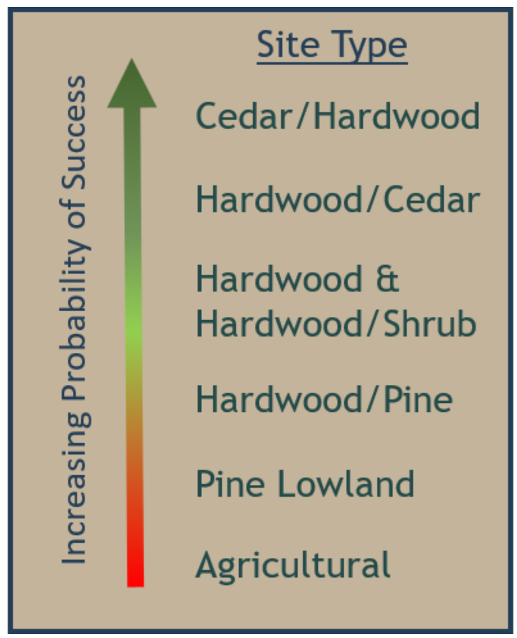


Figure 13: Hierarchy of site suitability for Atlantic white cedar restoration for this project. Agricultural sites are unique in that they have a very different set of complications than existing forested wetlands, mainly highly disturbed hydrology.

2.1 - Cedar/Hardwood

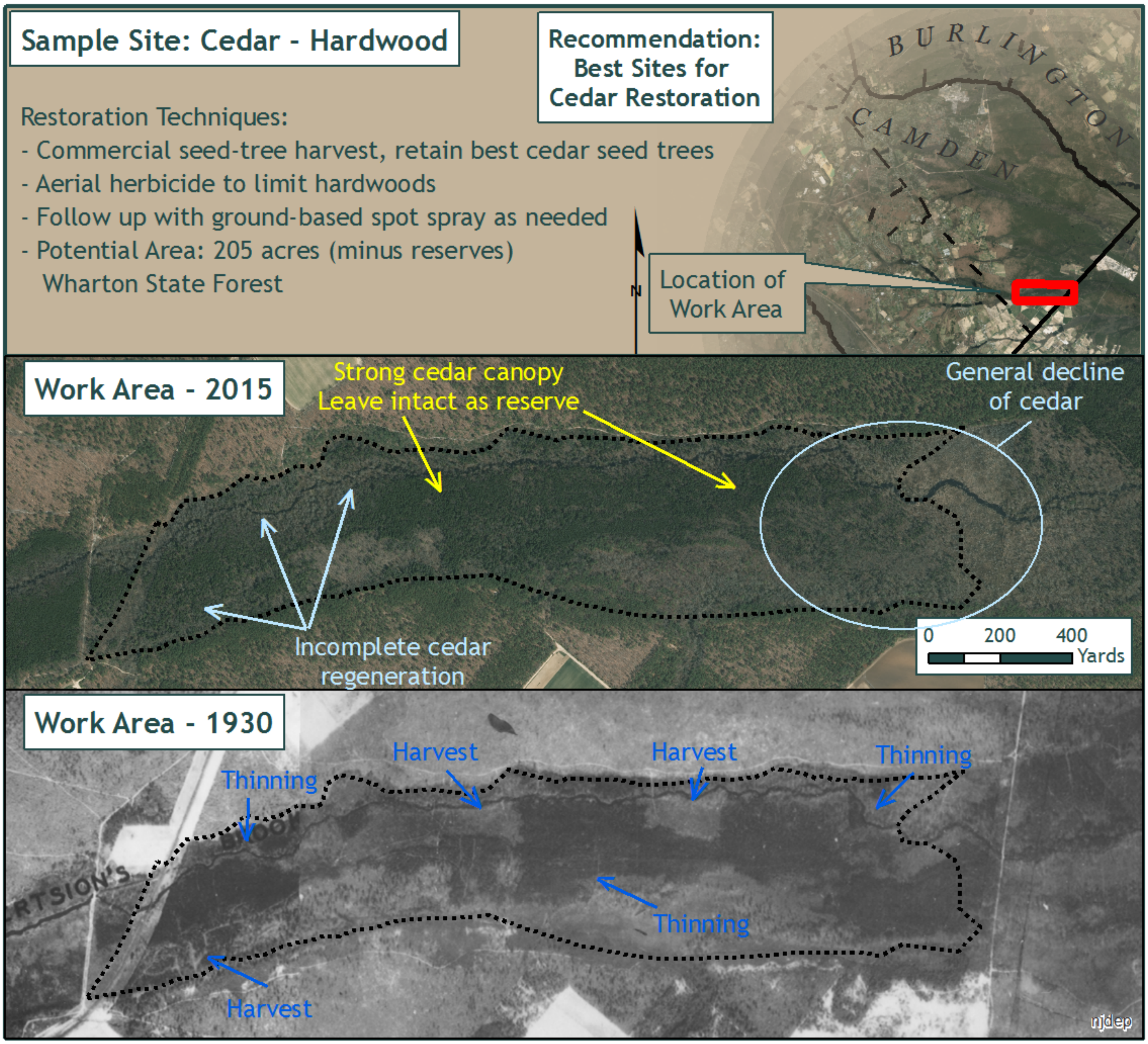
These are sites that may have been uniformly cedar in the past but are now shifting to a more mixed composition. The matrix is usually of mixed composition, with occasional pockets of solid cedar. Underlying soils are almost always muck.

Figure 14: Cedar/Hardwood site, Wharton State Forest. Source: B Isaacson, NJFS

For many of these locations, as individuals in the overstory of yesteryear's cedar forest died, they were replaced by hardwoods below them in the canopy. The hardwoods on these sites were able to get established in the first place as a result of poorly planned extractive logging. Overstory cedar were cut without the tool of selective herbicides to nudge residual stand composition and natural regeneration towards cedar. The values of associated hardwoods such as maple, blackgum, and sweetbay were so low that they did not pay for their own removal. Where they occurred, they were left or used for corduroy. There was no effort to supplement natural cedar regeneration by planting seedlings if there were insufficient cedar in pockets. This allowed hardwoods to gain a toehold next to or underneath the new generation of cedar. Today, as overstory cedars die, they are replaced by hardwoods such as red maple and blackgum.

The condition of these stands as cedar forests will likely only worsen in time if no action is taken. Cedar's competitive advantage comes from excluding its contemporary species by creating dense shade from its own natural monoculture. As openings occur, it is a gamble as to what species will establish in the new gap, but with hardwoods present, the scales are tipped against cedar.

Such sites represent today's best chance for cedar restoration. The underlying soils are known to support cedar, and their current hydrology is stable and suitable. There are abundant seed trees to supply cedar seed for natural regeneration and competing evergreens that would complicate herbicide treatment (pine and laurel) are absent. It may be possible to commercially harvest these sites to offset operation costs; the cedars not saved as seed trees would easily make such a sale possible. Following cutting, aerial herbicide would be applied to nudge natural cedar regeneration into a more advantageous position, allowing for a solid cedar canopy to develop. It may become necessary to spot spray herbicide, put up deer exclusion fencing, and plant seedlings, but these are not expected to be needed. Following treatment, a new generation of solid cedar is expected, returning these sites to their status as cedar sanctums.



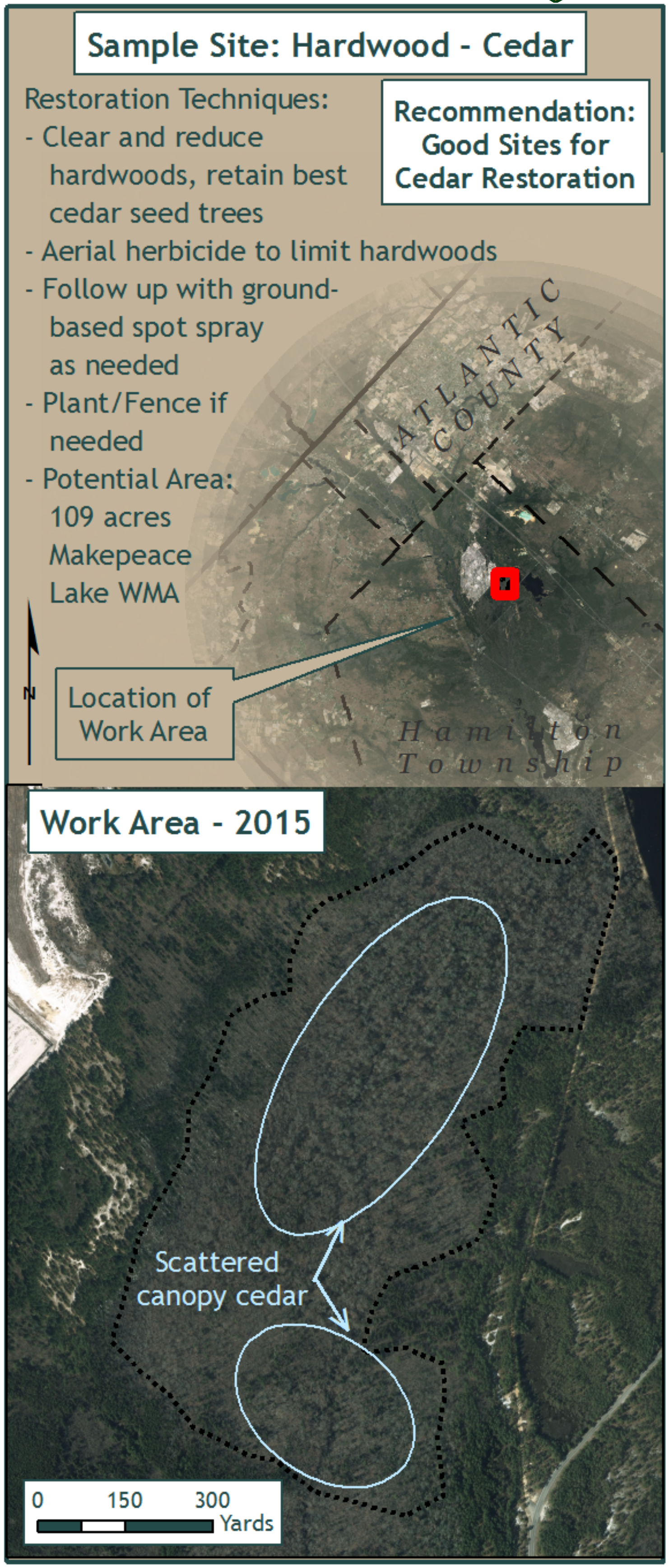
2.2 - Hardwood/Cedar

Figure 15: Hardwood/Cedar example area, Brendan T. Byrne State Forest. Source: B Isaacson, NJFS

Hardwood/cedar sites may have been uniformly cedar in the past or may have been previously mixed. Today, they are usually composed of a red maple/blackgum canopy with scattered cedars reaching the canopy, sometimes with a minor pine component. There may be rare clusters of cedar, or these sites may occur mixed with sites that are mixed cedar/maple forests as in the Cedar/Hardwood type, above. Underlying soils are almost always muck, though pockets may be excessively saturated. Hardwood stems in these swamps have little to no economic value, as their stems are mainly deformed and defective (3).

As with the mixed cedar/maple forests, these sites are often the result of improper silviculture in past decades and centuries. Repeated logging of cedar forests, that which targeted only cedar and left intact the undesired species such as red maple, led to ever-expanding importance of hardwoods within the stand; these are probably the most abundant of the sites that Pehr Kalm expressed serious concern about back in 1748. After past logging or disturbance, nearby hardwoods may have rained abundant seed upon cut areas, taking advantage of absent neighbors. Alternatively, there may have been a poor cedar seed supply in the cut area, or germination conditions immediately post-cutting may have been unfavorable for cedar. With no action today, these sites will almost certainly shift to solid hardwood forests, completing a trajectory that started with the first widespread cutting of cedar by European settlers in the 1600s. It is possible that single individuals of cedar may continue to survive to be truly ancient, but this is unlikely, given the small likelihood of such an occurrence for any individual. Instead, it is expected that hardwoods will continue to dominate these sites, perpetuating themselves through abundant stump sprouting after any disturbance. It is expected that the window of opportunity to return these sites to a cedar-dominated canopy is rapidly closing.

Immediate but thoughtful action has the potential to return these sites to cedar-dominated forests. Seed-tree cutting that takes advantage of the remaining cedars on the site has long been recognized as the appropriate method for regenerating cedars (Little 1950). Depending on the size of the patch in consideration, or if these sites can be paired with areas like Cedar/Hardwood sites as above, it may be possible for the state to financially break even with a commercial harvest in these sites. There will likely be a few sawlog-size and quality hardwoods per acre on the sites. However, it is expected that most of these sites will require non-commercial cutting that reduces the standing trees to slash in a way that doesn't inhibit regeneration. Existing cedar trees will be left and utilized as seed trees for natural regeneration. Treatment most likely will involve some sort of mechanized equipment to slash/lop the standing trees, followed by equipment that can break up or reduce the material down on the ground. Aerial herbicide will be used to give the advantage to cedar regeneration, with spot-spraying applied to deal with competing evergreen shrubs and hardwood sprouts missed by aerial application. Methods to control deer herbivory may be more extensive, here.



2.3 - Hardwood & Hardwood/Shrub

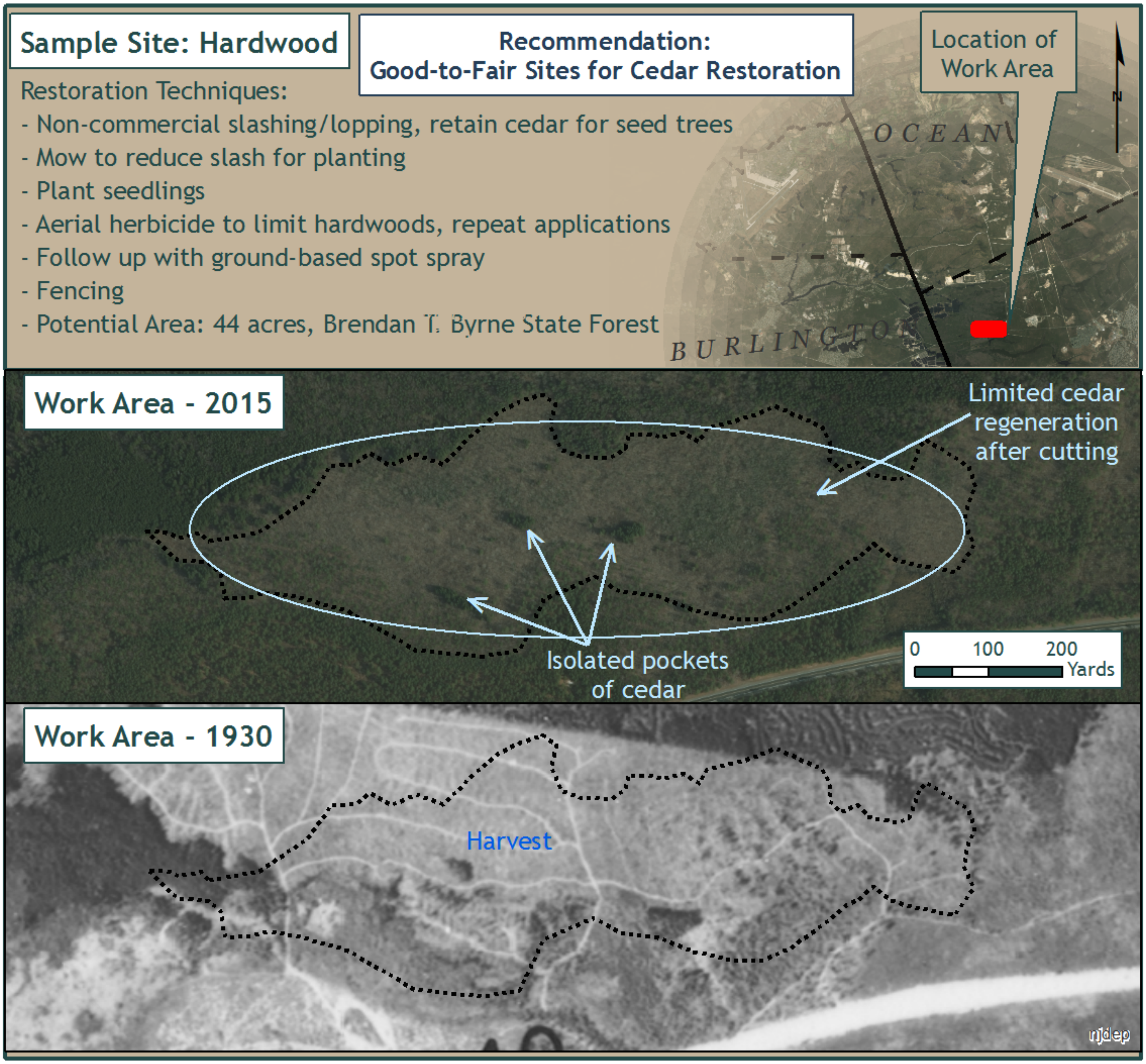
Figure 16: Hardwood site (formerly cedar) logged in late 1920s, Brendan T. Byrne State Forest. Source: B Isaacson, NJFS

These sites are similar to hardwood/cedar sites, where the current forest is mostly hardwood and shrubs, though these sites lack any widespread cedar component. Underlying soils are typically muck, although there may be a greater proportion of inorganic mineral material mixed in. Shrubs are extensive, making traverse difficult.

Here, too, old logging practices may have converted cedar forests to non-cedar types, shifting the tree cover of the site. However, it is likely that at least some of these areas are less ideal for growing cedar, as its current wholesale absence suggests. Slight changes in hydrology and loss of muck soils since the last time they were cedar may be responsible for its absence today.

These sites hold promise to grow a future cedar forest, but the window for doing so easily has closed. As there are no remnant cedars in the canopy, there is no immediate seed source with which to begin a new generation. With no treatment, these areas can be expected to perpetuate themselves as hardwood swamps.

With detailed and firm attention, cedar could be re-established on these sites. Non-commercial cutting to slash/lop the trees, followed by mowing to reduce the slash would be a necessary first step. Herbicide treatments, both from the air and from the ground would follow, and may need to be repeated to deal with the extensive hardwood seedbank that has developed underneath a solid hardwood canopy. As a matter of necessity, these sites would require planting, which necessitates a nursery seedling source. With diligent attention, it would be possible to return many hardwood swamps in the Pinelands to cedar, but the amount of effort required would make this activity less cost-effective than treating sites that currently have some cedar. Targeted attempts that take advantage of sites where it has been established that cedar was extirpated only recently are the most likely to meet with success. Hardwood and Hardwood/Shrub sites should be considered a longer-term restoration target.


Sample Site: Hardwood
Recommendation:
Good-to-Fair Sites for Cedar Restoration
Location of Work Area
Restoration Techniques:
- Non-commercial slashing/lopping, retain cedar for seed trees
- Mow to reduce slash for planting
- Plant seedlings
- Aerial herbicide to limit hardwoods, repeat applications
- Follow up with ground-based spot spray
- Fencing
- Potential Area: 44 acres, Brendan T. Byrne State Forest
OCEAN
BURLINGTON
N
Work Area - 2015
Limited cedar regeneration after cutting
Isolated pockets of cedar
0 100 200 Yards
Work Area - 1930
Harvest
njdep

2.4 - Hardwood/Pine

This site type is a mix between hardwood and pine lowland types. Often these sites are hardwood-dominated, with a significant pine component. Shrubs are thick and continuous. Underlying soils are a mix of all wetland types, including Atsion sands, Atsion-Berryland sands, Berryland sands, Berryland muck, and Manahawkin muck.

Figure 17: Hardwood/Pine site, Wharton State Forest. Source: B Isaacson, NJFS

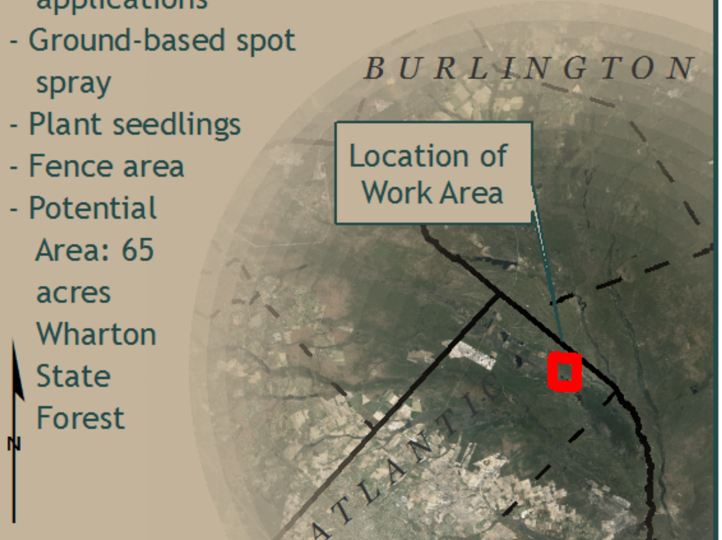
These sites hold some promise for cedar establishment but are currently marginal. There is no established seed source of cedar on the site, but pine is established. The presence of a competing evergreen with cedar makes it hard to tip the scales towards cedar with herbicide: pine is as insensitive to imazapyr as cedar. Also, it is not clear for many of these sites that they are capable of supporting cedar in competition with other species. The soils may be inappropriate, with insufficient muck depth as a result of natural or human factors.

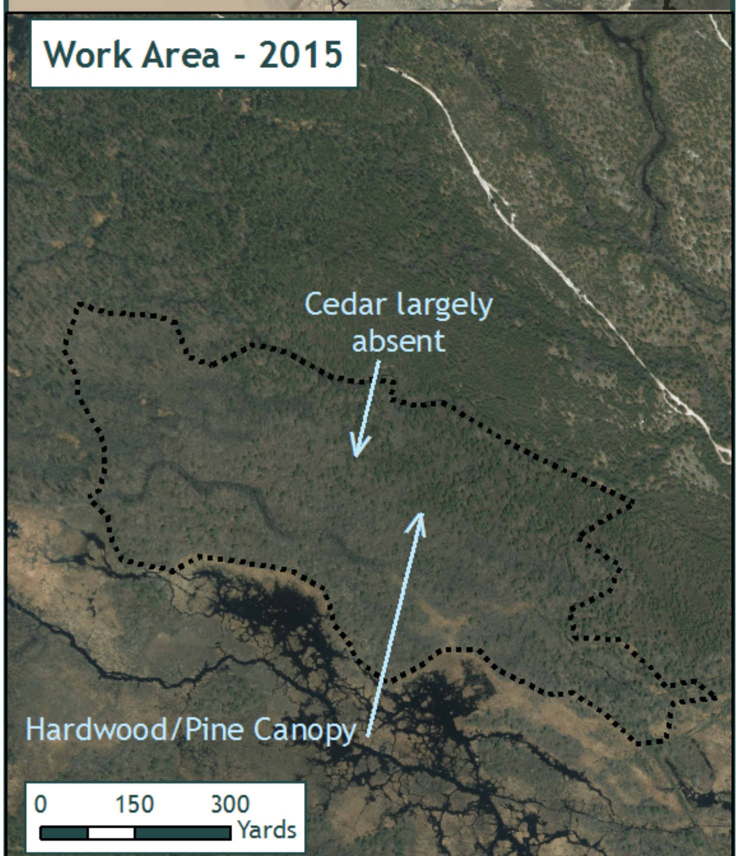
With intense attention, it is possible to return cedar to these sites, although the degree of cedar dominance will in large part be determined by individual site. To establish a new cohort of cedar here, the trees must be clearcut. Depending on the amount and quality of pine, it may be possible to conduct a commercial harvest here, or to at least break even. If a harvest cannot be completed, the site will need to be slashed/lopped. Under both scenarios, the site would require subsequent mowing to reduce slash and permit planting. Herbicide would follow, applied aerially to control hardwoods, and from the ground to kill competing pines. As there are insufficient cedars on the site, the whole area would require planting, and measures to reduce deer herbivory. The resulting forest may well be cedar-dominated, but a pine and shrub component is expected, leaving these sites with a mixed composition. For these reasons, as well as expense, NJFS intends to avoid working on these sites under this strategy, unless they occur as small fragments within a more extensive matrix suitable for cedar management.

Sample Site: Hardwood/Pine

Recommendation: No Cedar Restoration

Restoration Techniques:
- Non-commercial slashing/lopping
- Mowing to reduce slash
- Aerial herbicide to disfavor hardwoods, repeat applications
- Ground-based spot spray
- Plant seedlings
- Fence area
- Potential Area: 65 acres Wharton State Forest

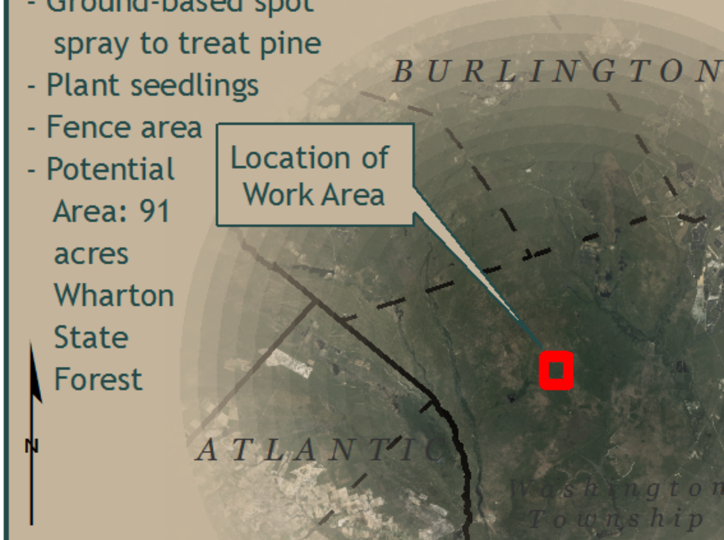


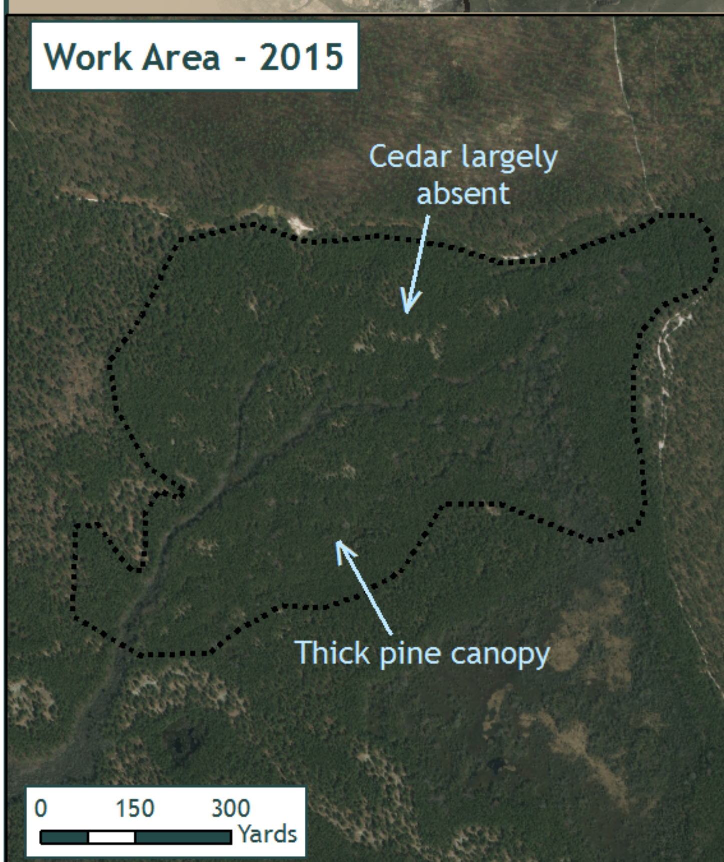


Sample Site: Pine Lowland

Recommendation: No Cedar Restoration

Restoration Techniques:
- Commercial harvest, clearcut
- Mowing to reduce slash
- Aerial herbicide to disfavor hardwoods
- Ground-based spot spray to treat pine
- Plant seedlings
- Fence area
- Potential Area: 91 acres Wharton State Forest





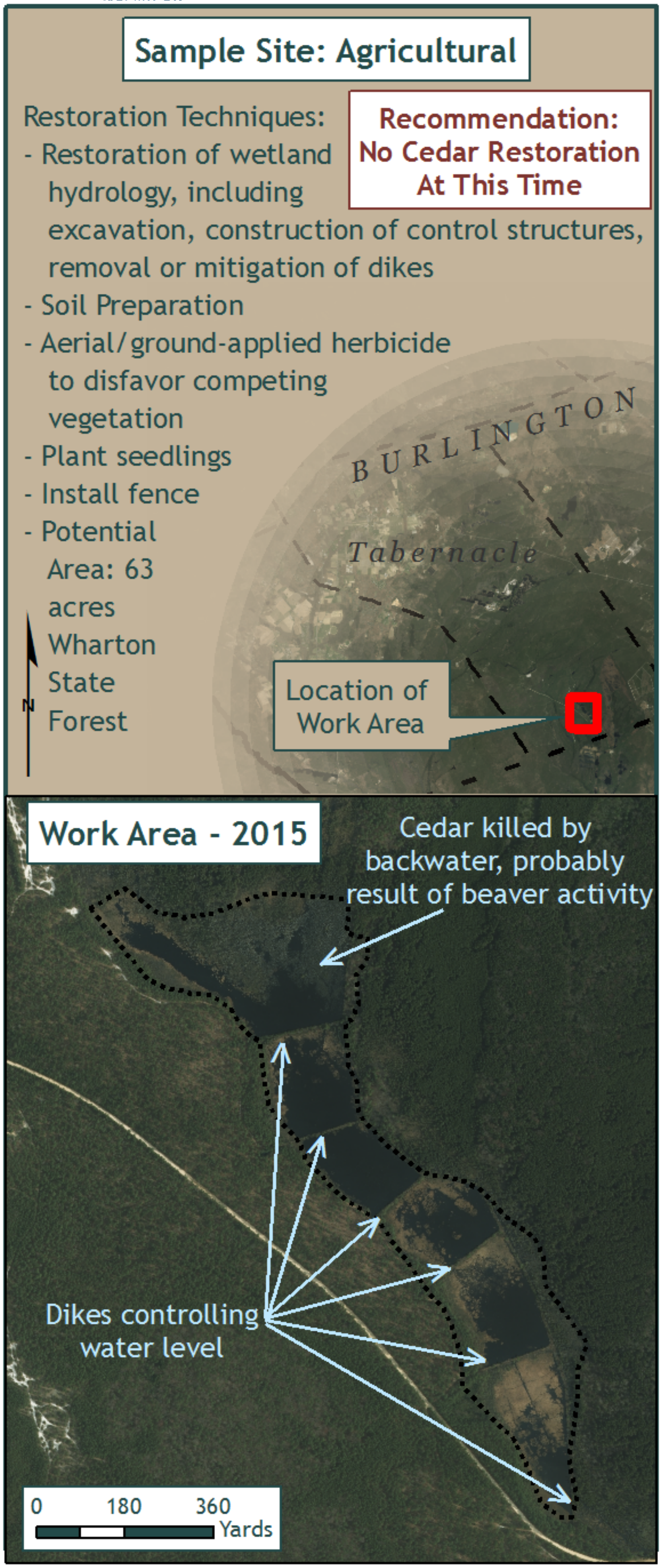
2.5 - Pine Lowland

Figure 18: Pitch pine lowland, Wharton State Forest. Source: NJFS

Pitch Pine Lowlands are a characteristic type of wetlands in the Pinelands that cover extensive areas. The canopy in these sites is nowhere near as dense as in cedar forests, but these sites generally have the highest basal area of pine in south Jersey, with thick and challenging shrub cover. There may be scattered individuals of hardwood species or even Atlantic white cedar, though pitch pine is obviously dominant.

Despite the occasional occurrence of cedar, these wetlands are usually inappropriate for management to enhance the state's cedar resource. Pitch pine lowlands and their soils may sometimes be the result of logging that removed cedar without planning for regeneration, but very often these sites are naturally marginal for cedar at best. In general, it is not clear that these wetlands ever supported extensive cedar forests. Little (25) made note of an experiment demonstrating that the surface duff of pine lowland soils is seasonally too dry for cedar seedling establishment in comparison to hardwood swamp soils, where cedar seedlings were able to both germinate, and thrive. Efforts to regenerate cedar on pitch pine lowland sites have resulted in, at best, a mixed canopy of pine and cedar in the resulting forest (47).

An additional complicating factor for these sites is herbicide selectivity. Herbicides that take advantage of the differences between angiosperms and gymnosperms will leave both cedar and pine to be unaffected, causing them to be inappropriate tools for selecting against pine. To use herbicide to effectively favor cedar over pine in these sites ground-based application is required, instead of the labor- and cost-saving use of aerial herbicide. As cost and work required go up, the likelihood of success goes down; rather than thoughtfully shaping the trajectory of a site using , trying to convert a pitch pine lowland to cedar becomes a fight against nature.



2.6 - Agricultural

Sites whose hydrology has changed as a result of ditching and/or diking present somewhat of a quandary for ecosystem restoration but are probably best avoided for the purposes of this landscape-scale cedar restoration strategy. Abandoned cranberry bogs and the like have been so extensively modified that their soils do not represent the pre-farming site. As well, hydrological controls such as sluice gates and dikes complicate water management and place restoration projects at greater risk from beaver damage.

While it is a laudable goal to return a site to its pre-development condition, it can be cost-prohibitive to do so. Due to significant changes in the way water moves through an altered wetland (versus an intact cedar forest), engineering planning and consultation will likely be needed to ensure successful cedar re-establishment in these sites. This would be followed with operations costs for the construction equipment used to execute engineered changes.

The sum of these costs to prepare the underlying site would need to be borne before the forestry methods could be used to add vegetation. Only after significant outlay would it be possible to attempt restoration on these sites, and site preparation, herbicide, fencing, and planting treatments would be needed. These costs make broad-scale restoration of these sites unrealistic at the time of this strategy. Instead, NJFS believes it would be most worthwhile to achieve greater acreage and continuity of cedar forest prior to widespread efforts to rehabilitate agricultural sites. Modified agricultural wetlands present a challenging but rewarding restoration site and should receive separate attention for restoration projects.

3. Management Techniques

The management methods described below are the result of decades of experimentation and investigation. Many parties have dedicated significant energy to develop methods for restoring cedar on different site types.

3.1 - Clearcut Harvest

Clearcutting causes dramatic changes in the local environment of a forest stand. However, the life history of some species, including Atlantic white cedar, make those species uniquely adapted to the dramatic changes caused by clearcutting. Similar to hot fire, a clearcut removes the cover of tall vegetation from a site, allowing sunlight to bathe the forest floor. Air temperature and soil become warmer, stimulating the seedbed to germinate. It has long been established that to encourage successful cedar regenearation, clearcutting is a valuable component of silvicultural management for this species (40) (25) (3) (21) (45).

Cedar takes advantage of a clearcut's brighter, warmer conditions to establish itself. While cedar seedlings will germinate underneath a closed canopy (25), their growth, and by extension survival and competitiveness is hindered by moderate to intense shade (25) (48). Clearcutting to regenerate cedar in mixed stands will be used in situations where abundant cedar seed is available, i.e. in situations where cedar occupies at least 25% of the site. For sites where cedar is absent, clearcutting for cedar restoration will be used to remove all competition from the new generation of cedar seedlings that will be planted.

3.2 - Seedtree Harvest

Seed-tree harvests appear physically very similar to clearcuts. When there are only 10-20 trees per acre remaining to cast shade, ambient light levels are very high, and the soil is still warmed up significantly. In contrast to a clearcut, a seedtree cut retains mature trees in the harvest area to act as a seed source, permitting the manager to choose which species will get to contribute their seed.

On sites with occasional or infrequent canopy cedars (< 25% cedar), this strategy will usually apply a seed tree cut, as there is likely very little existing cedar seed in the soil's seedbank. By retaining the best available cedar on the site, the seed trees provide a locally-adapted seed source. Trees that have clearly experienced a heightened wind load for their mature lives, often identifiable because they retain branches closer to the ground, will be chosen to be retained. Unfortunately, cedar is subject to windthrow when suddenly exposed from disturbance, as is often the case with seed-tree harvests. At least a few years of seed production can be

Figure 20: Example of suitable seed tree for cedar restoration. Note large proportion of stem with live branches, indicating adaptation to higher forces from wind. Source: B Isaacson, NJFS

obtained from the retained seed trees before they are toppled, though losses to legacy trees may be mitigated by better tree selection. In the cases where a site has higher densities of cedar, patches of windfirm trees can be retained to mitigate losses to blowdown. Regeneration success may require supplemental plantings, as would be the case with a site that is currently entirely devoid of cedar.

3.3 - Slashing/Reducing

It is unclear whether slash benefits or harms cedar regeneration, although strong evidence exists for both beneficial and harmful effects (40) (25) (42) (28). While many observers have noted the interfering effect of slash on cedar regeneration through shading, there has also been observed to be a benefit, possibly due to an interaction between heavy slash loads and reduced access for deer.

For those sites that are harvested, slash may be sparse enough that it is not a concern. On sites where harvesting is not plausible yet competing hardwoods must be removed, as well as on harvested sites with heavy slash loads, it may be necessary to treat slash. This might occur on mixed hardwood/cedar sites with large hardwoods. A determination must be made on a case-by-case basis; if a site can be successfully regenerated without slash treatments, NJFS will do so.

If competing material must be slashed/reduced outside of a harvest, it may be necessary to utilize harvesting equipment to cut competing hardwoods and shrubs. This could be accomplished using a tracked feller-buncher with a saw head or a processing head. Such a machine can take down the overstory without making a dense layer of chips, leaving valuable microsites available for germination of cedar seed.

Figure 21: Tracked harvester with a cut-to-length processer head, cutting cedar in Double Trouble State Park. Similar equipment could be used for both harvesting and slashing. Source: B Isaacson, NJFS

Alternatively, a cut-and-leave technique may be used on these sites. In this situation, competing tree and shrub species are cut and left on the ground, creating a heavy, yet open slash load, as branch architecture provides vertical structure. In effect, this would 'harvest' trees by leaving them as slash, without breaking the slash down further to maneuver around the site.

3.4 - Mowing

One method for control of competition is mowing, which also allows slash to be cleaned, as with reduction. A forestry mower chips vegetation into a loose mulch as it is driven over a site. The mower is not restricted to corduroy, but due to the soft nature of lowland peaty soils, even with proper equipment, a single pass is often all that can be achieved. Mowing has been successfully applied by NJFS in past cedar restoration activities, particularly in Bass River State Forest. NJFS has previously utilized a specialized, low-ground-pressure forestry mower that can operate on the soft soils of cedar swamps.

Figure 22: NJFS forestry mower clearing a site for cedar restoration. Bass River State Forest. Source: NJFS

Mowing, like reduction, can only be as selective as the operator of the equipment. Small cedar seedlings are not visible from the seat of a mower and are mulched or crushed just like competing vegetation. Mowing is most appropriate, therefore, either immediately after a harvest where there is abundant cedar seed in the soil, or where there are not expected to be suppressed cedar seedlings. NJFS expects to use mowing in hardwood sites, or hardwood/cedar sites where there is little regeneration.

3.5 - Herbicide

An alternative for controlling competition is the use of herbicide. Both aerial application and ground-based application have been used successfully in previous cedar restoration projects, and both are subject to site-specific considerations. In every case of herbicide application, the active ingredient and any other materials used, like surfactants, must be appropriate for the site and species targeted. As well, there are unique restrictions on the label of every herbicide that dictate for what species and at what time a chemical is most effective, narrowing the window of opportunity for when a spray can be applied. Of course, the label of every herbicide dictates proper use of the compound to ensure safety to human and non-target species (including animals).

Figure 23: Forester spot-applying herbicide on a cedar restoration site. Bass River State Forest. Source: NJFS

Ground-based herbicide application has the advantage of being able to target individual plants that are competing with cedar. This specificity can be beneficial, particularly for sites with populations of plant species of concern. As well, greater control of where spray lands allows for the use of a wider range of herbicides, as those chemicals that would harm AWC can be applied only to competing vegetation on a site. For example, wetland-approved herbicides with an active ingredient of glyphosate, such as Rodeo and Accord, are most appropriately applied from the ground. The disadvantages of ground-based application are that it is more expensive, more time-consuming, and can result in higher amounts of active ingredient being applied to the land, due to inherently variable coverage. As a matter of practicality, large sites sprayed from the ground may run into limitations because of timing windows: the longer it takes to spray a site from the ground, the less likely it will be able to occur during available spray windows.

Figure 24: Aircraft being readied for aerial application of herbicide to cedar restoration site in Double Trouble State Park. Source: C Compton, NJFS

For this and other reasons, aerial application is usually more appropriate for larger sites. It can be applied quickly, at low cost, and at precisely calibrated rates to ensure conformance with the label. Aerial application is not as specific for which individual plants are dosed with herbicide, so it is crucial to utilize wetland-approved compounds that do not harm cedar. NJFS and other forest managers have successfully utilized Arsenal AC (applicators concentrate) in aerial herbicide applications as part of cedar restoration. This method is described in the AWC BMPs (21). NJFS expects this to be used as the preferred method of control of competing vegetation due to its target specificity, low cost, and ease of application.

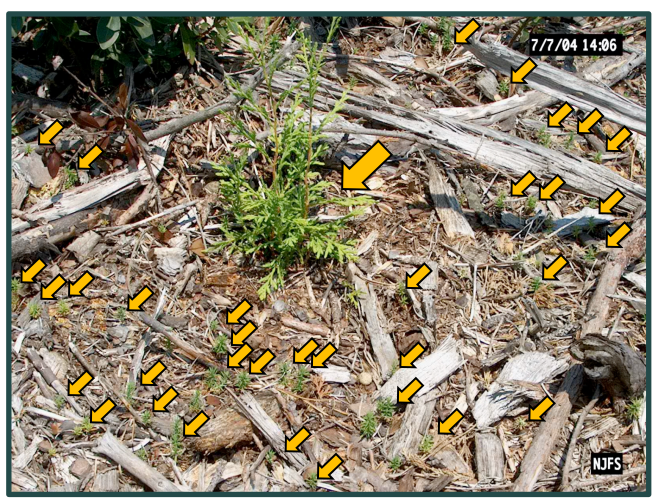


Figure 25: Natural cedar regeneration (small arrows) surrounding planted, "artificial" regeneration (large arrow). Bass River State Forest. Source: NJFS

3.6 - Planting

Planting of seedlings, or 'artificial regeneration,' is used where natural regeneration fails to achieve stocking goals. Seedlings are planted in early spring either as bare-root stock or tubelings, with care taken to avoid air pockets in sphagnum and freezing temperatures that may heave seedlings out of the ground.

Planting will be conducted where natural regeneration is inadequate to maintain a stocking level of at least 800 trees per acre, and 1,000 seedlings per acre will be specified (roughly 6x6 ft spacing between plants). In the past, the New Jersey Forest Service Nursery has provided cedar seedlings used in restoration activities. Other state nurseries along the southeast coast have produced AWC seedlings in the past, but do so no longer; the New Jersey Forest Service Nursery may be the only available supplier for seedlings. If properly supplied, the Nursery has the capacity to produce tens of thousands of cedar seedlings per year.

NJFS intends to use the Nursery for seedling production as a bulwark against activity failure. Seedlings would be planted on those portions of sites that do not develop sufficiently dense coverage of regeneration subsequent to other management activities.

3.7 - Fencing

Cedar swamps provide thermal cover for wildlife during the winter, and in addition cedar browse is the preferred dormant-season food source for white-tailed deer in southern New Jersey (29). Research from the 1950s and 1960s unequivocally demonstrated the impact of deer herbivory on cedar regeneration (29) (27). More recent research confirms that herbivory management is crucial for successful regeneration (28). Some drainages suffer more deer herbivory than others, though, so it should not be assumed that every site will fail to establish as a result of overbrowsing. Additionally, expansive regeneration on larger sites may dampen the capacity of a local population of deer to overbrowse seedlings, an observation that supports treating larger areas for each individual activity.

Figure 26: Example of hex wire fence used to protect cedar seedlings. Bass River State Forest. Source: W. Zipse, NJFS

To protect both natural and artificial regeneration, fence installation to exclude herbivores may be needed. In several situations on public and private land, specialized fencing has been successfully used to temporarily exclude deer from regenerating cedar stands. Both electric and wire mesh fences have been used to exclude deer and are subject to different limitations.

Electric fences usually consist of a cleared fence line, multiple strands of high tensile wire attached to fiberglass poles, powered by a photovoltaically-recharged battery. Electric fences have the advantages of ease of installation, cheaper materials, and that they allow non-target animals such as snakes and turtles to pass underneath the lowest strand of wire. Unfortunately, this type of fence is also more damaged by vandalism, as the removal or destruction of the battery and charging setup renders the entire fence useless.

Wire mesh fences are more costly and labor-intensive to install and maintain, but even if breached most of the fence remains effective at reducing herbivore pressure. Different types of wire fences have been used to exclude deer and address the shortcomings of electric fences; most sites on state land utilize PVC-coated hex wire. For this type of fence, three lines of high-tensile wire are strung in a mowed line along trees on the outside of a site at a height of 7-8 feet. From these lines, a 6- to 7-foot tall mesh is hung, which is additionally stapled to trees. After seeing rattlesnakes utilize debris to pass under this type of fence on earlier restoration projects, NJFS foresters began installing debris at regular intervals to lift the bottom of the fence several inches off the ground, allowing passage of herpetiles while still restricting access to deer.

Fencing can be very expensive, however, both for the cost of materials as well as for labor for installation. NJFS expects to utilize fencing only in those situations where deer overbrowsing has been documented and where there is a clear need for such measures. In some sites, it may be possible to utilize slash as a “biodegradable” fence, or to reduce the local deer population by supporting increased hunting pressure.

4. Assessing Cedar Extent

4.1 - Acreage estimates

4.1.a - Available Data and Needs

For the purposes of this strategy, NJFS sought a tool that would simultaneously assess the extent of cedar and its associated forest types on the landscape. At the inception of this effort two datasets were available for assessment of the spatial extent of the cedar resource: the USDA Forest Service Forest Inventory & Analysis (FIA) species raster for Atlantic white cedar, and the NJDEP Land Use 2012 dataset. While both of these made attractive starting points for targeting

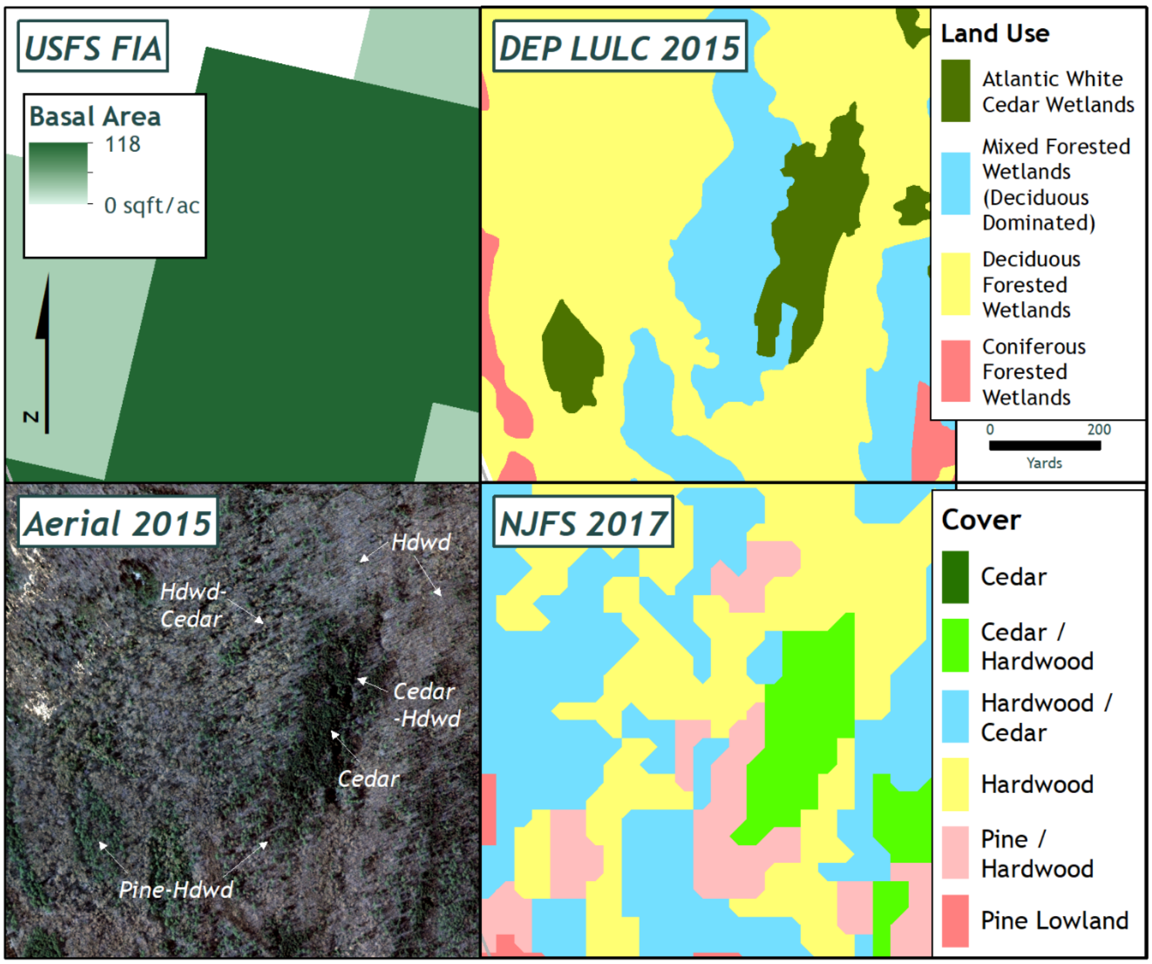


Figure 27: Comparison of methods for assessing cedar resources and restoration sites. Top left panel shows the 250m pixels of the USFS FIA raster, too coarse for siting. Top right is the DEP BGIS 2015 Land Cover data which shows cedar as occurring only in "Atlantic White Cedar Wetlands." Though mixed forests might be appropriate for restoration, there's no indication whether the conifer in them is cedar or pine. Bottom right panel is NJFS 2017 classification for this project, with cover types set by the proportion of species of management interest. Bottom left is a true-color aerial of the forest. Note the overgeneralized classes in the Land Use 2015 data: cedar and pine in mixed stands are confounded, and mixed wooded wetlands are not separated by which species of conifer is present.

restoration areas, significant shortcomings of each made it apparent that another method was needed to assess wetland forest resources of southern New Jersey.

The FIA raster data provides a basal area estimate (square feet per acre) for each inventoried species with 250m pixels at a nationwide scale. FIA raster data have the advantages of being validated, quantitative, and scalable with other classification systems. Unfortunately, the coarse pixel scale overlooks thin ribbons of cedar in the drainages of the Pinelands while identifying vast areas of cedar in uplands that don't actually exist. Raster products from FIA are derived from satellite imagery and are evaluated by USFS with tabular ground-based data. Those tabular data project 30,996 +/- 9,919 (68% confidence interval, 2018 data) acres of Atlantic white cedar forestland in New Jersey. This estimate comes from FIA inventory data collected on the ground between 2013-2018; the confidence interval means that based off of the FIA data, there's a 2/3 chance that the 'true' acreage of cedar in New Jersey is between 21,077 and 40,915 acres. These tabular estimates of cedar acreage are useful as a statistical evaluation of the acreage of the species in New Jersey, but the spatial representation of the raster data makes it unsuitable for planning.

NJDEP's BGIS created the 2012 Land Use dataset by comparing the 2007 Land Use dataset to 2012 color infrared aerial images and marking out areas that changed. This work was completed remotely by contractors in California under the oversight of BGIS. These data have the advantages of having high spatial resolution and being comparable over time, but methodological limitations undermine their utility for mapping the extent of Atlantic white cedar or suitable sites for restoration. For example, the only class label that includes the species is the "Atlantic white cedar wetlands" class, an inherently subjective classification. Although this class is intended to be pure cedar wetlands, mixed forests dominated by cedar, as well as forests where cedar is a relatively small component are treated the same. Further, there is no distinction of deciduous wetlands with a minor cedar component; both cedar and pine are lumped into the same coniferous category within "Mixed Wooded Wetlands (Coniferous Dominant)." This precludes straightforward attempts to isolate suitable work areas. The NJDEP 2012 Land Use data provide a cedar acreage estimate of 42,054 acres. The 2015 update reduces this slightly, to 41,878 acres.

Based on the determination that the existing FIA and NJDEP data sources would not be suitable for restoration choices, NJFS created its own assessment of the cedar resource tailored to this strategy. Given the site hierarchy established for successful restoration, we conducted a preliminary purpose-built method for rapidly classifying forested wetlands in the coastal plain into our site hierarchy. This spatial dataset was then used as a triage tool to locate wetlands on state land that might be suitable for Atlantic white cedar restoration.

4.1.b - NJFS 2017 Classification

The United States Geological Survey utilizes the Worldwide Reference System (WRS) to index images captured by the Landsat series of satellites, with WRS-2 used for Landsat 8. Two Landsat 8 image footprints cover southern New Jersey: Worldwide Reference System (WRS) -2, path 14 row 33, and path 14 row 32.

For each of these footprints, we retrieved a winter and summer Landsat 8 Operational Land Imager (OLI) scene from the Earth Explorer web interface (earthexplorer.usgs.gov/). At the time of downloading, USGS had already processed these to level 1T, or terrain-corrected images. We extracted the individual image bands and converted them to top-of-atmosphere reflectance using the formulae in the Landsat 8 Data Users Handbook (49) and the metadata for each image. Then, we stacked the individual image bands to create a multiband composite image for each scene, comprising OLI bands 2 through 7, or wavelengths from the visible to middle infrared portions of the spectrum. The two scenes per footprint were further stacked together into a composite image, with 12 total bands.

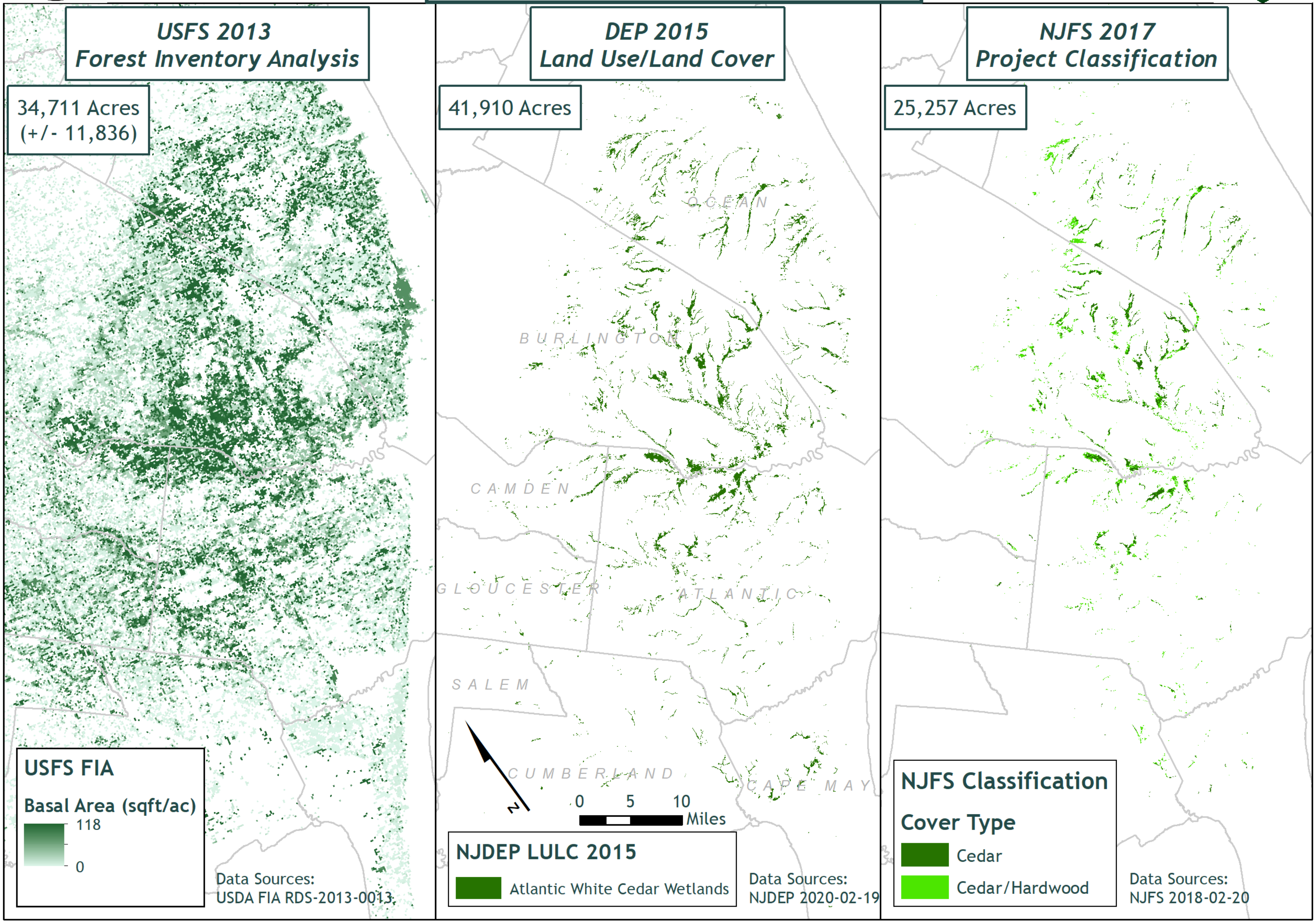
NJFS staff delineated training areas of varying sizes on each Landsat scene composite to use as references for a supervised classification of each footprint. The training areas corresponded to cover types of interest for this strategy (cedar/hardwood, hardwood/cedar, hardwood, etc.) as well as wetland types not being considered for restoration (open water, emergent marsh, pure cedar stands). We selected each training area by cross-referencing the satellite imagery with more spatially-detailed aerial imagery. Sufficient area was required for each training area so that the properties of that cover type could be evaluated statistically by band. After sufficient areas were collected, we combined them into fourteen separate 'signatures' sufficient to describe the land cover types in wetlands across the strategy area. We used the Supervised Classification module of ERDAS Imagine raster processing software (Hexagon Geospatial Inc. 2017) to classify each composite image. The parametric rule used was maximum likelihood, the non-parametric rule was parallelepiped, and for pixels that overlapped between classes or were unclassified initially, the parametric rule was used. The result was an image where each pixel was assigned the land cover type of the signatures that best corresponded to its spectral characteristics.

To only make classification predictions for wetlands, we selected the wetlands from the NJDEP BGIS Land Use 2012 layer. In addition, we looked to the Web Soil Survey (50) for New Jersey, and selected the following wetland soils: Atsion series, Berryland series, Fluvaquents series, and Manahawkin Muck series. Areas occurring in either the Land Use 2012 wetland layer or the above described soil series were then merged, with data were clipped to the extent of the two Landsat scenes, as well as to NJ. This layer was then used as a mask to clip the land cover classification from the Landsat data, which was first converted to a vector coverage from the original raster. This was further refined by running the elimination tool in ArcGIS to subsume any standalone spots of less than an acre into the cover type of the largest adjacent neighbor.

The result was fine-scale classification of the wetland land cover for all of southern New Jersey according to the project-oriented classification. For a coastal-plain-wide comparison of this method versus the existing datasets, see the map titled "*Atlantic White Cedar Extent: Contrasting Assessments*" on the following page, which compares the aforementioned assessments of the cedar resource.

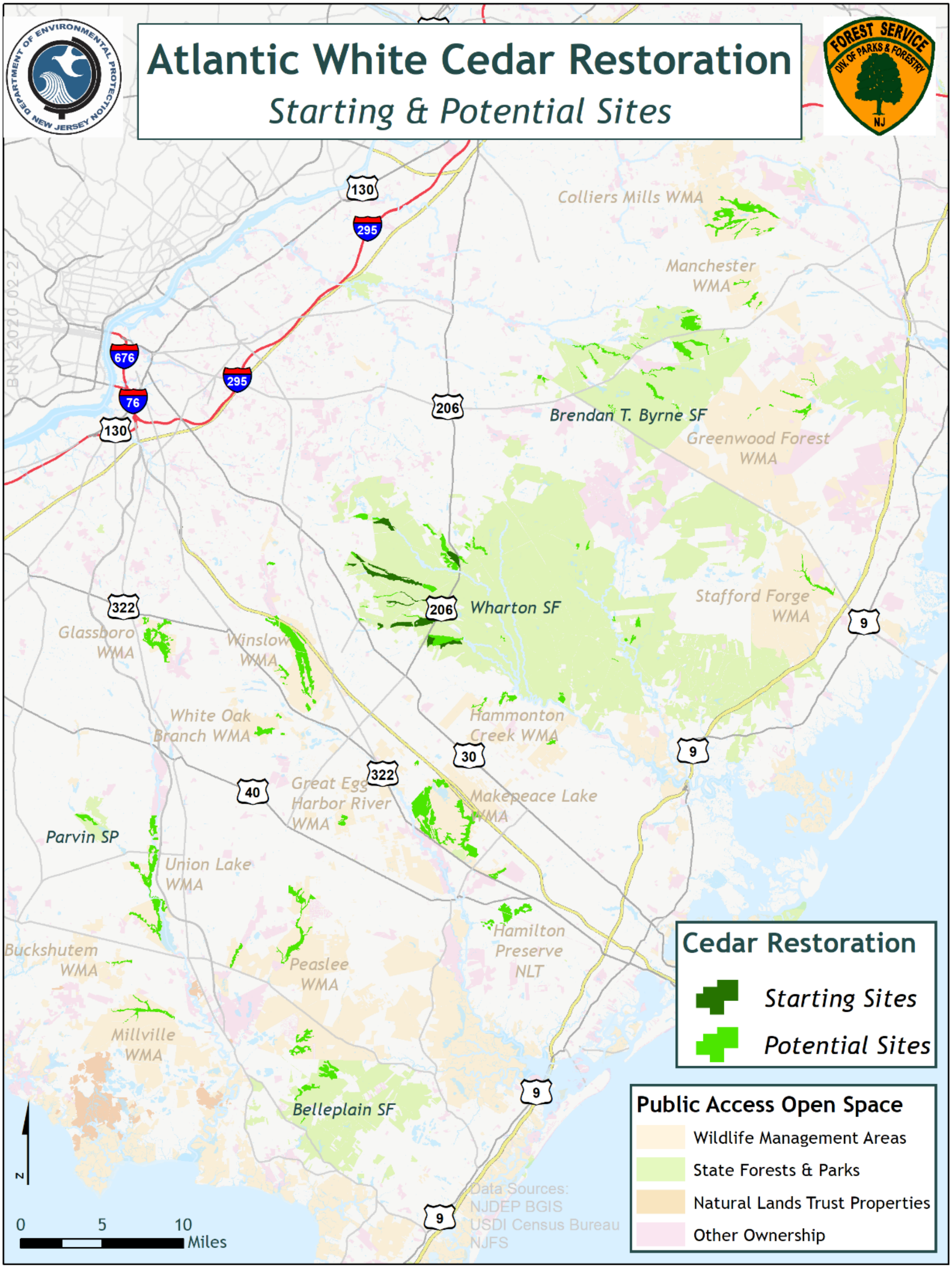
Atlantic White Cedar Extent

Contrasting Assessments



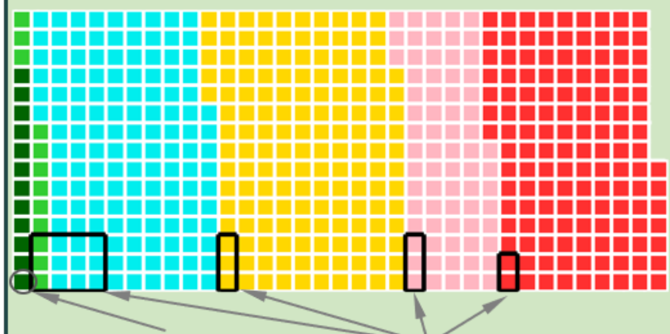
Atlantic White Cedar Restoration

Starting & Potential Sites



Atlantic White Cedar Restoration:
Proposed Acreage Breakdown

NJFS 2017 Classification



Each square represents 1,000 acres of wetland forest (this happens to be 1,000 acres of pure Cedar)

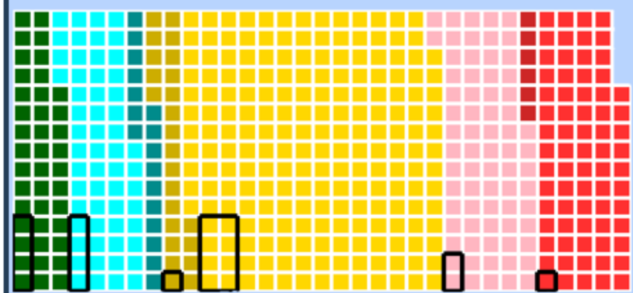
Black boxes represent all 21,000 acres proposed for cedar restoration. There may not be 21 black boxes due to rounding.

- Cedar
- Cedar/Hardwood
- Hardwood/Cedar
- Hardwood
- Pine/Hardwood
- Pine Lowland

Why are two systems being used? *NJFS used a separate classification system from the NJDEP Land Use data for project planning, but both are shown here for comparison. Early scouting indicated that the NJDEP Land Use categories were not sufficiently specific to discern conditions important for forest management choices.*

NJFS 2020-03-10

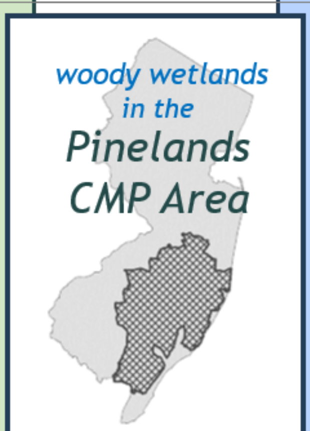
NJDEP Land Use 2015

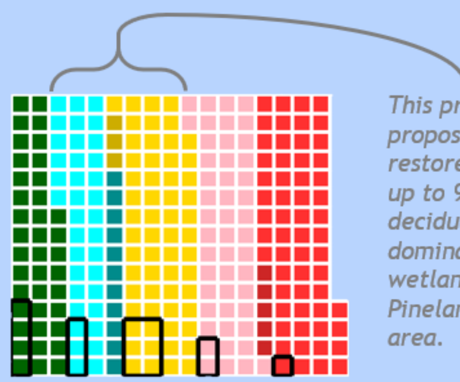


*The project goal is for 10,000 acres of restoration over ten years, so **only HALF of the black boxed areas will be affected**, and only the area equivalent of one box per year.*

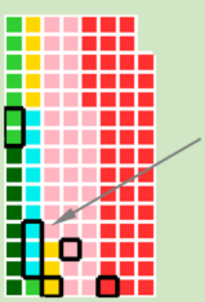
- AWC Wetlands
- Mixed Wooded Wetlands (Decid. Dom.)
- Mixed Scrub/Shrub Wetlands
- Deciduous Scrub/Shrub Wetlands
- Deciduous Wooded Wetlands
- Mixed Wooded Wetlands (Conif. Dom.)
- Coniferous Scrub/Shrub Wetlands
- Coniferous Wooded Wetlands

New Jersey Forest Service classification from 2017 shows there to be about 11,000 acres of pure Atlantic white cedar forest in the area covered by the Pinelands Comprehensive Management Plan

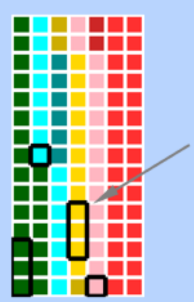




This project proposes to restore cedar in up to 9.7% of the deciduous-dominated woody wetlands in the Pinelands CMP area.



By NJFS's 2017 classification, about 3,000 acres of hardwood/cedar forest in the Pinelands Preservation Area are being considered for restoration of Atlantic white cedar



By DEP's Land Use 2015 classification, about 3,000 acres of hardwood forest in the Pinelands Preservation Area are being considered for restoration to Atlantic white cedar

5. Site Selection

After extensive discussion of concerns with stakeholders, as well as site visits to example project areas, roughly 22,000 acres were deemed suitable for further discussion, scattered from Belleplain State Forest to Colliers Mills Wildlife Management Area (see map titled *Atlantic White Cedar Restoration: Starting and Potential Sites* on page 36). These sites can generally be described as hardwood forest with a cedar component (cedar comprising between 10% and 50% of canopy), though the scale of mapping used shows many subsections that include mixed cover (see graphic titled *Atlantic White Cedar Restoration: Proposed Acreage Breakdown* on the previous page). NJFS and stakeholders purposely identified more than twice as much candidate acreage for the strategy than the 10,000 acre goal for restoration to ensure that there would be sufficient areas of agreement to meet the restoration goal. This extra acreage left room for partners to find agreement picking suitable sites with the most stakeholder consensus.

Stakeholders identified several thousand acres in western portions of Wharton State Forest as the most promising sites to begin restoration efforts, reflected in the map titled "Atlantic White Cedar Restoration: Starting and Potential Sites." Below are some of the technical concerns brought forward in the stakeholder process that helped to shape suitable locations.

5.1 - Sea-Level-Rise

Sites were initially selected using the NJFS 2017 cedar assessment as a guide. Once clipped to state lands, this spatial tool served as a guide towards wetland areas with promise for restoration: larger clusters of the cedar-hardwood and hardwood-cedar cover types. After a drainage was identified, we used LiDAR-derived hillshade images, soils data, historical aerials, and contemporary aerial imagery to select a portion that appeared suitable for management efforts.

Figure 28: Cedar forest recently killed by storm-driven saltwater inundation. Near Dennis, NJ, 2019. Source: B Isaacson, NJFS

Due to the increasing pace of sea-level rise as a result of climate change, stakeholders collectively decided to exclude low-lying coastal sites for restoration. We used sea-level rise data from the National Oceanographic and Atmospheric Administration (NOAA) to assess expected acreage losses against both the NJFS 2017 cedar assessment and the DEP Land Use 2015 data (Table 2). These data provide a useful estimate of future losses, but fail to capture the negative effects of storm surges on areas inundated with pooling salt water, widely-recognized as a peril for cedar (Figure 28).

We used storm surge data to ensure that this strategy does not expend effort restoring cedar on sites that will be lost to saltwater in the life of the new stand. Storm surge inundation data were obtained from the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model from NOAA to capture areas at risk of salt inundation (51). This made for a more conservative exclusion area than looking at sea-level rise alone. For the most part, we avoided areas that are predicted to be inundated at all, but we did include a handful of sites that are modeled to be affected by storm surge. In those sites, portions of work areas that will not be submerged by ten feet of sea level rise may be flooded by a direct hit from a category 4 hurricane.

Table 2: Projected losses of cedar forest acreage under different sea level-rise scenarios. Percentages shown are the percent of today's cedar acreage expected to be inundated for that amount of sea-level rise. For example, 6' of sea level-rise is expected to flood 5% of the current cedar acreage by the NJFS 2017 assessment. Expected sea level rise by 2100 is 2 to 6 feet (54). Starting acreages are different for NJFS 2017 data and NJDEP land use 2015 data due to differing methodologies in classification: areas with scattered or clustered but low amounts of cedar were not included in the NJFS assessment, while they were included in the Land Use 2015 total. NJFS analysis 2020-02-28, data from NOAA (https://coast.noaa.gov/slrdata/) (56). Localized losses are expected to be greater from additional storm surge depth but are not included here.

Sea Level Rise (feet)	NJFS 2017 Assessment (acres)			NJDEP Land Use 2015 (acres)		
	Dry	Inundated	%	Dry	Inundated	%
(Current, Modeled) 0	25,257	4	0	41,910	201	0
1	24,998	259	1	39,772	2,138	5
2	24,789	468	2	38,945	2,965	8
3	24,565	692	3	38,348	3,562	9
4	24,413	844	3	37,879	4,031	11
5	24,233	1,024	4	37,426	4,484	12
6	24,064	1,193	5	36,946	4,964	13
7	23,898	1,359	6	36,497	5,413	15
8	23,707	1,550	7	35,989	5,921	16
9	23,422	1,835	8	35,287	6,623	19
10	23,128	2,129	9	34,704	7,206	21

90% Confidence Interval (54)

5.2 - Rare Plants

Stakeholders brought forward general and specific concerns for rare plants. Cedar restoration brings both opportunities for new habitat as well as concerns over negative impacts to existing populations. For currently-known occurrences of rare plants, the extra acreage identified as possible for restoration was proposed in place of acres whose restoration might negatively impact a local population of rare plants. Several sites were removed or reshaped in light of known plant populations of concern.

Previous cedar restoration efforts conducted by NJFS have employed mitigating activities to enable cedar restoration activities on sites with known imperiled plant populations. In at least one case, a known population of swamp pink was temporarily covered with a waterproof tarp during aerial herbicide application, successfully protecting the rare plants and facilitating cedar restoration. Even on sites with known populations of rare plants, it is not clear that restoration should not proceed: what is clear is that those rare plants and their future should be considered as part of a balanced approach to restore cedar forests.

In contrast to concerns over the potential negative effects of management, cedar restoration can be beneficial to a rich diversity of native plants of the Pinelands that are dependent on disturbance (Figure 29). For instance, stakeholders noted that small lenses of pitch pine lowlands occurred within the boundaries of proposed sites; tree cutting and disturbance as part of restoration activities will provide habitat for rare plants on these lenses, but fighting nature to establish cedar seedlings on these drier sections would be detrimental. By cutting trees but avoiding planting/spraying these lenses, restoration actions could incorporate methods to benefit rare plants.

Figure 29: Diversity after cedar management. This rose pogonia (Pogonia ophioglossoides) was found in June of 2016 blooming amongst the sunny groundcover on a young, regenerating cedar stand. The area was aerially sprayed in August 2012 with the herbicide Imazapyr to control broadleaved competition. Wildfire 30 years prior had killed the cedar and pushed the site into hardwood shrubs, necessitating herbicide use. Source: B Isaacson, NJFS

Several stakeholders identified a desire to quantify the beneficial aspects of the strategy for rare plants. In an era of diminished disturbance of Pinelands forests, herbaceous species dependent on sunny woody wetlands have become less abundant. Cedar restoration will make growing space available for native plant species to grow amidst young forest conditions.

Pre-management rare plant surveys are planned as part of the restoration effort, both to search for populations that may require mitigation activities, as well as to document improvements in rare plant populations as a result of management. Surveys will provide a much-needed baseline for populations of species of interest in proposed restoration units. Such surveys are expected to be conducted through contract vendors, though stakeholders expressed interest in using survey efforts as a mobilization opportunity to harness the energy and interest of volunteers. Any volunteer surveys will supplement the work of trained, experienced surveyors for rare plants. At the time of writing, surveys are anticipated to search for federally endangered plant species, as well as those species on the List of Endangered Plant Species and Plant Species of Concern curated by the New Jersey Natural Heritage Program (10).

5.3 - Wildlife

Stakeholders identified three concerns regarding wildlife and Atlantic white cedar. There was concern over the impact of cedar restoration on barred owls (*Strix varia*) due to the theorized potential for home-range invasion by great horned owls (*Bubo virginianus*) following forest management activities. In contrast, there was concern over the impact of deer on cedar restoration, with high background levels of herbivory threatening success. Finally, stakeholders noted the disturbance provided by cedar restoration as being beneficial for disturbance-dependent insects.

5.3.a - Barred Owl

Figure 30: Juvenile Barred owl in tree cavity. Source: Vern Wilkins, Indiana University, Bugwood.org
https://www.forestryimages.org/browse/detail.cfm?imgnum=5497137

Stakeholders raised specific concerns about the impact of cedar restoration on barred owl populations for a subset of the proposed restoration areas, with more general interests for all sites. However, there was significant debate among stakeholders as to the impact of forest management on populations of this raptor. Habitat research suggests that barred owls prefer mature or older forests (52), likely the result of a greater availability of nest sites in these habitats (53) (54) (Figure 30). After the size of trees immediately surrounding the nest tree, proximity to a forest opening is the next most predictive habitat variable for the species, with owls choosing nests closer to forest openings (55). Indeed, recent work has shown that the raptors will continue to live in home ranges that include forest cutting, provided that suitable patches of old (and likely decadent) trees are left for nesting (56).

Though some authors have conflated human housing development with forest management (57) (58), housing developments have continuous pressure from the presence of humans that stands in contrast to the discrete event of a forest management activity. An interesting exception to the general unsuitability of human habitation for Barred owls is the population in Charlotte, North Carolina, where the birds occupy urban and suburban home ranges due to the availability of nest trees (59) (60). Regardless of their use of human-occupied habitat, forest managers can make choices for clumped retention around known nest sites and can choose to leave cavity trees of importance to these cavity-nesters.

Particularly for the Atlantic white cedar restoration strategized here, forest management activities that are not driven primarily by commercial interests have more flexibility in adjusting prescriptions to work with owls yet achieve forest management goals. Stakeholders expressed a desire to focus restoration efforts on forested wetlands that are younger or have smaller trees, conserving today's larger trees for future nest trees, a form of biological legacy. Areas of older hardwood forest will be considered a lower priority, when possible, with preference instead given to shrubby and younger sites.

NJFS looked to several data sources to assess the overlap of cedar restoration with Barred Owl in New Jersey. Barred owls are distributed from Alaska to Labrador, and Oregon to Florida, and are common across much of the continent. In New Jersey, Delaware, and Nebraska they are considered imperiled (61). Conversely, NatureServe shows that cedar is more abundant in New Jersey than elsewhere but is imperiled over the rest of its distribution. Breeding Bird Survey population trends for the species show that across the continent Barred Owl populations are rising, and though data are deficient for New Jersey on its own, the trend in our state is flat to somewhat positive (62). Data from the Landscape Project provide a method to quantify the overlap of management with habitat (Table 3) (63).

Table 3: Barred owl habitat availability and its overlap with proposed cedar restoration areas. NJFS analysis 2020-02-28, data from the New Jersey Landscape Project (61).

Barred Owl Habitat Type (Landscape 3.3)	Acres			% of Acres affected by Potential Cedar Sites	
	Statewide	Coastal Plain	Potential Cedar Sites	% of Statewide	% of Coastal Plain
Nesting	66,107	22,312	134	0.2%	0.6%
Breeding	1,242,076	811,252	18,826	1.5%	2.3%
Non-Breeding	787,944	441,270	7,378	0.9%	1.7%

Looking solely at the 'occupied breeding habitat' in New Jersey's coastal plain, there are roughly 19,000 acres of overlap with potential cedar restoration sites, translating to 2.3% of the total acreage for this species. At this time NJFS expects to conduct restoration activities over ten years on roughly 10,000 acres, or slightly more than half of the potential areas. If all 10,000 acres are treated over 10 years (and only happen in occupied breeding habitat for Barred owl) the overall proportion of the species' habitat in the coastal plain affected each year would be 0.12%, with a cumulative strategy total of 1.2%.

Atlantic white cedar restoration, like any natural resource management, should balance the needs of the creatures involved. For what has become a continentally scarce forest type, there must be balance with the needs of a locally-rare wildlife species; this reflects the debate amongst stakeholders as to the impact of forest management on Barred owls. While disagreement remained over some aspects of the strategy, there was widespread agreement on where and how to start conducting cedar restoration with respect to this avian species.

Stakeholders agree to several actions for restoration that would address possible adverse impacts to Barred owls. By starting in western Wharton State Forest, higher concentrations of known locations of the birds will be avoided. Throughout operational planning, NJFS will search for nests and keep track of decadent cavity trees. Where possible, NJFS will work to retain large-diameter hardwood trees as snags. Every effort will be made to conserve cavity trees of all species, though only cedar trees will be left alive after treatment. Hardwoods and pines with cavities will be killed using herbicide, girdling, or another similar method that keeps the trees standing. At this time there is no landscape-scale way to stratify sites by age, but project planning will include stand age and cavity tree conservation moving forward. These and other rare wildlife issues will continue to be addressed as we advance into other restoration areas, and NJFS is committed to listening to and working with all stakeholders throughout planning and implementation.

5.3.b - White-tailed Deer

Rampant and excessive herbivory from white tailed deer has been repeatedly raised as a concern for successful regeneration, as it has for land management in other portions of the state. Management actions to address deer herbivory can focus on decreasing the susceptibility of a site, or directly reducing pressure from deer. Examples of the former are site fencing and individual tree protection; examples of the latter include focal deer hunting and permissive regulations.

Figure 31: Example of deer browsing on greenbriar (Smilax spp.) at a potential cedar restoration site. Such browsing is a useful indicator of site-specific deer pressure. Source: J Dunn, NJFS

Fence installation and the use of tree tubes are expensive options to help a site regenerate, but they're not the only tools available for reducing herbivory. For sites large or small, leaving tangled masses of slash can protect seedlings from herbivory. Conducting activities on larger sites to locally overwhelm the deer population has also been suggested.

Experience in private land management suggests that above roughly 25 acres, deer herbivory is alleviated enough that sufficient seedlings will still regenerate the site rapidly. Though deer will eat the tops off of many seedlings, the expansiveness of the site provides more seedlings than can be browsed by the local deer population. Even if the deer population increases, the lag time of population growth takes longer than for the tops of cedar seedlings to grow taller than the deer can reach. Akin to the 'masting' strategy used by periodic cicadas, this idea holds promise. Many of the restoration sites were chosen with this size threshold in mind, but larger sites hold additional benefits, such as reducing proportional mobilization/demobilization costs, simplifying contracting, and reduced amounts of edge habitat.

Stakeholders also inquired about the possibility of reducing the local deer population through local hunts or focal deer management. NJFS will continue to work with stakeholders within and outside of NJDEP to explore options to increase local hunting to reduce herbivory. This may include working with game managers, hunting clubs, neighbors, or other groups to temporarily reduce the herbivory pressure on a freshly regenerating site.

Throughout planning and implementation NJFS staff will pay close attention to indicators of deer pressure for potential cedar sites (Figure 31). Signs of deer pressure can be noted from browse sign on palatable plant species.

5.3.c - Rare Arthropods

Figure 32: Hessel's hairstreak, a vulnerable butterfly species dependent on Atlantic white cedar, is expected to have long-term benefit from this project. Source: https://www.carolinanature.com/butterflies/hesselshairstreak.html

Stakeholders also brought up the effect of this strategy on rare insects. Many of the rare insect species of the Pinelands are dependent on disturbance and are rare in part because of the diminution of disturbance across the landscape. Forest management actions that put sunlight on the ground and encourage fresh, young growth of diverse herbaceous species will benefit these insects due to the habitat created. The host plants on which these insects depend will be able to flourish for a time after management, although such benefit is temporary. However, two rare Lepidopteran species, Hessel's hairstreak (*Callophrys hesseli,* Figure 32) and Lemmer's pinion moth (*Lithophane lemmeri*) (Figure 33) will receive longer-term benefit from cedar restoration, as both of these species are dependent on cedar.

Figure 33: Lemmer's pinion moth caterpillar. Source: Connecticut Agricultural Experiment Station,https://www.forestryimages.org/browse/detail.cfm?imgnum=1178079

5.4 - Wildfire

Stakeholders forcefully voiced concern about investment in the forest resource without accompanying investment in wildfire mitigation. Cedar swamps in the coastal plain often occur in the context of a landscape filled with pine forest; the ecology of these coastal pine forests is inextricably tied to fire. Consideration of the cedar resource without attention to the effects of damaging wildfire on that resource (Figure 34) gambles the longevity of restoration against stacked odds.

Figure 34: Wildfire that burned from adjacent upland down into cedar swamp, 2018. Burnt trunks had their crowns singed off; all cedars in this photo are dead. Source: B Isaacson, NJFS

NJFS approaches cedar restoration with the same landscape-scale holistic outlook that it intends to bring to the entire forest resource of New Jersey. To be successful in shifting the outlook for the cedar forest type, management efforts at many of the restoration units should be strategically paired with actions that reduce the wildfire risk in the surrounding uplands. NJFS and the New Jersey Forest Fire Service have worked in tandem for past cedar management projects, treating the adjacent uplands to reduce the risk of damaging wildfire.

This strategy will proceed with the same consideration of wildfire that is necessary for management of our pine forest landscape. The urgent need for broad-scale forest density management is discussed in the 2020 New Jersey State Forest Action Plan; the location of cedar restoration areas will certainly be included in the prioritization of density-management projects.

6. Conclusions

Atlantic white cedar forests are a wonder to behold. Currently, New Jersey is the last stronghold for dense stands of the species (Figure 35), yet even our cedar swamps are vastly diminished from historical levels. Cedar is important to the culture and ecology of the Pinelands, and its relative absence leaves an imprint from water chemistry, wildlife populations, the human economy, to even our perceptions of this landscape.

Figure 35: Cedar swamp in the Pinelands. Source: R Williams, Pine Creek Forestry

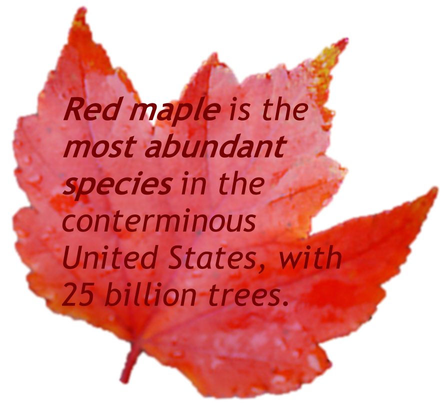
While we may quibble over an exact location or the placement of a boundary, throughout our discussions all stakeholders agreed that restoring cedar forest is an important and necessary action for responsible resource stewardship. As we progress with this strategy, all stakeholders agreed that it is important to move forward with the big themes on which we can agree: the important guiding principle of putting back what's lost.

Stakeholders view Atlantic white cedar restoration as a way to restore the integrity of Pinelands Forests and sustain this ecosystem into the future.

Natural resource management requires decisions that have real-world consequences. As independent systems, forests change whether we want them to or not. Choosing to take no action is still a deliberate choice with tangible consequences, not all of which are benign. Collectively, we choose to be active participants in restoring this forest environment.

Today's active choice is not ours alone. For decades conservationists and preservationists have agreed that restoring cedar is an important part of Pinelands stewardship. The Pinelands Comprehensive Management Plan states that forest management should, "encourage the establishment, restoration, or regeneration of Atlantic White Cedar in cedar and hardwood swamps…" (45). Similarly, the Pinelands Forestry Advisory Committee Recommended Forest Management Practices state that, "Cedar restoration is encouraged, but not limited, to sites where a preexisting cedar stand and degradation are evident." (64).

Red maple, prolific in the swamps that will be cut, is the nation's most numerous tree species, the northeast's most numerous tree species, and is increasing its presence on the landscape (65). In stark contrast, Atlantic white cedar, dependent on ever-diminished disturbance, has disappeared from much of its range in New Jersey, and much of its range along the east coast (21). Choosing to do nothing places too large a risk on the remaining cedar forests for stakeholders to accept. This strategy is a choice to sacrifice some acreage of maple-dominated forested wetlands to benefit Atlantic white cedar.



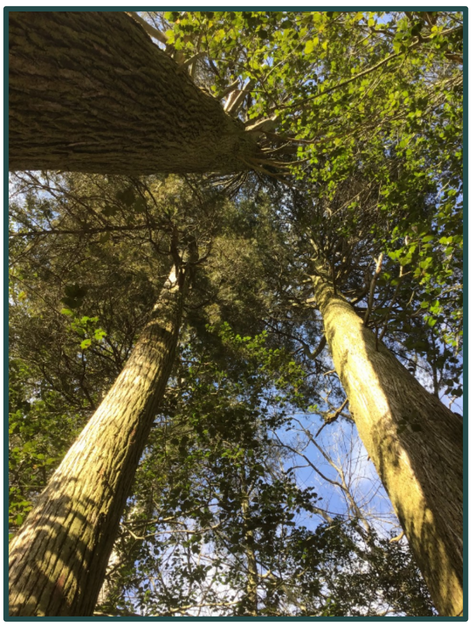


Figure 36: Giant cedars. Source: R Williams, Pine Creek Forestry

Cedar restoration achieves the tenets of faith for ecological forestry (66):

-It restores and sustains the integrity of forest and associated ecosystems;
-It reflects policies and practices that consider and sustain a broad array of ecosystem services through stakeholder engagement and participation;
-It is an adaptive process with many stakeholders who bring technical developments as well as the goals, priorities, and concerns of their constituencies; and
-It is an approach that reduces future risk to our forest assets and increases future options.

This strategy to restore Atlantic white cedar forests embodies the spirit of many of the intentions for publicly-shared forest resources. Our society is the steward of this forest, and the condition of the ecosystem is our legacy.

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