



**PROCEEDINGS OF THE
ECOLOGY and MANAGEMENT
of ATLANTIC WHITE-CEDAR:
SYMPOSIUM 2006
Atlantic City, New Jersey
June 6-8**

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Editor: George L. Zimmermann
The Richard Stockton College of New Jersey
Pomona, NJ

Assistant Editor: Diane Amico

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Preface

The 2006 Atlantic white-cedar symposium gave us a variety of insights into the fascinating puzzle of white-cedar and its ecosystems. During those few days in June 2006, participants heard 27 oral presentations from over 45 authors, saw 10 posters, and went on a variety of field trips to southern New Jersey to see short and long term experiments with white-cedar ecosystems. The breadth of the pieces of information presented underscored the need to view Atlantic white-cedar systems from all facets to truly understand and successfully restore, manage, protect and increase the acreage of these diminishing ecosystems.

Participants also saw some specially planned ‘summary’ talks by experts who explored the “state of the” white-cedar resource by geographic location, rare and endangered flora, wetland soils, and hydrologic models seen across the range of white-cedar.

In this publication we get a view of the resource through historical eyes (here in the paper by Timothy Morgan). Kalm saw the first wave of European alteration and destruction of North America, and it is crucial to understand all we can from this chapter in white-cedar’s saga. Knowing more of white-cedar’s past will help us to avoid the mistakes of the past and find ways to live on landscape level with a proper and balanced representation of functioning white-cedar ecosystems. Papers here by Belcher et al, and McCoy and Keeland, among others, give us insights into damage by hurricanes- a force which many think global warming will only enhance. Walbeck et al present evidence for the further decline of white-cedar in parts of Maryland and as a possible harbinger of rising sea-level impacts.

Given the threats, past, present and future, to the white-cedar resource it is even more important to understand its functioning, and develop strategies to restore and manage it. Mylecraine et al gives the reader the very basics about white-cedar’s range-wide genetics and a management strategy to preserve, maintain, and enhance the species. The paper by Hall helps us to further understand the hydrologic complexities seen in a white-cedar ecosystem - while papers by Pickens, Stowe et al, and an abstract by Hinesley give us important information on various aspects of white-cedar restoration. Finally the paper by Smith demonstrates the complexities of accomplishing white-cedar restoration in a world where ecological, social, economic and political considerations all must meet.

Printed here is only a sample of the impressive expanse of studies concerning this species that participants saw at the 2006 Symposium. I urge you to go to the Atlantic white-cedar web pages site I maintain for our community (<http://loki.stockton.edu/~wcedars>) and there you can see the complete list of topics and presenters at the 2006 Symposium, plus much more information on white-cedar.

George L. Zimmermann
Editor, Co-chairman 2006 White-cedar Symposium Planning Committee
Professor of Environmental Sciences
The Richard Stockton College of New Jersey

TABLE OF CONTENTS

PEHR (PETER) KALM AND ENVIRONMENTAL CHANGE IN THE MID-EIGHTEENTH CENTURY Tim Morgan.....	1
SPECIES COMPOSITION AND HURRICANE DAMAGE IN AN ATLANTIC WHITE CEDAR STAND NEAR THE MISSISSIPPI/ALABAMA BORDER John W. McCoy and Bobby D. Keeland.....	8
THE EFFECT OF PLANTING DENSITY ON THE GROWTH AND YIELD OF ATLANTIC WHITE-CEDAR-THIRD YEAR RESULTS Bill Pickens.....	21
ATLANTIC WHITE CEDAR REGENERATION IN THE GREAT DISMAL SWAMP FOLLOWING HURRICANE ISABEL: 2006 BLACKWATER CUT RESULTS Robert T. Belcher, Travis R. Comer, and Robert B. Atkinson.....	23
DEVELOPING MANAGEMENT AND RESTORATION REGIONS FOR ATLANTIC WHITE-CEDAR BASED ON PATTERNS OF GENETIC VARIATION Kristin A. Mylecraine, George L. Zimmermann, John E. Kuser, Lena Struwe and Peter E. Smouse.....	35
MANAGING ATLANTIC WHITE CEDAR AT DARE COUNTY BOMBING RANGE: HISTORY, HOPES AND ASPIRATIONS Scott B. Smith.....	50
ATLANTIC WHITE CEDAR SALVAGE EFFORTS IN THE GREAT DISMAL SWAMP FOLLOWING HURRICANE ISABEL Robert T. Belcher and Bryan Poovey.....	59
A PRELIMINARY ANALYSIS OF THE HYDROLOGIC REGIME AND WETLAND PLANT COMMUNITIES OF THE MANCHESTER CEDAR SWAMP Kimberly P. Hall.....	71
CYPRESS CREEK SAVANNA: A HISTORY OF VEGETATIVE CHANGES David E. Walbeck, Keith R. Underwood and Karl D. Benedict.....	86
ATLANTIC WHITE CEDAR RESTORATION IN SOUTH CAROLINA: EFFECT OF FALL PLANTING DATE ON GROWTH AFTER 2 YEARS IN THE FIELD Johnny Stowe, Eric Hinesley, Mike Wicker, Jamie Dozier, and James Sizemore.....	91
CULTURAL PRACTICES FOR CONTAINERIZED ATLANTIC WHITE CEDAR L. Eric Hinesley and Scott Derby.....	99

PEHR (PETER) KALM AND ENVIRONMENTAL CHANGE IN THE MID-EIGHTEENTH CENTURY

Tim Morgan

Morgan, Tim, Associate Professor of History (Ret.), Christopher Newport University
Newport News, VA, 23606
[8057 Tuckerman Lane, Potomac, MD 20854 (home)]

Abstract—This paper reviews the two-year visit of the Swedish botanist Pehr (Peter) Kalm to colonial North America, with general focus on his analyses and insights into deforestation in the Delaware River valley and particular attention to his comments on Atlantic white cedar (*Chamaecyparis thyoides*).

Keywords – Atlantic white cedar, *Chamaecyparis thyoides*, settlers, exploitation, deforestation, shingles, Delaware River valley, environment, Peter Kalm

INTRODUCTION

Environmental scientists wrestle with the problem of environmental restoration, one of the central questions being how to decipher what an environment might have looked like. A second, related issue concerns to what time do the restorers want to get the environment. Lack of historical sources is one key issue regarding such restoration. Few historical sources address the issue, except in passing perhaps. Historians interested in past environments must dig deep, although there is more evidence of what past environments looked like the closer one gets to the present. For environmental questions, however, an excellent source is the narrative of northeastern North America left by the Swedish scientist Pehr (Peter) Kalm. His work contains a wealth of material related to what the Delaware River valley looked like while he was in it, plus he reported much of what it had looked like decades before.

In fall 1748, Kalm arrived in Philadelphia after a long journey from his native Sweden, through England to North America. He spent the next two years in North America, traveling and collecting in the Delaware, Hudson, and St. Lawrence River valleys, and visiting Niagara Falls. He wrote notes and discourses on all aspects of his travels, publishing it in the 1750s, with an English translation appearing in 1770. In his publications about his travels, Kalm referred repeatedly to environmental changes Europeans had made since their arrival a little over a century before. His primary mission was to find trees and shrubs adaptable to his native Sweden, but his insights into the consequences of European intrusion and settlement into those regions form a substantive ethnographical and botanical record of northeastern regions of North America around 1750, a record much broader than his mission would indicate. He discussed what he thought were the reasons for the changes he saw in the analyses he included in *Travels*. He paid specific attention to those regions where Europeans had cleared major portions of the forests as they settled into the valley. His insights into deforestation's effects indicate a shrewd, observant, intelligent mind. He focused on Atlantic white cedar, devoting a number of pages to his analysis of the consequences of widespread clearing of the tree in the freshwater swamps in the Delaware valley.

NORTH AMERICAN FORESTS AND THEIR CULTURAL IMPACT

North American forests totaled about 1 billion acres when Europeans began their invasion of the continent about 1600 (Achenbach 2002; Floyd 2002). Since then, most of those forested acres have been cut over at least once (Achenbach 2002; Floyd 2002). In the United States today, few old growth forests remain, those uncut since European intrusion. Into the early 17th century forests, however, came an increasing number of Europeans who soon began repopulating themselves through natural means rather than immigration. The immigrants from the Chesapeake Bay to New England used the timber they found in a variety of ways. For them, the trees they found were a treat. European period narratives describe species, possible uses, and qualities of trees as the narrators hiked through the forests. While calling the forests wildernesses, they usually commented on the deer-park like quality of

the woods they traversed. Kalm mentions repeatedly in his *Travels* his concerns about what he thought were the wasteful abuses of forests in the Delaware valley (Kalm 1964). By 1600, a large percentage of Europe's forests had been leveled, and used for everything from firewood to building material to charcoal for smelting iron to shipbuilding. For example, with the exception of the King's forests in England, most English forests had been cut. Woodlots and small groves of trees remained, but the forested woodlands of early medieval England were gone by 1600. In colonial North America, the same wasteful practices (cutting without reforestation, etc.) began almost as soon as the English arrived. In Virginia, the very first cargoes sent to England by the first settlers at Jamestown were loads of wood from sassafras and cedar (perhaps Atlantic White) trees.

Eighteenth-century Europeans and Indians both regarded forests as dark and forbidding places. Indians of colonial Pennsylvania used a rite called "At the Woods' Edge" in which travelers, after passing through forests to visit Indian towns, were cleansed of evils they might have acquired on their journeys through the woods. As James H. Merrell reminds his readers in *Into the American Woods*, we still have regard for "the woods' ancient power." We still use words like "bewildered;" someone who is new to something is a "babe in the woods," and someone who is quite ill is "not out of the woods" (Merrell 1999: 23). Forests also had positive meanings for natives. They supplied Delaware River Native-Americans with game, fish, and wild fruits, nuts, vegetables, and roots to supplement the maize, beans, squashes, and pumpkins they cultivated. Forests gave the native peoples shelter and fresh land for planting when their old lands gave out. Delaware River valley natives used the river and its surrounding forests for food, medicines, and raw materials for shelter and warmth.

When Europeans (Swedish and Dutch traders and fur merchants) came into the Delaware valley, they pressured the local natives, the Lenni Lenape or Delaware Indians, to trade lands and furs for European manufactured goods like pots, pans, cloth, beads, bells, and weapons, especially guns, powder, and ammunition. Between 1630 and 1730, Delaware natives bartered extensively with the Swedish, Dutch, Finnish, and English newcomers. By 1730, the English, particularly, had displaced large numbers of the Lenni Lenape and cleared tens of thousands of forested acreage along the Delaware River shorelines. The complexities and demands of trade among the European and Indian peoples dwelling in the area put new pressures on the plants and animals native to that river valley.

PETER KALM, HIS *TRAVELS*, AND ENVIRONMENTAL CHANGE

When Pehr (Peter) Kalm arrived in North America, he was 32. Born March 6, 1716, he died November 16, 1779. He grew up in Ångermannland, Sweden. With his parents, Gabriel and Catherine Ross, a Scotswoman, Kalm had taken refuge there from the Great Northern War (1700-1721). Sweden and Finland were joined at that time. Kalm was well educated in sciences, especially biology. He traveled extensively as a young man, visiting Russia, Sweden, Ukraine, and North America. As a student of Linné's, he was chosen to go to North America to undertake the research into the flora of the continent. Although schooled in the sciences, he was also an ordained Lutheran minister like his father and, while in the Delaware valley, served as pastor in a Swedish-Finnish Lutheran church. In 1750, he married a widow while in North America. When he returned to Sweden, he taught at Åbo Academy until his death in 1779. He wrote numerous articles on his botanical research in North America, had many graduate students, and directed their research along lines he developed from his North American expedition.

When Kalm came to Philadelphia in fall 1748, he brought with him letters of introduction, most notably to Benjamin Franklin, who introduced him around the city. After a brief rest, he began exploring the Delaware River valley, collecting as he went. He noted there were few conifers, mostly deciduous hardwoods forming a canopy under which one could ride even in a carriage. He saw oaks, chestnuts, walnuts, locusts, apples, and hickories. He noted blackberry bushes as he traveled with Peter Cock, born in Karlskrona, Sweden, who had Anglicized his name. Kalm noted farms strung out along the roads and paths he traversed those early days of his visit. He mentioned a few red cedars he saw on a trip to Wilmington, Delaware, but made no mention of Atlantic white cedar (Kalm 1964).

Kalm's biological education had reached its fruition when Karl Linné took an interest in him in the 1730s. Born Carl von Linné in Stenbrohult, Sweden, on May 23, 1707, Linnaeus, as he is generally known, developed a love for plants under his father's tutelage. His father, a Lutheran minister who loved gardening, passed on his love of plants to his son. Called the Father of Taxonomy, he trained many botanists, Kalm included, and sent them on extensive collecting expeditions. He was responsible for the selection of Kalm for the mission to North America.

Kalm's ideas about the environment, and humans' manipulation and change of it, derived more from his biological than theological educations. Although an ordained Lutheran minister, he saw the hand of man more than the hand of God in environmental change. Enhancing his observations and studies of the flora and fauna of the valley was his ability to communicate directly with the older Swedes and Finns who had settled there. Several older Scandinavians had come in the last quarter of the 17th century, thus having lived in the valley for 60, 70, or 80 years. In the *Travels*, Kalm refers repeatedly to his conversations with older settlers, but, unfortunately, he seldom identifies them by name. He wrote down the conversations and used them as additional evidence to go with his own observations. Memories may not be as accurate as written documents, but written sources may be skewed for the purposes for which they were written. In a preliterate or semi-literate culture, however, memories are often much sharper and more accurate than those of a literate culture that relies on written sources.

In November 1748. Kalm noted for the first time the consequences of European assault on the forests of the Delaware valley. He discussed the collapse of the valley's wild game bird population. The disappearance of wild cranes and the near-extinction of turkeys he attributed to a number of factors:

1. clearing so much habitat land along major rivers and their tributaries
2. wholesale killing of hens and fledglings
3. taking eggs in enormous numbers
4. wholesale killing of birds (taking way more than necessary for food or feathers) (Kalm 1964).

Kalm said that a hunter could walk for more than eight hours looking for turkeys and never even spot one, let alone kill one. Eighty years before, he asserted, hunters could fill their larders in a few hours. Consequences for the settlers were dramatic, Kalm asserted. Loss of so many bird populations opened niches for many other species, among them jackdaws (grackles) and other inedible birds who feasted on the corn and other small grains European farmers planted in the newly-cleared fields. Squirrel populations also exploded in number, themselves also feasting on the grains and garden patches settlers created. He predicted that as Europeans continued clearing forest lands, populations of unwanted birds and animals would likewise continue to explode in numbers (ibid).

Kalm's work in North America merited his recognition, as far as Linné was concerned. As the great biologist worked his way through the many examples Kalm sent him from North America, he began naming plants for his student. He named one plant genus for Kalm, a genus that contains mountain laurel species. The number of mountain laurel cultivars has grown dramatically since the colonial era. There are at least 42 separate cultivars of mountain laurel attributed to Richard Jaynes, a Connecticut plant breeder, alone (Brand 1997-2001)

For Kalm, the assaults on forests in the Americas led to the too-rapid depletion of wood stocks. The extensive trade network that had grown up between Pennsylvania and the English West Indies (supplemented by smuggling and other forms of illegal trade between Pennsylvanians and French, Dutch, and Spanish West Indian colonies) exploited West Indian woods as part of that trade, especially West Indian mahogany. Kalm affirmed that most West Indian mahogany had been used up by 1750. From the Delaware valley, large quantities of naval stores, especially tar taken from New Jersey pine forests, had left Philadelphia for English and colonial shipyards. Colonists had taken so much tar that "the forests of which [New Jersey] province are consequently more ruined than others" (Kalm 1964).

Another of Kalm's environmental insights related to gray wolves. He thought that laying out farms singly in the Delaware valley, rather than clustering the houses into hamlets and villages, had as much to do with the absence of wolves and other important predators as the deliberate killing of them. He wrote that wolves have migrated "since they encountered houses everywhere, and people fired at them" (Kalm 1964). The constant cutting of new roads further destroyed faunal habitat, Kalm argued. He said that colonial roads were free (few tolls, few brigands), but they were not well cared for. More to the point, however, he called attention to the fact that as more and more roads were built through forests, forests were cut into smaller and smaller segments, a road building consequence still argued today.

Kalm also interviewed prominent figures in Philadelphia. He was particularly interested in discussing with John Bartram, one of the great naturalists of the time, his views on environmental change since the beginnings of European settlement in the valley. In September 1748, Kalm asked Bartram if he thought substantial drying out of the climate had taken place, and Bartram said definitely. He pointed to many pieces of evidence to support his reply. He said water mills built sixty or seventy years before always had plenty of water when constructed. The last few years, he noted, required great rainfalls or heavy snow melts in order for there to be sufficient water for operation. Kalm concluded from Bartram's comments that forest clearing was a primary factor in climate desiccation. He wrote

“the diminution of water in part arises, from the great quantity of land which is now cultivated, and from the extirpation of great forests for that purpose” (Kalm 1964). Kalm did not, however, know about the dramatic change in climate known as the Little Ice Age, a period of cooling in the Northern Hemisphere that lasted from about 1300 until about 1850. That climate change may have played a potent role in the climatic changes occurring in the Delaware valley, but forest destruction was also an important factor (Fagan 2000).

For over 300 years European farmers had used water meadows as a means of getting hay for their winter fodder. Europeans coming to North America brought with them the techniques and methods of farming learned at home. Husbandmen created water meadows by running streams and brooks into fields on which they could grow water grasses suitable for winter fodder. Delaware River valley farmers diverting water sources from their natural stream and river beds into water meadows contributed further to desiccation going on in the valley, Kalm noted. He wrote “summer continues for seven months here. The inhabitants seldom fail to use a brook or stream in this manner (for water meadows), if it is not too far from the meadows” (Kalm 1964). Farmers usually mowed their meadows three times during the summer, Kalm commented, due to the constant supply of water to maintain rapid growth. Confirming his insight were his interviews with older Swedes and Finns who told him that they could remember times when there was much more water, and that there were many more lakes, ponds, brooks, and streams that had dried up in the last several decades. An old Swede, who had anglicized his name to King, reported that there were many ponds and lakes on which he had rowed as a young man, but were now dried up. He stated that many fish died as the bodies of water dried out (Kalm 1964). From all this evidence that he saw and discussed with colonists, Kalm evidently concluded that the forests, which Euro-Americans were so busily clearing, presented many advantages, including holding water in the soil and keeping air humidity up. The desiccation he saw around him, he believed, derived from misuse of the forests and woods. Although native populations made extensive use of woodlands—building their homes, firewood, burning to make “deer parks,” as examples—their impact was minimal on forested regions. They had adapted their lives to their environments, while Euro-Americans wrestled the environment to their specifications.

KALM AND ATLANTIC WHITE CEDAR

If Kalm understood generally what settlers did environmentally, one of his specific examples was Atlantic white cedar (*Chamaecyparis thyoides*). Called in colonial sources white cedar, cedar, juniper (Chesapeake Bay southward), or false cypress, the tree was used heavily. Since it grows best in freshwater swamps, it is not yet known how Euro-Americans found it, but presumably local natives, who made use of the tree for everything from canoes to shingling for their homes, showed the settlers where the tree was. By the time Kalm visited North America, colonists used the tree for the following: fence poles, roof shingles, cooperage (barrels, pails, butter churns, buckets, for example), siding, interior paneling, crates, fencing, boxes, and boat construction. Lightweight, rot-resistant, easily worked, and fragrant, the wood finished well.

There existed a debate between Swedish and English botanists when Kalm came to North America over the proper name of the tree. Swedes believed it was a juniper, calling it white juniper. The English called it white cedar. Kalm, following Swedish tradition, named the tree *Cupressus thyoides*, but later changed to its current name in the 19th century, *Chamaecyparis thyoides* [(L.) B. S. P.] (Kalm 1964). The name debate evidently was important to the intellectual circle that included Kalm when he stayed in Philadelphia.

The City, founded in 1681, was the capital of William Penn’s colony, Pennsylvania. His aggressive promotion of the city and colony in the German Rhineland, England, and Wales lured substantial numbers of European peoples to his colony by 1700. By 1700, the colony’s European population numbered 20,000 and Philadelphia had about 4,000. By 1750, the city was close to being the largest in population in the colonies.

Philadelphia and several other towns in the Delaware valley had used Atlantic white cedar as roofing shingles. Kalm reported that large numbers of public and private buildings had used the roofing since settlement began. So much cedar had been used for roofing and other purposes that “swamps and morasses formerly were full of them, but for the present these trees are for the greatest part cut down and no attempt as yet has been made to plant new ones “ (Kalm 1964). Colonial builders liked the shingles because they were lightweight, decayed less rapidly than any other shingle wood in the area, and were easily riven. They had a life expectancy of about 40-50 years. Use of them lightened roof weights and meant that expensive slates or tiles did not have to be imported from Europe. Kalm

measured bearing walls and found that using white cedar shingles meant builders could halve their thickness. Walls that in Europe would measure 18" thickness of brick were being built 9-10" in thickness due to the lighter roofs.

Although Kalm stated that many roofs in Philadelphia were built using Atlantic white cedar, research has so far found only two buildings that might have AWC shingles (Kalm 1964). One, Stenton, -James Logan's house, has definitely been identified as having AWC; another in the city seems to have them, judging by the appearance of the roof in illustrations. Stenton, built in the 1720s, was the home of Pennsylvania's Secretary, James Logan. Logan was a Welshman who came to the colony at Penn's request. He became one of the most powerful political leaders of the colony, often challenging Penn himself before Penn's death in 1718. Stenton was located just outside the City's original boundaries, but since then has been incorporated into the town limits. A two story brick house built in the Georgian fashion, the house was restored in the 1970s and early 1980s. When the restorers reached the third floor, they found a stash of Atlantic white cedar shingles stored under the floor boards, confirming the use of AWC as roof shingles in its construction. The shingles were still in good shape, though probably not useable for roofing.

One of Kalm's singular contributions to the study of Atlantic white cedar was his use of dendrochronology to obtain an idea of the tree's growth rates and years to maturity. He measured three AWC tree trunks (table 1). From his measurements, he concluded that AWCs needed about 80 years from sprouting to maturity. He wrote that colonials "are not only lessening the number of these trees, but are even extirpating them entirely. People are here (and in many other places) in regard to wood bent only upon their own present advantage, utterly regardless of posterity" (Kalm 1964). He evidently had some fondness for AWC because he devoted much less time to other trees. For no other tree did he do dendrochronology, and for no other tree did he provide such a complete catalogue of its uses.

CONCLUSION

Kalm's insights into Euro-American abuses of Atlantic white cedar echoed his dissension with what he regarded as colonists' generally wasteful uses of forests and wood. Colonials had used so much wood in the Delaware valley since the 17th century that they were scrambling to find new ways of building fences that did not require wood. Kalm's sensibilities reflect his scientific education and training. He wondered in his *Travels* about the effects Euro-Americans were having on the forests and environments of the Delaware valley. He thought that in pursuit of their own self-interest or happiness, they committed many follies. Rampant exploitation of natural resources, consequences of overuse of everything natural like trees, game birds, rivers, streams, and pools led, he thought, to the environmental changes he witnessed and reported.

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Table 1—Kalm's Atlantic white cedar dendrochronology.

Tree Number	Trunk Diameter	Number of Rings
1	18 inches	102
2	17 inches	116
3	24 inches	142

SPECIES COMPOSITION AND HURRICANE DAMAGE IN AN ATLANTIC WHITE CEDAR STAND NEAR THE MISSISSIPPI/ALABAMA BORDER

John W. McCoy and Bobby D. Keeland

General Biologist and Ecologist, USGS, National Wetlands Research Center
700 Cajundome Blvd., Lafayette, LA 70506

Abstract --Atlantic white cedar (*Chamaecyparis thyoides*; cedar) can be found growing naturally as individual trees or small stands in 5 coastal or near coastal counties in Mississippi. The majority of cedar stands in the state are located along river and stream channels in Jackson County, near the Alabama border. One of the larger stands is located along Interstate 10, near the Mississippi Welcome Center, on the Grand Bay National Wildlife Refuge. This area was heavily impacted by flooding and wind damage from Hurricane Katrina in August 2005, with many trees snapped or uprooted. We conducted a study on Grand Bay NWR to determine the composition and structure of the cedar stand and to examine the level of hurricane damage on the site. The living cedars (usually less than 30 cm but up to 64.8 cm dbh) were restricted to sandy soils along a narrow slope, swamp, natural levee, and river edge. Tree species found on the site, in order of relative importance, include swamp titi (*Cyrilla racemiflora*), water tupelo (*Nyssa aquatica*), swamp tupelo (*N. biflora*), sweetbay (*Magnolia virginiana*), loblolly pine (*Pinus taeda*), red maple (*Acer rubrum*), cedar, bald cypress (*Taxodium distichum*), water oak (*Quercus nigra*), American holly (*Ilex opaca*), buckwheat tree (*Cliftonia monophylla*), southern magnolia (*Magnolia grandiflora*), and swamp bay (*Persea palustris*). High winds associated with Hurricane Katrina affected at least 32 % of the cedar trees on the site. Eight percent were snapped, 5 % were uprooted, and 19 % were leaning. Most of the damaged cedar trees were in the larger diameter classes. Periodic burning in an adjacent pine stand occasionally affects cedar trees along the border between the two stands.

Keywords – Atlantic white cedar, *Chamaecyparis thyoides*, Mississippi, Hurricane Katrina, Gulf Coast, flooding, witches broom, canopy, wind, sea level rise, Grand Bay National Wildlife Refuge

INTRODUCTION

Atlantic white cedar (*Chamaecyparis thyoides* (L.) B.S.P; cedar) is known to exist along the Mississippi Gulf Coast, yet little information is available on the distribution or dynamics of these stands. Some limited information on the occurrence of cedar along the Gulf Coast was provided by Korstian and Brush (1931), but these data were more anecdotal than quantitative. Little (1950) reported that most of the cedar may have been logged from the area. Eleuterius and Jones (1972) provided the only quantitative data on cedar stands in Mississippi in their description of a stand on Bluff Creek near the town of Van Cleave. Clewell and Ward (1987), Ward and Clewell (1989), and Laderman (1987, 1989) presented data on cedar stands in Florida, Alabama, and Mississippi, but their coverage of Mississippi was taken from Eleuterius and Jones (1972). McCoy and Keeland (2003) reported on several cedar locations in southern Mississippi. They found that the majority of cedar stands were associated with the Pascagoula and Escatawpa rivers or their tributaries, in Jackson County ([figure 1](#)). A more rigorous determination of cedar stand structure and dynamics is presented here to further define and quantify the role of cedar in the present day coastal Mississippi forest landscape.

Site Description

The Grand Bay study site is located on Grand Bay National Wildlife Refuge, about 10 km from the Gulf of Mexico and less than 10 km west of the town of Pascagoula, in Jackson County, Mississippi (U.S. Fish and Wildlife Service 2006; [figure 1](#)). The site is about 1.5 km northwest of the Mississippi Welcome Center, with the Escatawpa River forming the north boundary, a dredged canal to the west, a small pine savannah to the southeast and Interstate 10 to the south ([figure 2](#)). The pine savannah is situated about 3 to 4 m above a small cypress-tupelo (*Taxodium distichum*)

(L.) Rich., *Nyssa aquatica* L.) swamp, with cedar trees distributed along the slope between the savannah and swamp. A large number of cedar trees are also found on the natural levee along a tidally influenced portion of the Escatawpa River. The pine savannah is managed by the refuge and has been recently burned. The cedar swamp is not actively managed according to recent conversations with refuge personnel.

Soils on the site are of a sandy nature, grading from a Maurepas muck at the river to an Axis mucky sandy clay loam in the swamp and slope. The savannah is a Wadley loamy sand. All of these series are strongly acidic soil types. Significant amounts of sand have been deposited in the northeast corner of the site near the water's edge where many living cedar are found. Dredge spoils up to 2 to 3 m high along the canal have, on occasion, impounded water in the central swamp.

Climate in the area is hot and humid during the summer with mild winters. The average low is 3.9° C (39.1° F) and the average high is 32.1° C (89.7° F). Killing frosts are rare in this area. The 30-year average precipitation is 170 cm (67 in) at Pascagoula. During June of 2006 the site was in an extreme drought (CLIMVIS 2006). However, the drought state is variable through time with the site averaging normal precipitation to marginal drought for the last 250 years (Cook and others 1999).

METHODS

Vegetation Measurements

Canopy trees were sampled along five belt transects, each 10 m wide and of variable length (21 to 110 m), extending down the slope and toward the Escatawpa River. Transects were situated to capture the distinct zones of the site, including slope, swamp, levee, and water's edge. Slope transect lengths were highly variable from 10 to 50 m in length as determined by the elevation gradient. Slabs from cedar trees recently killed by fire in the pine savannah were removed for approximate age determination. All trees greater than 2.5 cm encountered within the belt transects were measured for diameter at breast height (140 cm, dbh) and evaluated for tree vigor. Vigor is a class measure (1 is excellent condition to 6, a snag) of the trees health. Ten-square-meter shrub plots were placed at 10-m intervals along transects, and all woody species less than 2.5 cm dbh were counted and classed by height. Herbaceous vegetation was sampled for percent cover by species using 1-m² plots placed at 10-m intervals along the transects.

All individual cedar trees at the site (including those not on transects) were counted pre- and post- Hurricane Katrina. Each tree was measured for dbh, vigor, level of infestation with witches broom (*Gymnosporangium ellisii*), generalized habitat type (slope, swamp, levee, and water's edge), evidence of fire, and if the tree was split into two or more distinct tree stems. The location of each cedar tree was also recorded by GPS. Witches broom was subjectively classed as none observed, minor only in smaller branches, major on main branches, and conservative estimates were made.

Water levels within the swamp were recorded with an Infinities USA water level data logger. The water level well was installed according to the methods of Sprecher (2000), and was situated at the top of the slope adjacent to the swamp. Stage data for the Escatawpa River at the Interstate 10 highway bridge, near the southwest boundary of the study site, were obtained from the U.S. Geological Survey (USGS) (gage number 0248018020). Surface water salinities were measured with a conductivity meter (Model 30, YSI Inc., Yellow Springs, OH, USA) and obtained from the aforementioned USGS gage.

RESULTS AND DISCUSSION

The most important influences that govern cedar occurrence at the site were topography and hydrology. Many cedar trees were found growing along the water's edge. Water levels at the site were influenced by flow in the Escatawpa River, tidal fluctuations ([figure 3](#)), and the by the integrity of the dredge spoil bank along the canal that formed the western boundary of the study site. A recent breach in the dredge spoil levee, however, has allowed water levels in the swamp to drop. The site is perched 0.5 m above the Escatawpa River and the majority of the cedars were not flooded during most of the current study. Short-term flooding events that coincided with high flow on the river inundated the lower stem of many cedar trees. In addition, seepage of water downslope from the pine savannah provided sufficient moisture to support many large cedar trees. The pine savannah remained wet enough to support many typical bog species, even during drought conditions. Many gullies that were cut into the slope remained

especially wet throughout the study. Lower water levels in the swamp, which may have resulted from the breaches in the dredge spoil levee, and any resultant lowering of the local water table, could result in increased invasion of woody species, not only into the swamp, but also into the adjacent areas of the levee and slope. Conversely, higher water stage on the river related to sea-level rise could jeopardize growth and survival of many of the cedar.

Trees and Shrubs

The forest canopy at the Grand Bay study site was primarily composed of species other than cedar ([table 1](#)). Cedar had a limited importance value (IV, importance value explained in [table 1](#)) of only 19.6 out of 300 total, but the importance of cedars varied depending on location within the site. Larger cedars were found along the slope (IV=21.3) while smaller cedars were located in the swamp (IV=12.1). Only 22 percent of live cedar stems were found in the swamp, and 50 percent were found on the levee next to the river. Cedar stems ranged from 2.9 to 64.8 cm dbh and had a quadratic mean diameter of 25.3 cm. Diameter distribution of cedars show a predominance of stems in the 10-15 cm range ([figure 4](#)). Less than 5 percent of cedars counted in the transects were less than 6 cm dbh. This disproportionate low number of small cedar could impact future cedar regeneration. A total of 299 cedar stems was found growing across the site, and an additional 110 dead stems were observed. Twenty-nine percent of the dead stems were lying on the ground while the remainder was still standing. The largest dead cedar was 55.9 cm dbh. Many cedar trees were also found growing on the pine savannah. These cedar trees were usually less than 30 cm dbh and were found primarily in the northeast part of the site, within about 50 m of the slope. The majority of cedars on the pine savannah and several along the slope had been killed by fire. In some cases the stems did not seem damaged by the fire, but apparently the cambium heated sufficiently to kill the trees as reported by Korstian and Brush (1931).

The most important tree species on the site included swamp titi (*Cyrilla racemiflora* L.), water tupelo (*Nyssa aquatica* L.), swamp tupelo (*Nyssa biflora* Walt.), sweet bay (*Magnolia virginiana* L.), loblolly pine (*Pinus taeda* L.), red maple (*Acer rubrum* L.), and cedar. These seven species combined have an importance value of 220 (of 300, [table 1](#)). All of these species with the exception of water tupelo are found throughout the site, and are commonly associated with cedars along the Gulf of Mexico and the East Coast of the United States (Laderman 1989). Water tupelo was found only in the swampy parts of the site along with baldcypress and green ash (*Fraxinus pennsylvanica* Marsh.) and a few scattered cedars. Cedar trees growing in the swampy, permanently flooded zones of the site were found on slightly more elevated land than most of the surrounding area in the swamp. The most common species across the site was swamp titi, which was found along the lower edge of the slope, through the levee zone and along the water's edge. Buckwheat trees (*Cliftonia monophylla* (Lam.) Britt. ex Sarg.) formed clumps, primarily along the edge of the swamp and along the water's edge. Cedar trees were also found clinging to the water's edge, sometimes with their bases submerged in the river. The river's edge has changed over time through the processes of erosion, sedimentation, and sea-level rise, and these cedars may have been established under different conditions than now observed. The swamp bay, sweetbay, red maple, and swamp tupelo were found mostly in the slightly better drained areas along the slope and levee.

The tree species observed at this site are mostly common native trees found throughout the Southeastern United States. Some trees may be under represented in the data because of the low number of transects or the short length of some transects. The most notable example of an under represented species was live oak (*Quercus virginiana* L.). Much of the upper portion of the slope and onto the pine savannah, especially near the southern end of the site, was dominated by live oaks as well as the monocot saw palmetto (*Serenoa repens* (Bartr.) Small). Witch hazel (*Hamamelis virginiana* L.), was also relatively common but was not counted in any transects or plots. This may have been due to the clumpy distribution and small diameters of witch hazel. One camphortree (*Cinnamomum camphora* (L.) J. Presl.), an aggressive invasive, was found in transects. This tree has the potential to become more pervasive across the site, but the native swamp titi and buckwheat trees are aggressive competitors that may hold the camphortree in check.

Witches broom (*G. ellisii*), a rust that alternates between cedar and wax myrtle (*Morella cerifera* L.), was observed on 33 percent of the cedar trees. A similar proportion of dead cedar trees (31 percent) were found with witches broom. W.H. Snell and N.O. Howard (as cited in Korstian and Brush 1931) reported that this rust can kill young cedar trees in Rhode Island. Although it may seem reasonable to expect that rusts would be more virulent in the South, no trees at the Grand Bay study site were found to have a severe infestation of witches broom. In fact, most

trees at the Grand Bay study site that were infected with witches broom were only minimally affected. How much this disease affects the vigor of individual cedar we counted at this site is unknown.

Dredging the canal and the construction of Interstate 10 certainly had an effect on cedar at the site. Dredge spoils from the canal afforded cedar new areas to colonize, yet few cedar were found on dredge spoils along the canal. Many mature cedar, however, were growing on a high dredge spoil mound at the confluence of the canal and the Escatawpa River, at the northwest corner of the study area.

Saplings and Seedlings

Few shrubs were observed on most parts of the study site. At least one third of the site consisted of swamp, where flooded conditions appear to be limiting sapling establishment. The dense canopy limited light penetration to the ground and potentially limited survival of shrubs on the levee. The slope supported a relatively dense growth of shrubs (59 percent shrub composition) even though the relative area of slope was small. The shrub layer included many young stems of the canopy species ([table 2](#)), indicating that many of these tree species are regenerating at this site.

The most common shrubs were species of holly (*Ilex* L.), primarily large gallberry (*Ilex coriacea* (Pursh) Chapman), at 49.1 stems per ha. Other species included swamp titi, coastal doghobble (*Leucothoe axillaris* (Lam.) D. Don), blueberry (*Vaccinium* L.), and buckwheat tree at 27.9, 25.2, 15.9, and 15.3 per ha respectively. The remainder of the saplings combined made up less than 30 stems per ha.

Only 8.0 percent of the saplings found were cedar (15 per ha), and only one seedling was found in the herbaceous vegetation quadrates. Flooding would have limited the growth of cedar seedlings in the swamp, while dense shade would have limited their growth on the levee. Numerous first-year and second-year cedar seedlings were observed along the forest edge, near the top of the slope. Cedar seedlings presence is encouraging, but their long-term survival is questionable due to the incidence of fire on the pine savannah.

Herbaceous

Overall there were few species and individual plants at the herbaceous plant level. The herb layer consisted primarily (99%) of tree/shrub seedlings, woody vines, or small woody plants ([table 2](#)). Areas along the slope had less canopy cover, but these areas did not reflect a much greater abundance of herbaceous plants. The slope is oriented to the northwest and away from the sun in the morning. During the afternoon, the slope is shaded by the trees growing in the adjacent swamp. In all, very few herbaceous plants were encountered, with only sparse amounts of sedges, grasses, ferns, violets (*Viola* L.), and Carolina spider lily (*Hymenocallis caroliniana* (L.) Herbert) observed in the quadrates. Many quadrates had large amounts of bare ground or leaf litter.

Hurricane Katrina

A storm surge associated with Hurricane Katrina increased water levels on the study site by as much as 4 m, as shown by the Interstate 10 gage. Flooding caused by the surge lasted for about one week. Exact water levels at the study site could not be determined, as the surge overtopped and damaged the water-level recorder. Along with the depth of water, a surge in conductivity to 2,600 micro siemens per centimeter, or 1.56 ppt (parts per thousand), salinity impacted the cedar stand. Salinity at concentrations as low as 0.4 ppt have been shown to impact cedar seedlings (Sedia and Zimmerman 2006 in press). Although the storm surge may not have directly killed cedar, the high water combined with the salinity surge may affect seedling growth (Derby and Hinesley 2003) and decrease vigor of mature trees.

High wind during Hurricane Katrina caused extensive damage within the cedar stand. The site was within the 104 km (65 mile) per hour sustained wind field (unpublished USGS data). Thirty two percent of the cedar trees were damaged ([figure 2](#)) with 8 percent snapped, 5 percent uprooted, and 19 percent leaning as a result of the winds. The diameter of cedar affected by Hurricane Katrina was, on average, about 4 cm larger at 26.7 cm than the mean cedar stem size for the site. Several trees along the Escatawpa River may have been damaged through a combination of wind and storm surge.

Slightly more trees along the slope were damaged, possibly because of less protection from wind related to the openness of the pine savannah. Many trees lost limbs or were blown down during the hurricane, allowing more light to reach the ground. More light available in canopy gaps may give the cedar seedlings and saplings an increased chance of surviving (Clewel and Ward 1987). Observations of this site following Hurricane Katrina revealed cedar seedlings on the slope. These seedlings could be found scattered in open areas as well as among debris left from the tree limbs downed from the hurricane. Logging slash has been shown to be a detriment to the establishment of cedar (Korstian and Brush 1931, Zimmermann 1995), and so long-term survival of these new seedlings is questionable.

Another factor concerning the establishment of cedar may be the presence of herbivores. White-tailed deer (*Odocoileus virginianus*) are known to predate cedar in its northern range (Zimmermann and Mylecraine 2003), and deer tracks were visible on trails into the site. It is unknown to what extent deer or other herbivores impact cedar seedlings, seedlings, or saplings in Mississippi. We do know that the cedar planted in an area used by a hunt club in St. Tammany Parish, Louisiana, had a greater than 95 percent survival rate after 10 years (McCoy and others 1999). Perhaps deer along the Gulf Coast either do not have the search image for cedar, or it is not a preferred food.

CONCLUSIONS

The stand at Grand Bay NWR is a healthy forest with a relatively small proportion of cedar. The general lack of cedar seedlings and saplings, however, is troubling. For many years now any cedar seedlings that germinated have not survived, probably due to heavy shade produced by the canopy and long-term flooding in the swamp. Cedar trees that successfully invade onto the adjacent pine savannah have a doubtful future due to controlled burns that sometimes extend down onto the slope. As such, with limited regeneration, the future of cedar in the stand is questionable. The relatively low number of cedar stands along the Gulf Coast, combined with the low proportional composition of cedar within those stands has resulted in little attention from local forest products companies. The stands are not targeted for harvest, but then again, they are not necessarily protected either.

Damage to the forest caused by Hurricane Katrina may be a benefit to cedar. Opening of the canopy may help cedar regeneration, especially along the slope. The presence of cedar seedlings on the slope following the hurricane is encouraging. Although witches broom appears to be damaging many of the cedar trees, it does not indicate a serious problem. Most trees seemed able to remain healthy in spite of the infestation. Cedar trees weakened by Hurricane Katrina continue to be exposed to the spores of witches broom and it may be possible that the level of infestation will increase. It seems unlikely that this fungus will cause serious loss of vigor for most of the cedars, but this issue does warrant further investigation.

As sea-level rise continues, cedar trees growing along the water's edge may be impacted, and the overall proportion of cedar in the stand could decrease. Again, this issue needs further study to determine the long-term sustainability of cedar along the Northern Gulf of Mexico Coast. Perhaps, as more information regarding cedar stands in this area is made available, greater interest could develop and result in focusing the needed resources to further research on this uncommon community type.

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Table 1--Stem densities, basal areas, relative frequency, density, dominance, importance values, and quadratic mean diameters (QMD) of canopy trees (> 2.54 cm dbh at 140 cm above the ground) encountered on the transects. The key to species for the symbol codes (Kartesz and Meacham 1999) can be found in Table 2. Measurements are on a per hectare basis. Relative frequency is the percentage a species occurred in plots, relative density is the number of stems of each species divided by the total stems for all species, and relative dominance is the percentage basal area each species occupies as compared to the total basal area. Importance values (IV), the sum of the relative frequency, density, and dominance, has an overall sum of 300. Species with greater sums are assumed to be more central to stand composition and function.

Symbol code	Stems / ha	Basal area m ² / ha	Freq.	Relative Den.	Dom.	IV	QMD (cm)
ACRU	188.8	1.865	11.2%	7.9%	3.8%	22.9	11.2
CHTH2 (CEDAR)	89.3	4.472	6.7%	3.8%	9.1%	19.6	25.3
CHVI3	17.2	0.044	0.6%	0.7%	0.1%	1.4	5.7
CICA	3.4	0.010	0.6%	0.1%	0.0%	0.7	6.2
CLMO2	48.1	0.356	3.9%	2.0%	0.7%	6.7	9.7
CYRA	923.4	2.964	13.4%	38.9%	6.0%	58.3	6.4
DIVI5	17.2	0.123	1.1%	0.7%	0.2%	2.1	9.5
FRAXI	13.7	0.179	1.7%	0.6%	0.4%	2.6	12.9
ILOP	92.7	0.226	5.0%	3.9%	0.5%	9.4	5.6
ILEX	6.9	0.005	1.1%	0.3%	0.0%	1.4	3.2
LIST2	3.4	0.375	0.6%	0.1%	0.8%	1.5	37.3
MAGR4	44.6	0.768	2.2%	1.9%	1.6%	5.7	14.8
MAVI2	171.6	2.794	10.6%	7.2%	5.7%	23.5	14.4
MOCE2	6.9	0.009	0.6%	0.3%	0.0%	0.9	4.2
NYAQ2	274.6	10.922	10.1%	11.6%	22.2%	43.8	22.5
NYBI	140.7	8.270	6.1%	5.9%	16.8%	28.9	27.4
PEPA37	27.5	0.138	3.4%	1.2%	0.3%	4.8	8.0
PITA	99.6	7.974	2.8%	4.2%	16.2%	23.2	31.9
QUHEH	24.0	0.250	3.4%	1.0%	0.5%	4.9	11.5
QULA3	17.2	0.149	2.2%	0.7%	0.3%	3.3	10.5
QUNI	37.8	2.497	3.9%	1.6%	5.1%	10.6	29.0
QUVI	6.9	0.086	1.1%	0.3%	0.2%	1.6	12.6
TADI2	58.4	4.593	5.0%	2.5%	9.3%	16.8	31.7
VAEL	6.9	0.006	0.6%	0.3%	0.0%	0.9	3.4
VACCI	34.3	0.084	1.7%	1.4%	0.2%	3.3	5.6
VAST	20.6	0.037	0.6%	0.9%	0.1%	1.5	4.8
Total	2375	49.2	100.2%	100.0%	100.1%	300.3	

Table 2--List of species found at the Grand Bay site, organized by plant group (herbaceous, shrub, or tree). The column T/S/H indicates if a species was found in a tree / shrub, sapling, and/or herbaceous plot. Tree or shrub species found in more than one of the plot types shows the possibility of regeneration from seedling to tree. Plants with no indication in the T/S/H column are known to be at the site but were not counted in any of the plots.

Symbol code	T/S/H	Group and Family	Species	Common name
Herbaceous Species				
CAREX	--/--/H	Cyperaceae	<i>Carex</i> spp.	Sedge
HYCA9	--/--/H	Liliaceae	<i>Hymenocallis caroliniana</i> (L.) Herbert	Carolina spiderlily
OSCI		Osmundaceae	<i>Osmunda cinnamomea</i> L.	Cinnamon fern
SAAL4		Sarraceniaceae	<i>Sarracenia alata</i> Wood	Yellow trumpets
SEAP	--/--/H	Selaginellaceae	<i>Selaginella apoda</i> (L.) Spring	Meadow spike-moss
VIAF2	--/--/H	Violaceae	<i>Viola affinis</i> Le Conte	Sand violet
VIOLA	--/--/H	Violaceae	<i>Viola</i> spp.	Violet
WOAR	--/--/H	Blechnaceae	<i>Woodwardia areolata</i> (L.) T. Moore	Netted chainfern
Shrubs				
CIEA4	T/--/--	Fabaceae	<i>Cercis canadensis</i> L.	Redbud
CHVI3	T/--/--	Oleaceae	<i>Chionanthus virginicus</i> L.	Fringetree
CLAL3	--/S/--	Clethraceae	<i>Clethra alnifolia</i> L.	Coastal sweetpepperbush
CLMO2	T/S/--	Cyrillaceae	<i>Cliftonia monophylla</i> (Lam.) Britt. ex Sarg.	Buckwheat tree
CRATA	--/S/--	Rosaceae	<i>Crataegus</i> L.	Hawthorn
CYRA	T/S/H	Cyrillaceae	<i>Cyrilla racemiflora</i> L.	Swamp titi
HIVI4		Hamamelidaceae	<i>Hamamelis virginiana</i> L.	American witchhazel
HYHY	--/S/--	Clusiaceae	<i>Hypericum hypericoides</i> (L.) Crantz	St. Andrew's-cross
ILCA	--/S/H	Aquifoliaceae	<i>Ilex cassine</i> L.	Dahoon
ILCO	--/S/H	Aquifoliaceae	<i>Ilex coriacea</i> (Pursh) Chapman	Large gallberry
ILGL		Aquifoliaceae	<i>Ilex glabra</i> (L.) Gray	inkberry
ILSP	T/--/--	Aquifoliaceae	<i>Ilex</i> L.	Holly
ILLO		Aquifoliaceae	<i>Ilex longipes</i> Chapman ex Trel.	Georgia holly
ILOP	--/S/H	Aquifoliaceae	<i>Ilex opaca</i> Ait.	American holly
ILVO		Aquifoliaceae	<i>Ilex vomitoria</i> Ait.	Yaupon
LYLI	--/S/--	Ericaceae	<i>Lyonia ligustrina</i> (L.) DC.	Maleberry
LYLU3		Ericaceae	<i>Lyonia lucida</i> (Lam.) K. Koch	Shinyleaf
MOCE2	T/S/--	Myricaceae	<i>Morella cerifera</i> (L.)	Wax myrtle
ROCA7		Ericaceae	<i>Rhododendron canescens</i> (Michx.) Sweet	Mountain azalea
RHCO	--/S/--	Anacardiaceae	<i>Rhus copallinum</i> L.	Winged sumac
SERE2	--/S/--	Arecaceae	<i>Serenoa repens</i> (Bartr.) Small	Saw-palmetto
VAAR	--/S/H	Ericaceae	<i>Vaccinium arboreum</i> Marsh.	Tree sparkleberry
VAEL	--/S/H	Ericaceae	<i>Vaccinium elliotii</i> Chapman	Elliott's blueberry
VACCI	--/S/--	Ericaceae	<i>Vaccinium</i> L.	Blueberry
VAST	--/--/H	Ericaceae	<i>Vaccinium stamineum</i> L.	Deerberry
VAVI2		Ericaceae	<i>Vaccinium virgatum</i> Ait.	Smallflower blueberry
Trees				
ACRU	T/S/H	Aceraceae	<i>Acer rubrum</i> L.	Red maple
CHTH2	T/S/H	Cupressaceae	<i>Chamaecyparis thyoides</i> (L.) B.S.P.	Atlantic white-cedar
CICA		Lauraceae	<i>Cinnamomum camphora</i> (L.) J. Presl	Camphor tree
DIVI5	T/--/--	Ebenaceae	<i>Diospyros virginiana</i> L.	Common persimmon
FRAXI	T/--/--	Oleaceae	<i>Fraxinus</i> L.	Ash
FRPE	T/S/H	Oleaceae	<i>Fraxinus pennsylvanica</i> Marsh.	Green ash

FRPR	T/--	Oleaceae	<i>Fraxinus profunda</i> (Bush) Bush	Pumpkin ash
LIST2	--/S/--	Hamamelidaceae	<i>Liquidambar styraciflua</i> L.	Sweetgum
MAGR4	T/S/--	Magnoliaceae	<i>Magnolia grandiflora</i> L.	Southern magnolia
MAVI2	T/S/--	Magnoliaceae	<i>Magnolia virginiana</i> L.	Sweet-bay
NYAQ2	T/--	Nyssaceae	<i>Nyssa aquatica</i> L.	Water tupelo
NYBI	T/S/--	Nyssaceae	<i>Nyssa biflora</i> Walt.	Swamp tupelo
PEPA37	T/S/--	Lauraceae	<i>Persea palustris</i> (Raf.) Sarg.	Swamp bay
PITA	T/S/--	Pinaceae	<i>Pinus taeda</i> L.	Loblolly pine
QUFA	--/S/--	Fagaceae	<i>Quercus falcata</i> Michx.	Southern red oak
QUHEH	--/S/--	Fagaceae	<i>Quercus hemisphaerica</i> Bartr. Ex Willd.	Darlington's oak
QULA3	--/S/--	Fagaceae	<i>Quercus laurifolia</i> Michx	Laurel oak
QUNI	T/--	Fagaceae	<i>Quercus nigra</i> L.	Water oak
QUVI	--/S/--	Fagaceae	<i>Quercus virginiana</i> P. Mill.	Live oak
TADI2	T/--	Taxodiaceae	<i>Taxodium distichum</i> (L.) L.C. Rich.	Bald-cypress
BICA	--/--/H	Bignoniaceae	<i>Bignonia capreolata</i> L.	Crossvine
SMBO2	--/--/H	Smilacaceae	<i>Smilax bona-nox</i> L.	Fringed greenbrier
SMLA	--/--/H	Smilacaceae	<i>Smilax laurifolia</i> L.	Laurel-leaf greenbrier
SMRO	--/--/H	Smilacaceae	<i>Smilax rotundifolia</i> L.	Horsebrier
TORA2		Anacardiaceae	<i>Toxicodendron radicans</i> (L.) Kuntze	Eastern poison-ivy
TRDI	--/--/H	Apocynaceae	<i>Trachelospermum difforme</i> (Walt.) Gray	Climbing-dogbane
VITIS	--/S/H	Ericaceae	<i>Vitis</i> L.	Grape

Figure 1--Location of known cedar stands in Mississippi, including the Grand Bay study site.

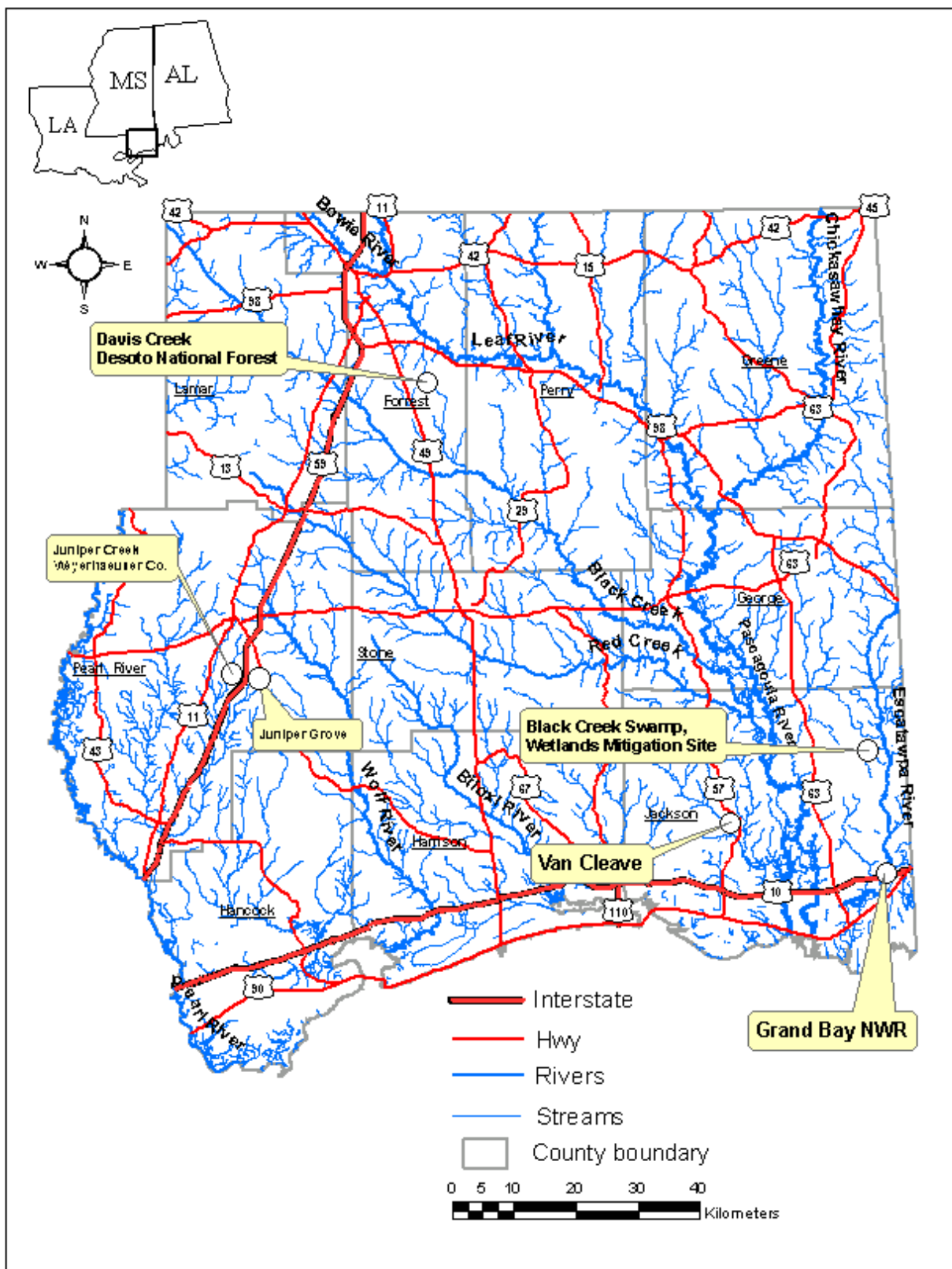


Figure 2--Locations of cedar trees at the Grand Bay NWR study site. Live, dead, and Hurricane Katrina damaged cedar trees are marked. The area mostly devoid of cedar is the cypress-tupelo swamp. The study area is ~ 4.7 ha. The relative size of the circles indicates relative dbh. Contour lines are at ~ 0.75 m (2.5 feet).

Figure 2. Locations of cedar trees at the Grand Bay NWR study site. Live, dead, and Hurricane Katrina damaged cedar trees are marked. The area mostly devoid of cedar is the swamp. The study area is ~ 4.7 ha. The relative size of the circles indicates relative dbh. Contour lines are at ~ 0.75 m (2.5 feet).

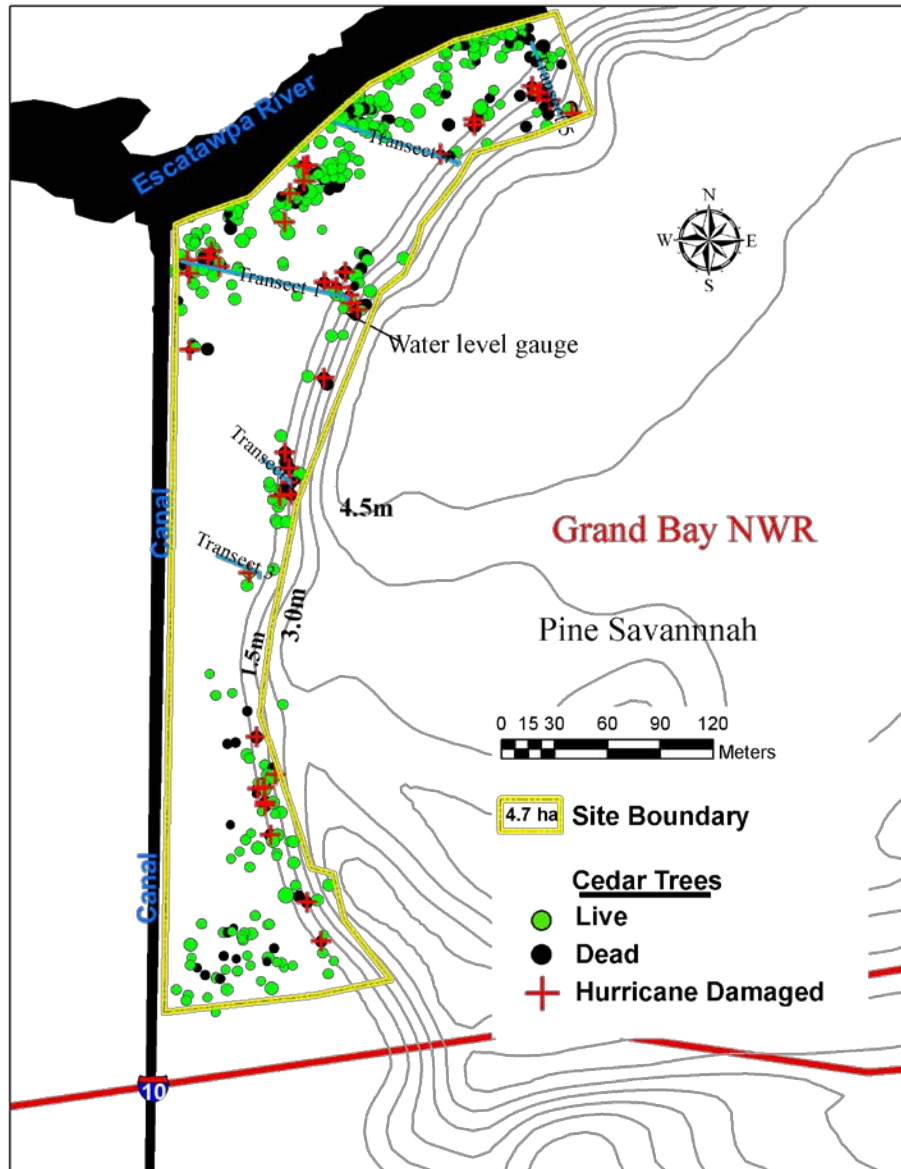


Figure 3--Water levels at the Grand Bay study site (black line) and at the Interstate 10 bridge over the Escatawpa River (gray line).

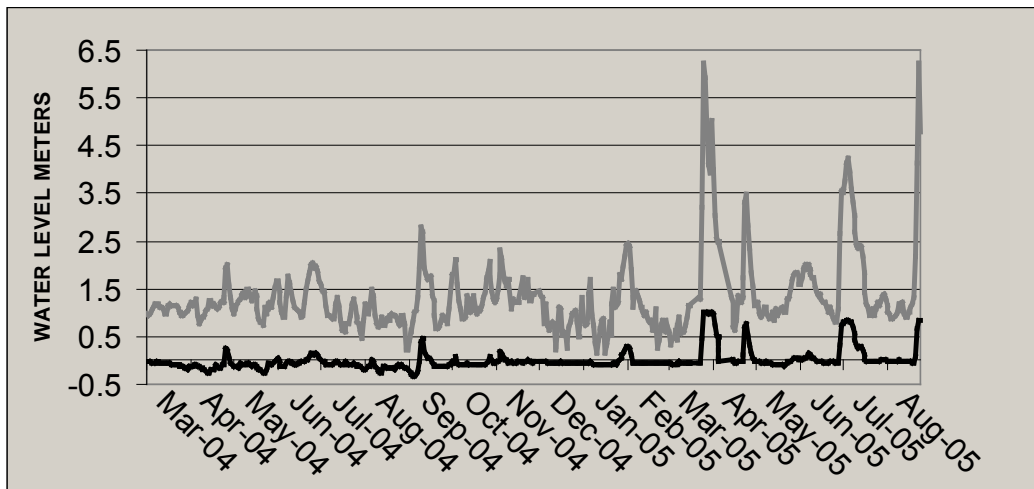
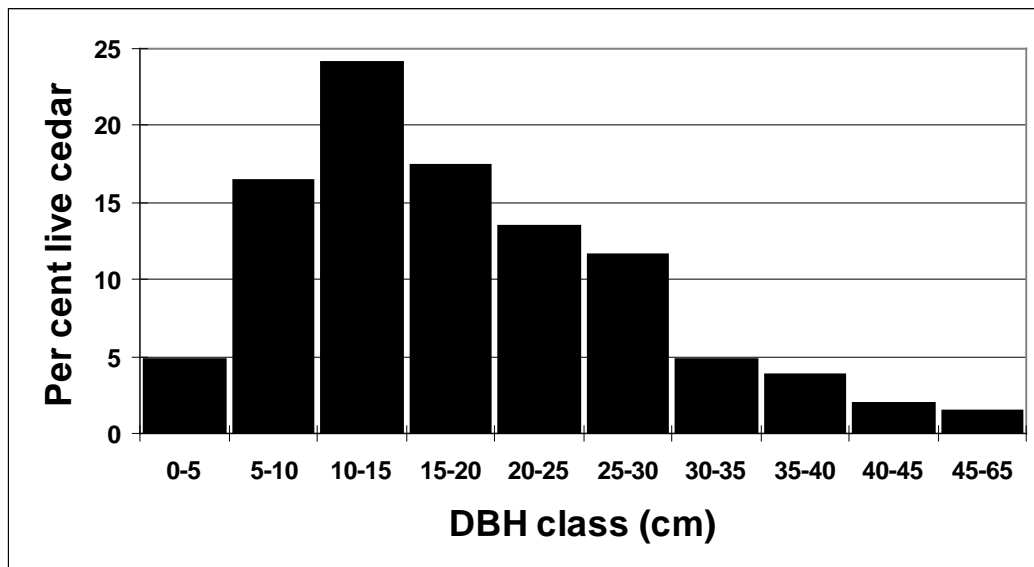


Figure 4--Diameter distribution of all living cedar trees at the Grand Bay study site.



THE EFFECT OF PLANTING DENSITY ON THE GROWTH AND YIELD OF ATLANTIC WHITE-CEDAR-THIRD YEAR RESULTS

Bill Pickens

Conifer Silviculturalist, North Carolina Division of Forest Resources, Clayton, NC 27520

Abstract--This study examines the influence of planting density on the growth and yield of Atlantic white-cedar (*Chamaecyparis thyoides* (L.) B.S.P.) plantations. Following a clearcut harvest, the study site was root-raked, burned, and planted with bare root Atlantic white-cedar seedlings at three planting densities: 6 ft x 12 ft (605 trees/acre), 6 ft x 6 ft (1210 trees/acre), and 4 ft x 6 ft (1815 trees/acre). After three growing seasons, the tree height was similar across all treatments, averaging 6.4 feet. Survival was 91% (605 trees per acre), 86% (1210 trees per acre), and 83% (1815 trees per acre). Early growth was not affected by planting density in this study.

Keywords: Atlantic white cedar, *Chamaecyparis thyoides*, North Carolina, density, establishment, regeneration

INTRODUCTION

Atlantic white-cedar (*Chamaecyparis thyoides* (L.) B.S.P.) is a wetland species that has been in decline across its range since the late 1800s when it was extensively logged as a valuable timber product. Today it is valued both ecologically and economically. Regeneration efforts are needed to restore Atlantic white-cedar to its original range. Artificial regeneration by private landowners is an important component of the restoration effort. The conical shape and small bole of Atlantic white-cedar (2-16 inch diameter at breast height) allow it to naturally regenerate and maintain dense stands (250 to 300 ft² basal area per acre). Because of high seedling and site preparation costs, artificial regeneration of Atlantic white-cedar is expensive. Planting fewer trees per acre reduces establishment costs, but may not optimize economic returns. Currently, many resource managers recommend planting densities common to loblolly pine (600-800 seedlings per acre), but that may not be appropriate for Atlantic white-cedar. Little data is available on how planting density affects the growth and yield of Atlantic white-cedar stands. This study examines the influence of planting density on the growth and yield of Atlantic white-cedar plantations to determine if higher planting densities will increase volume yield and result in a better rate of return that will offset high establishment costs.

METHODS

The study is located at the NCSU Hoffman Forest, Onslow County, North Carolina on a former pond pine forest. The soil is very poorly drained, but the tract is extensively ditched. The soil type is a Pantego black fine sandy loam that has a site quality index (base age 50) of 95 for loblolly pine. The site was clearcut, raked, and burned in preparation for the planting. Planting density treatments were: 1) 605 trees/acre, 2) 1210 trees/acre, and 3) 1815 trees/acre.

The treatments were established in a randomized complete block design with four replications per treatment. Each treatment plot was approximately 0.25 acre in size. North Carolina Division of Forest Resources personnel hand planted a total of 4061 seedlings with dibble bars in February of 2001. The 1-0 bare root seedlings were propagated from seed at the North Carolina Division of Forest Resources Claridge Nursery in Goldsboro, NC. Overall seedling quality was poor, as a great many of the seedlings planted were less than 4 inches tall and had sparse root systems. The largest seedlings were about 4-5 inches tall.

The first data collection was made after three growing seasons in March of 2004. Surviving trees were measured for height to the nearest 0.1 feet, and stocking density and survival was determined. DBH was not measured since many trees were less than 4.5 feet tall.

RESULTS

After three years in the field, survival was 91%, 86%, and 83% for treatments 1, 2, and 3 respectively. Height was 6.2 feet, 6.6 feet, and 6.5 feet for treatments 1, 2, and 3 respectively, with no significant differences among treatments at $P = 0.05$ (table 1).

Even with the smaller seedlings and medium intensity site preparation, the survival of the Atlantic white-cedar seedlings was high. The high survival rate was consistent with rates observed by the author from previous Atlantic white-cedar plantings. Land resource managers should expect good survival with adequate site preparation and competition control.

Seedlings grew quickly and were able to outgrow the emerging competition of gall berry, fetterbush, wax myrtle, cat briar, blackberry, poke weed, and various grasses. Most mortality was in very wet areas or in areas of very dense grass or woody shrubs. Deer or rabbit browse was not a problem on this site, as is often the case in other plantings.

Height growth averaged 2.13 feet per year, with the largest trees averaging about 3 feet of annual height growth. The tallest tree measured was 10.8 feet tall. The Atlantic white-cedar height was comparable to loblolly pines planted on adjacent fertilized beds the same year. Atlantic white-cedar is a good choice to reforest this soil type. In general, the trees are above the predominate competition and do not appear to need a release treatment to survive.

Table 1. Average height in feet for AWC trees three years after establishment

Treatment	n	Height (feet)	St. Dev.
Treatment 1 (605 trees/acre)	656	6.2 a	1.39
Treatment 2 (1210 trees/ acre)	1156	6.6 a	1.34
Treatment 3 (1815 trees/acre)	1640	6.5 a	1.38

Means followed by the same letter are not significantly different at the alpha-level of $p=0.05$

ATLANTIC WHITE CEDAR REGENERATION IN THE GREAT DISMAL SWAMP FOLLOWING HURRICANE ISABEL: 2006 BLACKWATER CUT RESULTS

Robert T. Belcher¹, Travis R. Comer¹ and Robert B. Atkinson²

¹Robert T. Belcher and Travis R. Comer, Project Scientist, Malcolm Pirnie, Inc.,
Newport News, Virginia, 23606

²Robert B. Atkinson, Associate Professor, Christopher Newport University,
Newport News, Virginia, 23606

Abstract: The Great Dismal Swamp National Wildlife Refuge began a large-scale salvage logging and cedar restoration project in response to the considerable damage caused by Hurricane Isabel in September 2003. The objectives of this study were to quantify and compare cedar regeneration associated with salvage logged areas and skidder trails in the Blackwater Cut, and adjacent areas not salvaged logged to help guide future site management and additional restoration work. In 2006, permanent plots were established on a 28-ha site within the Great Dismal Swamp National Wildlife Refuge. Cedar regeneration was quantified within 25-m² plots and the height of each seedling was measured. Seedling height ranged from 5 to 75 cm, however 93 percent of all seedlings surveyed were less than 20 cm tall. The number of seedlings within plots varied greatly, from 0 to 77. Mean seedling density in the salvage logged areas, skidder trails and un-salvaged plots were 14,533; 4,400; and 0 stems/ha respectively, compared to 1,006 stems/ha in the pre-Isabel mature forest. These results suggest conditions within the Blackwater Cut have been suitable for the establishment, survival and growth of cedar, but regeneration failed in the un-salvaged areas.

Keywords: Atlantic white cedar, Great Dismal Swamp, Hurricane Isabel, establishment, *Chamaecyparis thyoides*

INTRODUCTION

Chamaecyparis thyoides, Atlantic white-cedar populations have declined dramatically throughout its range (Korstian and Brush 1931, Little 1950). Nowhere has the decline been as significant as in the historic limits of the Great Dismal Swamp (GDS). The pre-colonial extent of cedar within the GDS is not precisely known; however, Shaler (1890) estimated the original extent of the swamp as 569,804 ha and pollen analysis conducted by Whitehead and Oaks (1979) suggested that cedar was a significant component of the GDS for the past 3,000 years. In 1907, a forestry trade publication, the American Lumberman, estimated the cedar holdings of the John L. Roper Lumber Company within the GDS at 24,281 ha, and Akerman (1923) estimated that 45,527 ha of cedar swamps occurred within the Virginia portion of the GDS. Carter (1987) estimated that pure cedar populations, i.e. stands where cedar comprised at least 80 percent of total basal area, had dwindled to a mere 1,000 ha in Great Dismal Swamp National Wildlife Refuge (GDSNWR).

The dramatic decline of the cedar population is thought to have been caused by poor silvicultural practices and anthropogenic degradation at a landscape level (Akerman 1923, Little 1950, Laderman 1989, Belcher 2005). As a result, species composition and functions were altered which comprised self-maintenance potential. Between the 1870s and 1970s, anthropogenic degradation had become progressively more destructive. The alteration included changes in wildfire frequency and intensity, conversion to agriculture or silvicultural plantations, and extensive hydrologic modifications (Akerman 1923, Little 1950, Phillips and others 1998).

In September 2003, Hurricane Isabel inflicted considerable damage to the forest throughout North Carolina and Virginia. Some of the worst damage occurred within the remaining 1,000 ha of mature cedar in the GDSNWR. Storm damage included snapping and uprooting trees, which left the forest floor littered with a thick layer of debris

that would prohibit the natural regeneration of cedar. Without salvage and restoration, these damaged cedar stands would likely convert to a maple-gum swamp. Therefore, the GDSNWR began a large-scale salvage logging and cedar restoration project (Belcher and Poovey, These Proceedings).

The objectives of this study were to quantify and compare cedar regeneration associated with salvage logged areas and skidder trails in the Blackwater Cut, and adjacent areas not salvaged logged.

METHODS

Site Description

The Blackwater Cut is approximately 28 ha in size and is located on the south side of Corapeake Ditch Road approximately 5.5 km from the western border of the GDSNWR ([figures 1](#) and [2](#)). The site was salvage logged between spring 2004 and spring 2005 with the use of an excavator mounted with a grapple saw and a rubber tire skidder ([figure 3](#)). Cedar seedlings were released from woody competition by an aerial application of Habitat[®] in September 2004. Habitat was applied at a concentration of 32-fluid ounces per acre. Mentholated seed oil was used as a surfactant.

Prior to Hurricane Isabel, the site was dominated by approximately 65 - 75 year old cedar (Merry 2005) and was part of a multiyear study funded by the USEPA. The structural attributes of the stand were previously described by DeBerry and others (2003, [table 1](#)). Loomis and others (2003) and Shacochis and others (2003) described the floristic composition. Thompson and others (2003) and Atkinson and others (2003) characterized soil physical and biochemistry characteristics and site hydrologic signatures, respectively. The Blackwater Cut was referred to as “Dismal Swamp-Mature” in each of the above referenced publications.

Cedar regeneration associated with salvage logged areas and skidder trails in the Blackwater Cut, and adjacent areas not salvaged logged were quantified by assigning cedar seedlings to 10-cm height classes within 25-m² (5 m x 5 m) plots between January and February 2006. Nine permanently marked plots established in the USEPA study described above, were re-established and used as salvage logged plots, and three additional salvage logged plots were established at 100 m intervals along a fourth transect. Ten skidder trails plots were randomly established within the site’s network of skidder trails. Ten un-salvaged plots were established in a nearby cedar stand that was damaged by Hurricane Isabel but not salvage logged. Examples of salvage logged, skidder trail, and un-salvaged plots are shown [figure 4](#).

RESULTS

A total of 546 cedar seedlings were located and measured during this study. Seedling height ranged from 5 to 75 cm and 93 percent of seedlings were less than 20 cm in height. The remaining 7 percent of cedar seedlings ranged in size from 20 cm to 87 cm. The number of seedlings within each plot varied greatly, from 0 to 77.

Salvage logged plots contained a total of 436 seedlings, which represented 79.9 percent of all seedlings found, and Skidder trail plots contained a total of 110 seedlings (20.1 percent of all seedlings found). No seedlings were found in the un-salvaged plots. For the 0 to 10-cm, 10 to 20-cm, and 20 to 30-cm size classes, the mean number of trees per size class was greatest in the salvage logged and lowest in the un-salvaged plots ([table 2](#)).

Mean cedar density in salvage logged plots was 14,533 seedlings/ha, much greater than the 4,400 seedlings/ha in the skidder trail plots. Cedar seedlings occurred within a fairly narrow elevation range throughout the site. No cedar seedlings were observed in inundated swales or on the tops of hummocks.

DISCUSSION

Cedar regeneration within the Blackwater Cut appears to be sufficient to restock the site, excluding some unforeseen catastrophic event. Only 7 and 23 percent of the existing cedar seedlings in the salvage logged and skidder trails, respectively, would need to reach maturity to exceed the pre-Isabel stocking levels reported in DeBerry and others (2003). However, the restocking densities reported here are unlikely to limit invasion by cedar competitors, i.e., red maple, and continued herbicidal treatment may be required.

Overall, conditions within the Blackwater Cut have been suitable for the establishment, survival and growth of cedar, but regeneration failed in the un-salvaged areas. These findings support earlier observations and findings. USFWS (2004) stated that salvage logging would facilitate cedar regeneration as opposed to taking no action, which would likely result in the establishment of red maple. Laderman (1989) illustrated a similar result when mature cedars were toppled in a violent storm and when other seed sources were plentiful.

Akerman (1923) and Little (1950) consider light, moisture, and microrelief as critical factors affecting cedar regeneration. These factors appear to explain much of the variability in cedar regeneration in the current study. Shading caused by storm debris and accelerated growth of understory species prevented cedar germination in un-salvaged plots in the same manner as dense logging slash. In salvage logged plots, the removal of the timber and competition control, allowed cedar germination to occur in suitable microsites. The variability between skidder trails and salvage logged plots may be associated with moisture differences. Soil disturbance caused by multiple passes of the skidder included compaction, lateral displacement and incorporation of large amounts of peat, all of which appeared to cause many portions of skidder trail to be either too wet or too dry for cedar regeneration.

Additional monitoring is recommended in order to quantify seedling mortality and recruitment, assess invasion by red maple, evaluate the effect of heart rot on cedar with age, and to determine the conditions that favor reestablishment of cedar.

ACKNOWLEDGEMENTS

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Table 1--Pre-Isabel structural attribute table ranked in order of aboveground biomass contribution for tree (≥ 2.54 cm dbh, >305 cm) and shrub (< 2.54 cm, but ≥ 33.0 cm tall) strata for Blackwater Cut
(Source: DeBerry and others 2003)

Tree Species	Basal Area (m ² / ha)	Relative			Relative	
		Basal Area Percent	Number (stems/ ha)	Biomass (kg/ha)	Percent Biomass	Mean dbh (cm)
Cedar	55.08	90.82	1,006	179,886	86.63	25.36
<i>Acer rubrum</i>	3.88	6.39	211	18,136	8.73	13.35
<i>Pinus serotina</i>	0.61	1.00	17	3,534	1.70	13.57
<i>Persea borbonia</i>	0.40	0.65	156	1,723	0.83	3.60
<i>Magnolia virginiana</i>	0.27	0.45	67	949	0.46	6.43
<i>Pinus taeda</i>	0.18	0.30	6	854	0.41	20.40
<i>Vaccinium corymbosum</i>	0.13	0.21	150	323	0.16	3.19
<i>Nyssa biflora</i>	0.04	0.06	22	106	0.05	4.60
Other tree species	0.07	0.12	117	90	0.04	
Tree Stratum Total	60.64	100.00	1,750	205,602	99.01	
Shrub Stratum Total			19,965	2,047	0.99	
Total Aboveground			21,715	207,649	100.00	

Table 2--Cedar seedlings by size class

Treatment	# of 25-m ² plots	Total Seedlings	Mean (total) number of seedlings per size class [percent of total size class]			
			0-10 cm	10-20 cm	20-30 cm	30+ cm
Salvage logged	12	436	24.2 (290) [66.5]	9.3 (111) [25.4]	2.3 (28) [6.4]	0.6 (7) [1.6]
Skidder trails	10	110	8.5 (85) [77.3]	2.2 (22) [20]	0.1 (1) [0.01]	0.2 (2) [0.02]
Un-salvaged	10	0	0 (0) [N/A]	0 (0) [N/A]	0 (0) [N/A]	0 (0) [N/A]
Total	32	546	(375) [68.7]	(133) [24.4]	(29) [5.3]	(9) [1.6]

Figure 1--Great Dismal Swamp National Wildlife Refuge Vicinity Map

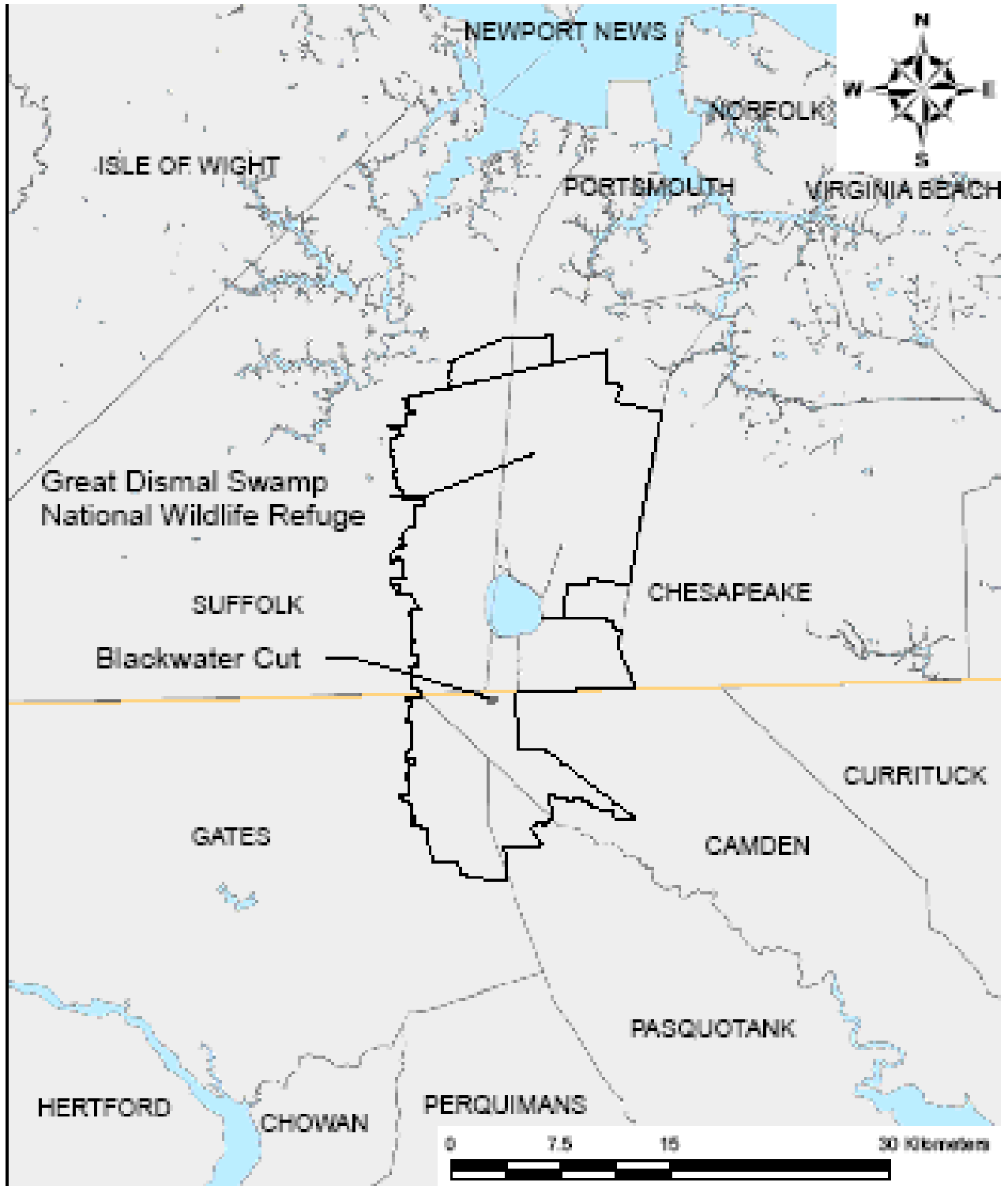


Figure 2--Aerial photograph of Blackwater Cut, courtesy of Brian Martin.



Figure 3--Hydraulic Grapple skidder used to salvage log the Blackwater Cut, courtesy of Brian Martin



Figure 4--Example of: (a) salvage logged plot, (b) skidder trail plot, (c) un-salvaged plots

a.



b.

c.



DEVELOPING MANAGEMENT AND RESTORATION REGIONS FOR ATLANTIC WHITE-CEDAR BASED ON PATTERNS OF GENETIC VARIATION

Kristin A. Mylecraine¹, George L. Zimmermann², John E. Kuser³, Lena Struwe⁴ and Peter E. Smouse⁵

¹Department of Ecology, Evolution and Natural Resources, Rutgers, The State University of New Jersey
14 College Farm Road, New Brunswick, NJ 08901. Current address: Wildlife Biologist, Ohio Division of Wildlife,
ODNR, Olentangy Wildlife Research Station, 8565 Horseshoe Road, Ashley, OH 43003

²Professor, Natural and Mathematical Sciences, Richard Stockton College of New Jersey, P.O. Box 195,
Pomona, NJ 08240

³Associate Professor Emeritus, Department of Ecology, Evolution and Natural Resources, Rutgers, The State
University of New Jersey, 14 College Farm Road, New Brunswick, NJ 08901

⁴Associate Professor, Department of Ecology, Evolution and Natural Resources and Department of Plant Science,
Rutgers, The State University of New Jersey, 14 College Farm Road, New Brunswick, NJ 08901

⁵Professor, Department of Ecology, Evolution and Natural Resources, Rutgers, The State University of New Jersey,
14 College Farm Road, New Brunswick, NJ 08901

Abstract--Atlantic white-cedar (*Chamaecyparis thyoides*; AWC) is an important wetland tree species occurring along the Atlantic and Gulf of Mexico coasts. The economic and ecological importance of AWC, coupled with significant population decline, has led to increasing interest in its management and restoration. The geographic distribution of genetic variation is an important consideration for developing management and restoration strategies. We present an overview of rangewide genetic variation within AWC, including allozyme, provenance, cpDNA, and morphological variation, and combine this information with ecological and geographic data to identify suggested management regions within the species. We identified three major geographic regions: (1) Atlantic coast, (2) Florida peninsula, and (3) Gulf of Mexico coast, with further division of Regions 1 and 3 each into three subregions. This pattern of variation should be taken into account when identifying populations for conservation, developing management and restoration plans, and selecting propagules for regeneration and restoration purposes.

Keywords: Atlantic white-cedar, *Chamaecyparis thyoides*, genetic variation, morphology, provenance, management, distribution, Atlantic Coast region, Peninsular Florida, Gulf Coast

INTRODUCTION

Atlantic white-cedar (*Chamaecyparis thyoides*; AWC) is a wetland tree species, occurring in freshwater swamps and bogs along the Atlantic and Gulf coasts of the United States. It is a highly valued timber species (Korstian and Brush 1931), although the amount harvested has declined significantly over the past several decades, due to reduced supply and increased protection of remaining stands. Ecologically, AWC creates a unique habitat that supports a wide variety of plant and wildlife species (Mylecraine and Zimmermann 2000). Since European settlement, there has been a significant decline in the area occupied by AWC, due to overharvesting, conversion to agriculture and development, ditching and draining of wetlands, changing fire regimes, and excessive browsing by white-tailed deer (Frost 1987, Kuser and Zimmermann 1995, Mylecraine and Zimmermann 2000). The ecological and economic importance of AWC, coupled with these declines, have led to increasing interest in the species' conservation, management and restoration (Wicker and Hinesley 1998, Mylecraine and Zimmermann 2000, Smith 2003, Zimmermann and Mylecraine 2004).

Genetic variation should be an important consideration when developing restoration and management plans. Genetic diversity within populations is important for maintaining the species' ability to adapt to variable environments over space and time, reducing vulnerability to pests, and providing material for any potential breeding programs (Ledig 1986). Patterns of variation among populations may be used to infer the historical biogeography of the species, as well as to identify genetically homogenous regions of utility for management and conservation plans. For example, conservation plans should support the protection of representative populations in each unique genetic region, in order to maximize genetic variation in future generations. Such regions are also important for developing guidelines for seed and propagule movement. The geographic source of propagules should be a major consideration for restoration projects (Montalvo and others 1997, Lesica and Allendorf 1999), as the ultimate success of a restoration may depend on choosing genetically adapted material. If genetic material is not adapted to the local climatic, edaphic and biotic environments, heavy mortality and regeneration failure may result (Millar and Libby 1989).

A series of recent studies have examined geographic patterns of genetic variation in AWC (Kuser and others 1997, Eckert 1998, Haas and Kuser 1999, Dugan and Kuser 2003, Mylecraine and others 2004, Mylecraine and others 2005). In this paper, we summarize information based on neutral genetic markers (allozymes and sequences from non-coding regions of cpDNA), morphology, and adaptive traits (provenance trials). We combine this information with geographic and ecological data to suggest a number of unique management regions.

METHODS

Current Distribution

To determine the current geographic distribution of Atlantic white-cedar, we examined the published literature, examined herbarium specimens, and conducted field observations, while collecting samples for genetic studies (Mylecraine 2004, Mylecraine and others 2004, Mylecraine and others. 2005). We used this information to produce an updated range map, including all counties in which we were able to document the species' presence.

Sample Collection

We collected foliage samples from a total of 52 populations throughout the range of AWC between 1999 and 2001. Samples ranged from 44°20'N south to 29°12'N, spanning the full latitudinal range of the species. Detailed descriptions of collection methods and sampled locations are presented in Mylecraine (2004).

Genetic Methods

To examine rangewide patterns of genetic variation, we conducted allozyme analyses, DNA sequencing, morphological examination, and provenance testing. We analyzed 31 populations (n~30-50 per population) for variation at eleven allozyme loci. Detailed lab and data analysis methods are presented in Mylecraine and others (2004). We examined 43 populations for morphological variation, including foliage, seed cone and seed characters. Detailed methodology is presented in Mylecraine (2004). We also sequenced two non-coding regions of chloroplast DNA, *trnD-trnY* intergenic spacer and *trnL* intron for individuals from 25 populations (Mylecraine 2004). To examine patterns of provenance variation, we rooted cuttings from 34 populations and planted them in three common garden plantations: two in New Jersey and one in North Carolina. We monitored growth and survival through the first two growing seasons. Detailed provenance methodology is presented in Mylecraine and others (2005).

RESULTS

Current Distribution

We present an updated range map ([figure 1a-e](#)), including all known counties of occurrence, based on the published literature, herbarium specimens and field observations during this study. Atlantic white-cedar is found along the Atlantic coast, from southern Maine to central Florida, and along the Gulf of Mexico coast, from Florida to

Mississippi. There is a large disjunction between the Atlantic and Gulf coastal populations, with only a few populations in the sandhills of western Georgia. The northernmost known population is located at Appleton bog, Knox County, Maine (44°20'N), while the southernmost population is located in Ocala National Forest, Marion County, Florida (29°12'N). The easternmost population is located at Northport, in Waldo County, Maine (69°01'W), and the westernmost population is found along Juniper Creek in Pearl River County, Mississippi (89°33'W). Korstian and Brush (1931) state that the distribution extended to eastern Louisiana along the Pearl River valley, but there is no recent evidence to support this (Little 1950, Clewell and Ward 1987, Ward and Clewell 1989). The only known populations in Louisiana have been planted (McCoy and others 2003).

Within its range, the distribution is patchy and disjunct, depending on the occurrence of suitable wetland habitat (Little 1950). In general, it is found within a narrow coastal belt, 80 to 160 km wide, and decreases in abundance with increasing distance from the coast. The species occurs from sea level to 457 m elevation, but the majority of stands are found below 50 m (Laderman and others 1987). Southeastern New Jersey, North Carolina, and northwestern Florida contain the largest natural areas occupied by this species (Kuser and Zimmermann 1995).

Summary of Patterns of Genetic Variation

AWC exhibits significant genetic variation in allozymes (Kuser and others 1997, Eckert 1998, Mylecraine and others 2004), cpDNA sequences (Mylecraine 2004), morphology (Mylecraine 2004) and adaptive traits (Haas and Kuser 1999, Dugan and Kuser 2003, Mylecraine and others 2005). Different classes of traits exhibit different geographic patterns of variation, a common finding among conifer species, which may be attributable to different evolutionary forces (Wheeler and Guries 1982, Libby and Critchfield 1987). Among AWC populations, neutral genetic markers, such as allozymes, exhibit regional patterns of variation, often associated with range disjunctions, a pattern that may have resulted from decreased gene flow and increased genetic drift, over long periods of geographic isolation. In contrast, adaptive traits, such as survival, height growth, and foliage color, exhibit clinal variation, a pattern that is likely to have developed from local adaptation to climatic conditions at the latitude of origin. In this section, we summarize results of these studies for each set of traits that have been examined.

Allozymes--AWC exhibits significant population differentiation, with an overall 'population structure' criterion $\Phi_{PT} = 0.12$. Patterns of variation suggest three distinct geographic regions, which correspond with natural disjunctions in the species range: (1) Atlantic coast, (2) peninsular Florida, and (3) Gulf coast. Within the Gulf coast, three genetically homogenous subregions are apparent: (3a) central Florida panhandle, (3b) western Florida panhandle, and (3c) southern Mississippi (Mylecraine 2004, Mylecraine and others 2004). These patterns may have resulted from decreased gene flow and increased genetic drift, over long periods of isolation, associated with range disjunctions, suggesting the possibility of at least three refugial areas during Pleistocene glaciations. Among Atlantic coastal populations, there is a significant negative latitudinal relationship for both measures of genetic diversity (mean number of alleles per locus and proportion of polymorphic loci), consistent with a loss of rare alleles as populations spread northward from a southern refugium (Critchfield 1984).

Morphological variation--Several authors have suggested that AWC populations along the Gulf Coast are morphologically distinct, and have recognized them as a separate species (*Chamaecyparis henryae*, Li 1962) or varieties (*Chamaecyparis thyoides* var. *henryae*, Little 1966, Clewell and Ward 1987, Ward and Clewell 1989). Analysis of rangewide patterns of morphological variation strongly suggests separation of the species into two distinct groups, corresponding to the geographic delineation of two subspecific varieties by Clewell and Ward (1987, Ward and Clewell 1989). *Chamaecyparis thyoides* var. *henryae* is restricted to the western Florida panhandle and Alabama (figure 1a), and *C. t.* var. *thyoides* occurs throughout the rest of the species range. The varieties are distinguished by the presence or absence of resin glands on the facial leaves (figure 2a). Both varieties may have resin glands on the main axis (figure 2b), but *C. t.* var. *thyoides* individuals also have resin glands on all facial leaves (Figure 2a and 2b), whereas *C. t.* var. *henryae* individuals lack these facial glands (figure 2a). Despite some degree of overlap in seed cone characteristics, *C. t.* var. *henryae* typically has smaller cones, with a lower length/width ratio (figure 2c), five total unfused scales and three ovules per scale, whereas *C. t.* var. *thyoides* typically has slightly longer cones, a greater length/width ratio (figure 2d), and two (sometimes three) ovules per scale (Mylecraine 2004).

In addition to discrete varietal differences, AWC populations exhibit a wide range of morphological variation. For example, a latitudinal cline is apparent in foliage color, with northern populations (on average) exhibiting bluish-green foliage with a greater mean hue, lower mean value and lower mean chroma than southern populations having

lighter green foliage (Mylecraine 2004). Several other conifers exhibit bluer or grayer foliage in drier or harsher environments (Wright 1976), which may be an adaptation for cold hardiness and/or decreased water loss. The occurrence of bluer foliage among both northern (Jull and others 1999, Mylecraine 2004) and high elevation (Dugan and Kuser 2003) AWC populations suggests that this trait may contribute to winter hardiness.

Chloroplast DNA variation--Sequence variation in two non-coding regions of chloroplast DNA suggests patterns of variation similar to allozymes and morphology. The geographic distribution of haplotypes (unique DNA sequences) of the *trnL* intron suggests a split between Atlantic and Gulf coastal populations, with four haplotypes restricted to Atlantic coastal populations and four different haplotypes restricted to Gulf coastal populations. The ninth and final haplotype was identified throughout both regions. Two haplotypes of the *trnD-trnY* intergenic spacer region were found, which correspond completely with the distribution of the two varieties, based on morphology. Haplotype 2 was detected among all individuals of the western Florida panhandle and Alabama, coincident with the range of *Chamaecyparis thuyoides* var. *henryae*; all other individuals contained haplotype 1 (Mylecraine 2004).

Provenance variation--In common garden plantings, AWC populations exhibit significant variation in survival, height growth and growth phenology (Haas and Kuser 1999, Dugan and Kuser 2003, Mylecraine and others 2005). In general, this variation is correlated with latitudinal climatic variation. Northern Atlantic coastal populations, planted in New Jersey and North Carolina, tend to exhibit increased winter hardiness, slower growth rates, and they complete a greater proportion of their total height growth early in the spring. By contrast, southern Atlantic populations exhibit slightly reduced winter hardiness in New Jersey, but have faster growth rates, and they complete a greater proportion of their growth later in the growing season. Florida and Gulf coastal populations outgrew more northern populations under ideal greenhouse conditions (Mylecraine 2004), but exhibited significantly reduced survival and growth in New Jersey and North Carolina (Mylecraine and others 2005). In addition to growth and survival traits, provenance variation has been identified in stratification requirements for seed germination (Jull and Blazich 2000), seedling temperature optima (Jull and others 1999), and possibly flowering phenology (Mylecraine 2004).

AWC occurs within a narrow range of elevations, from sea level to 457 m, with most stands occurring below 50 m (Laderman and others 1987). Elevation may also have a significant influence on adaptive variation. Individuals from the highest elevation stand at High Point, NJ (457 m) grew significantly less than other New Jersey sources in a central New Jersey planting (Haas and Kuser 1999). High elevation adaptation notwithstanding, climatic variation associated with latitude appears to be the dominant force influencing patterns of adaptive variation within this species.

DISCUSSION

Suggested Management Regions

Among AWC populations, different sets of traits exhibit varying geographic patterns, but several trends are recurrent among the different markers and traits that have been examined to date. In this section, we combine the available genetic information with ecological and geographic information to suggest three major management regions, and then further divide two of these regions into three subregions.

Region 1: Atlantic Coast

Atlantic coastal populations should be managed as a distinct region, based on patterns of allozyme, cpDNA and provenance variation. In this region, AWC occurs along the coast from southern Maine to Richmond County, Georgia. It typically forms dense monospecific stands (Korstian and Brush 1931), which may be even-aged or uneven-aged (Zimmermann and others 1999), but is often found in mixed stands with a variety of hardwood species (Mylecraine and Zimmermann 2000). AWC is largely confined to areas of organic peat overlying a sandy subsoil, often with a pH between 3.5 and 5.5 (Korstian and Brush 1931, Little 1950), but can also be found on poorly drained mineral soils (Korstian and Brush 1931, Mylecraine and Zimmermann 2000).

Clinal variation is apparent among Atlantic coastal populations, suggesting that populations that are geographically distant are more genetically distinct. For example, we see a relationship between geographic and genetic separation

(Mylecraine and others 2004). We also see clinal variation in provenance traits, including height growth and growth phenology (Mylecraine and others 2005). We have divided this region into three subregions, but the boundaries between regions are somewhat artificial, given the clinal pattern of variation in this region.

Region 1a: New England--New England populations ([figure 1b](#)) exhibit reduced growth rates, compared to other Atlantic populations, when planted in New Jersey and North Carolina. They also complete a greater proportion of their growth earlier in the spring and cease height growth earlier in the fall (Mylecraine and others 2005). On average, they have darker green or bluish foliage (Mylecraine 2004), which may be an adaptation for enduring harsher winters. AWC is often associated with glacial features, including glacial kettles or old lake beds (Laderman 1989). It is commonly found with red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*), white pine (*Pinus strobus*), eastern hemlock (*Tsuga canadensis*), and in some areas more boreal species such as black spruce (*Picea mariana*) red spruce (*Picea rubens*), and gray birch (*Betula populifolia*) ([figure 3a](#), Lynn 1984, Golet and Lowry 1987, Laderman and others 1987, Stockwell 1999). AWC occurs in portions of central and southern Maine, reaching its northern limit at Appleton Bog, in Knox County, ME ([figure 1b](#)). It also occurs in five counties of southern New Hampshire, with a total of approximately 193 ha containing at least 25 percent AWC (Sperduto and Ritter 1994), as well as several counties of Rhode Island and Connecticut, and portions of New York. Prior to human development, AWC forests dominated much of Long Island; many of these stands have been drained and cleared for development, harvested, and lost due to lowered water tables associated with damming of streams. Few New York populations remain outside of Long Island; these include Sterling Forest State Park (Lynn 1984), and a few small remnant individuals or populations in Orange County (Karlin 1997). This region will be addressed in greater detail by Laderman (this volume).

Region 1b: Mid-Atlantic Coast--Mid-Atlantic populations ([figure 1c](#)) are characterized by intermediate growth rates and phenology patterns (Mylecraine and others 2005). In this region, AWC occurs in New Jersey, Delaware and Maryland ([figure 1c](#)). In New Jersey, it occurs mainly in the southern unglaciated portion of the state, with most stands in the New Jersey Pinelands. A few stands are found in the northern part of the state, including the highest elevation population (457 m) at High Point State Park, in Sussex County. Populations occur on both Delaware and Maryland portions of the Delmarva Peninsula, but represent only a small portion of the species' former range in this area (Dill and others 1987). In addition, a number of small, isolated populations occur on the western shore of Maryland (Sheridan and others 1999b). AWC commonly forms dense, monospecific stands ([figure 3b](#)) or occurs in mixed stands with red maple, blackgum, sweetbay magnolia (*Magnolia virginiana*) and pitch pine (*Pinus rigida*). Williams (this volume) will address this region in more detail.

Region 1c: Southern Atlantic Coast--In general, southern Atlantic populations ([figure 1d](#)) grow faster and exhibit a greater proportion of growth later in the season, in New Jersey and North Carolina plantations. In this region, AWC occurs from southeastern Virginia to Richmond County, Georgia. Historical records suggest a relatively continuous population in this area, but hydrologic disruption, intense logging, and alteration of the fire regime have greatly reduced the area occupied by the species. The original acreage in the Carolinas alone has been reduced by more than 90% (Frost 1987). AWC occurs in pure stands or mixed with red maple, blackgum, baldcypress (*Taxodium distichum*), sweetbay magnolia, loblolly pine (*Pinus taeda*), and redbay (*Persea borbonia*) (Laderman 1989).

Region 2: Peninsular Florida

AWC populations in the Florida peninsula ([figure 1e](#)) should be identified as a unique management unit, based on both genetic and ecological distinctiveness (Mylecraine and others 2004). Morphologically, they appear similar to remaining *Chamaecyparis thyoides* var. *thyoides* populations. One population from this region was included in provenance trials in New Jersey and North Carolina, and exhibited reduced survival in New Jersey and reduced growth in North Carolina (Mylecraine and others 2005), despite faster growth rates under ideal greenhouse conditions (Mylecraine 2004). Some early distribution maps have identified AWC throughout northern Florida and extending half-way down the eastern peninsula (Korstian and Brush 1931, James 1961). However, these maps were likely based on unsubstantiated reports (Ward 1963), and only two populations are currently known from peninsular Florida. Both are found along spring-fed streams that discharge ultimately into the St. Johns River. The southernmost population occurs along Juniper Creek and its tributary, Morman Branch, in Ocala National Forest, Marion County (Ward 1963, Clewell and Ward 1987). The second population is found along a portion of Deep Creek in Putnam County. Unlike the acidic streams generally associated with AWC in many other parts of the range (Little 1950), these streams are neutral to mildly alkaline (Collins and others 1964, Clewell and Ward 1987).

Associated species include red maple, cabbage palmetto (*Sabal palmetto*), sweetbay magnolia, swamp tupelo (*Nyssa biflora*), loblolly bay (*Gordonia lasianthus*), swampbay (*Persea palustris*), slash pine (*Pinus elliottii*), and three oak (*Quercus*) species (figure 3c, Ward and Clewell 1989).

Region 3: Gulf Coast

We have identified the Gulf coast as the third region (figure 1e), based on genetic evidence. There is also a large disjunction between Atlantic and Gulf coastal populations, with only a few populations in the sandhills region of western Georgia (Sheridan and others 1999a, Sheridan and Patrick 2003). Historical records indicate that this disjunction predates early exploitation in these areas (Frost 1987) and is a natural pattern of occurrence. Gulf coast populations form a distinct cluster based on allozymes (Mylecraine and others 2004), and exhibit a number of cpDNA haplotypes that are not found in Atlantic coastal populations (Mylecraine 2004). Little is known about provenance variation in this region, because none of these populations reached their full potential in New Jersey and North Carolina plantations (Mylecraine and others 2005). AWC populations along the Gulf coast have received little scientific study, and their distribution has not been well documented (Clewell and Ward 1987, Ward and Clewell 1989). AWC is found from Gadsden, Liberty and Franklin counties in the central Florida panhandle west to southeastern Mississippi. The easternmost population is nearly 300 km from the peninsular Florida populations (Ward and Clewell 1989). Western Georgia populations are approximately 225 km to the north of these coastal populations, but are included in this region, because they are within the Gulf of Mexico watershed, and are found along streams that eventually flow into the Apalachicola River (Ward and Clewell 1989). In contrast to the dense, monospecific stands typical of many Atlantic coastal populations (Korstian and Brush 1931), AWC along the Gulf coast is found in mixed stands with pondcypress (*Taxodium distichum* var. *imbricarium*), slash pine, and a number of hardwood species (figure 3e, Ward and Clewell 1989).

Within this region, we have identified three subregions (figure 1e), based on allozymes, cpDNA, and morphological variation, which correspond with three distinct distribution centers along the Gulf coast.

Region 3a: Central Florida panhandle--We separated the central Florida panhandle from the rest of the Gulf coast region, because we found a unique *trnL* haplotype (haplotype 7) in this region (Mylecraine 2004), and because this region is morphologically distinct from the western Florida panhandle *C. t.* var. *henryae* populations. This cluster of populations includes stands along Telogia Creek and other tributaries of the Ochlockonee River, in Gadsden and Liberty Counties; along the New River of Liberty and Franklin Counties; tributaries of the Apalachicola River, Liberty, Franklin, Gulf and Calhoun Counties; and streams directly entering the Gulf of Mexico at St. Vincent Sound and St. Joseph Bay, Gulf County. The scattered populations in several counties of western Georgia are included in this region, because they occur along streams that feed into the Apalachicola River, and are genetically similar to other populations of this region (Mylecraine and others 2004).

Region 3b: Western Florida panhandle--Populations along the western Florida panhandle and Alabama coast exhibit distinct morphological characteristics and a unique cpDNA haplotype. These *C. t.* var. *henryae* populations lack resin glands on the facial leaves, and generally have smaller cones than *C. t.* var. *thyoides* populations. In this region, AWC occurs from just east of the Choctawatchee Bay, southern Walton County, FL, west to Mobile County, AL. Some of the largest living AWC individuals occur in this area (figure 3d, Ward and Clewell 1989).

Region 3c: Mississippi Coast--The division between *C. t.* var. *henryae* populations and *C. t.* var. *thyoides* populations occurs near the Alabama/Mississippi state line. Populations in Alabama, along streams draining into Mobile Bay have characteristics of *C. t.* var. *henryae*, while those in Mississippi, along streams draining into the Gulf further west have characteristics of *C. t.* var. *thyoides* (Mylecraine 2004). McCoy and Keeland (2006, this volume) have identified several locations of *C. t.* var. *thyoides* individuals or populations in coastal Mississippi, with the westernmost known stand along Juniper Creek, in Pearl River County.

Management Recommendations and Research Needs

We have identified broad geographic regions based on current information on geographic patterns of genetic variation. We suggest the following management guidelines for these regions:

1. Representative populations from each region and subregion should be targeted for long-term protection and management, to maximize the amount of genetic variation present in future generations.
2. Propagules for restoration and regeneration should be obtained within the region and/or subregion of interest to maintain the natural genetic structure among regions. In some cases, propagules may be moved between subregions, but this should be done with appropriate caution. For example, trees from Region 3c (southern Atlantic coast) have been shown to survive and outgrow native stock in New Jersey plantations, but there is increased risk of winter damage, and long-term data on the survival and fitness of these individuals is currently lacking.
3. Propagules for restoration and regeneration can likely be moved northward within regions and subregions without negative consequences. However, data on microgeographic adaptation (i.e. for different soil types or water regimes) is minimal (but see Summerville and others 1999) and should be explored in future studies.
4. In general, propagules should not be moved southward for regeneration and restoration, even within a region or subregion. Populations originating from the north of a planting site will probably grow slower than native and more southerly sources, probably due to phenological differences that do not allow them to take advantage of the full growing season in more southern locations.

The research summarized here provides baseline genetic information for AWC managers, based on genetic markers, morphology and adaptive traits, but there are a number of research questions and needs that remain. For example, provenance plantings should be expanded to include sites in New England and along the Gulf coast. Little is known about provenance variation among Florida and Gulf coast populations, but we suspect that such differences exist because of the extent of genetic and morphological variation in this region. We also know little about adaptation to microgeographic habitat variation within the broad geographic regions identified here. Summerville and others (1999) examined ecotypic variation among North Carolina populations and found only slight differences between populations on mineral and organic soils, but this is a matter that warrants further study. Variation among individual families may also become important for selecting desirable traits. There is evidence of family-to-family variation within AWC populations (Summerville and others 1999), and the matter needs further exploration.

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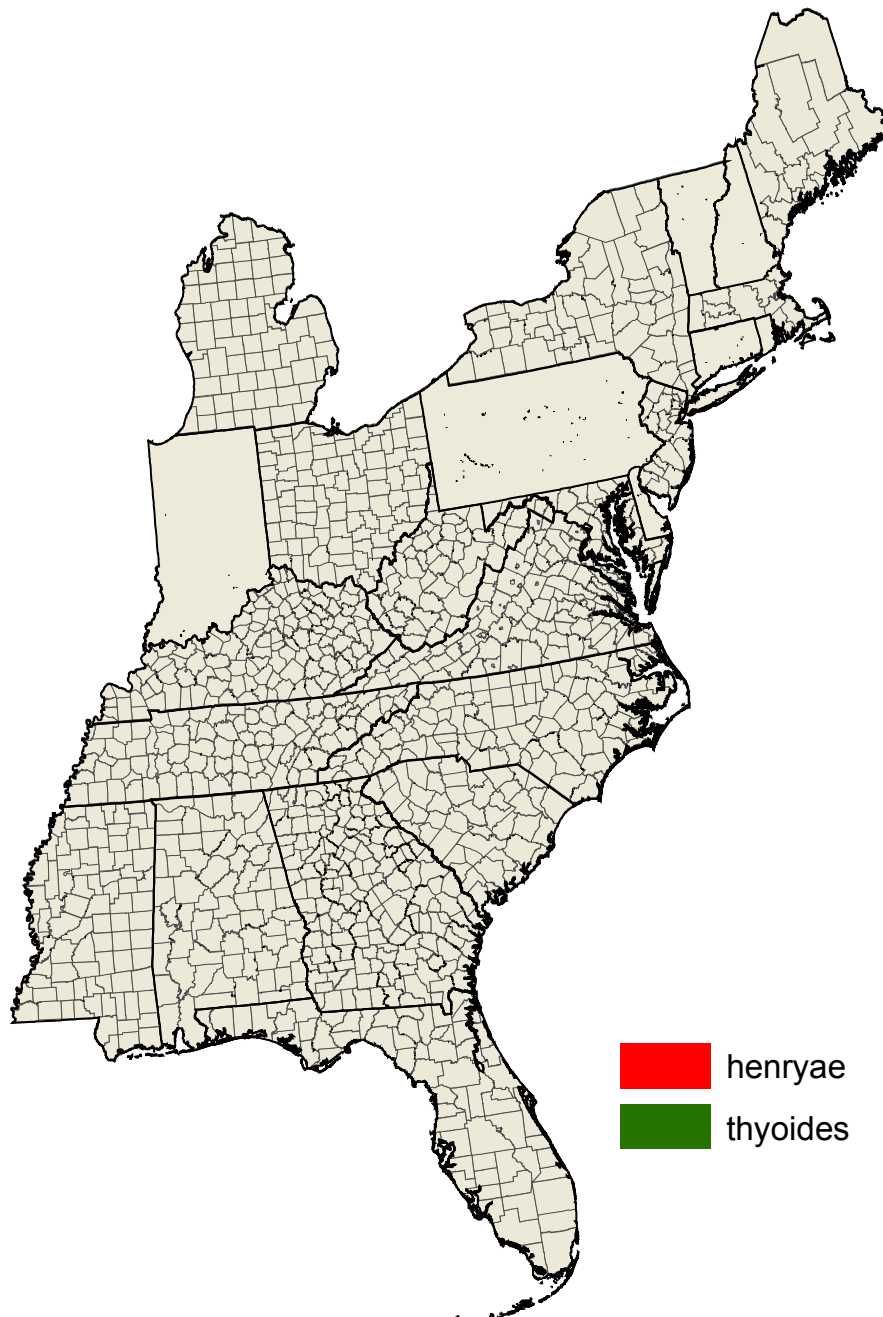
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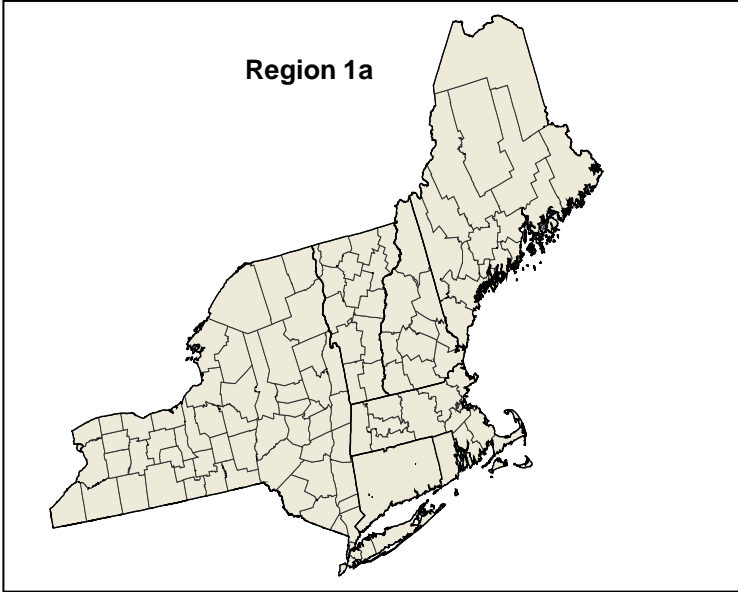
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Figure 1--Range of Atlantic white-cedar, *Chamaecyparis thyoides*, including all counties in which the species has been identified, based on published literature, herbarium specimens, and field observations. (a) Rangewide distribution of *C. t.* var. *thyoides* and *C. t.* var. *henryae*; (b) distribution in Region 1a, New England; (c) Distribution in Region 1b, mid-Atlantic coast; (d) distribution in Region 1c, southern Atlantic coast; and (e) distribution in Region 2, Florida peninsula, and Region 3, Gulf coast.

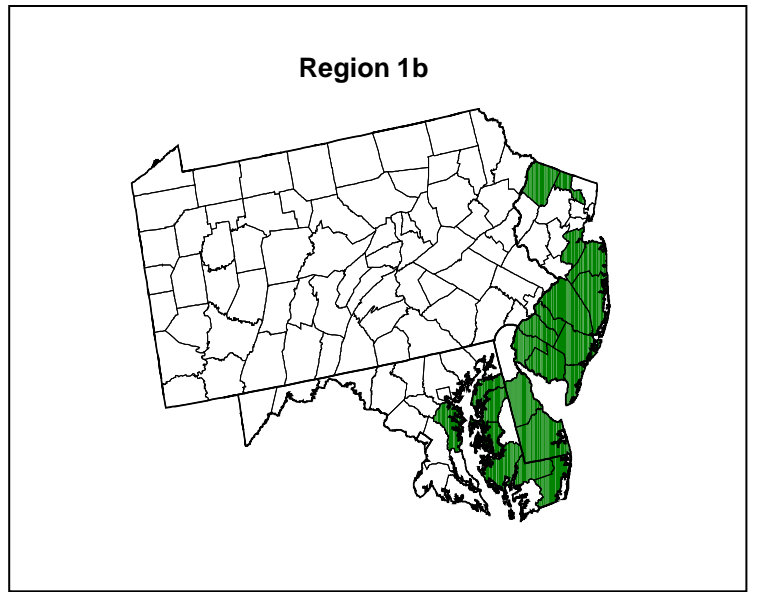
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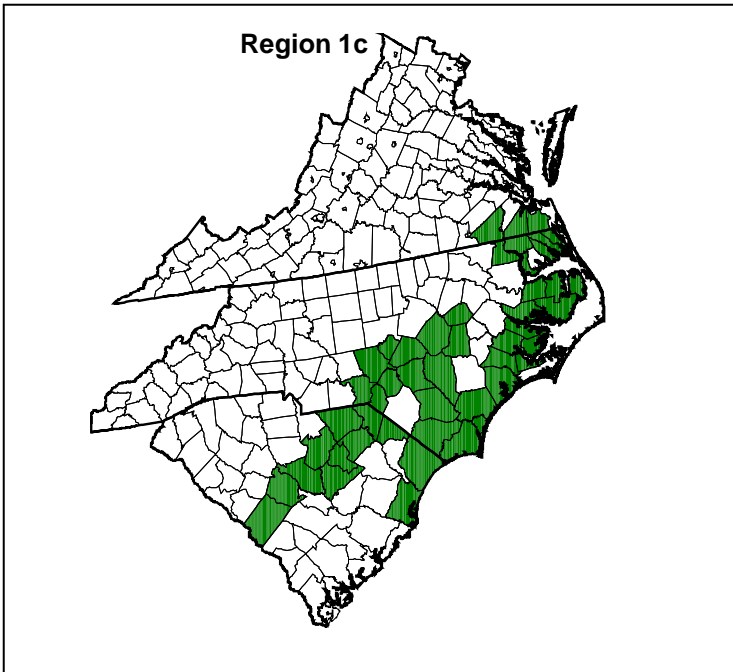
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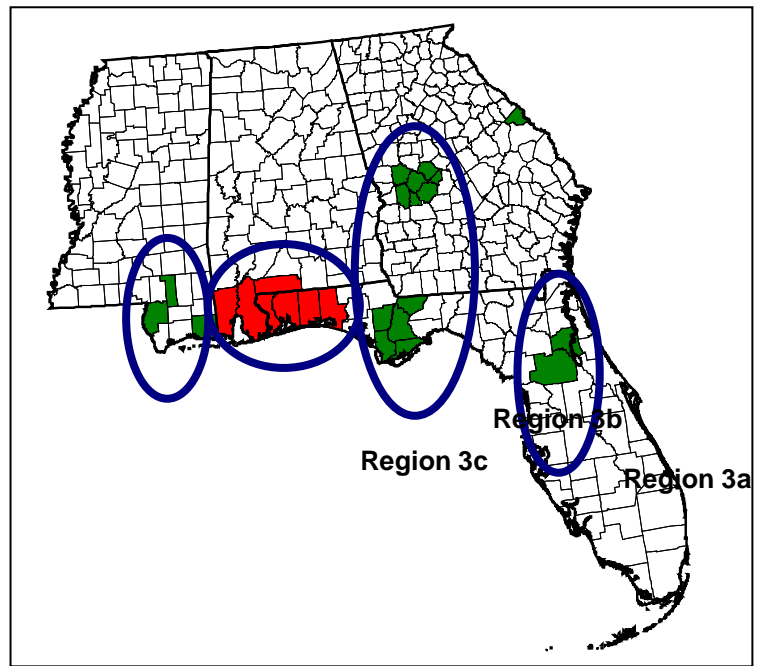
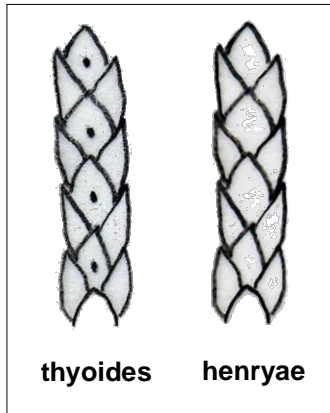
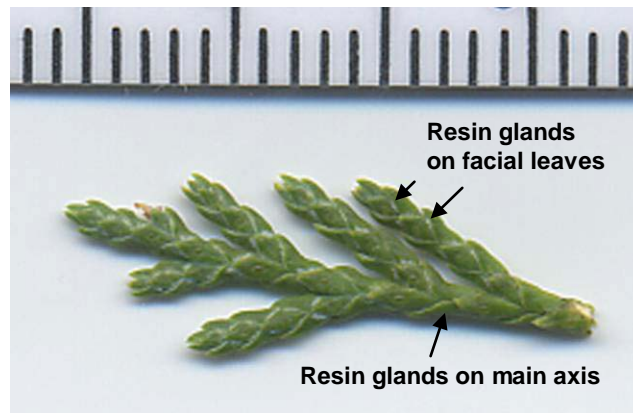


Figure 2--Morphological characteristics of *C. t.* var. *thyoides* and *C. t.* var. *henryae*. (a) Foliage characters; (b) foliage resin glands on *C. t.* var. *thyoides*: individuals of both varieties may have resin glands on the main axis, but only *C. t.* var. *thyoides* individuals have resin glands on all facial leaves; (c) typical seed cones of *C. t.* var. *thyoides*; and (d) typical seed cones of *C. t.* var. *henryae*.

a. Foliage characters



b. Foliage resin glands on *C. t.* var. *thyoides*



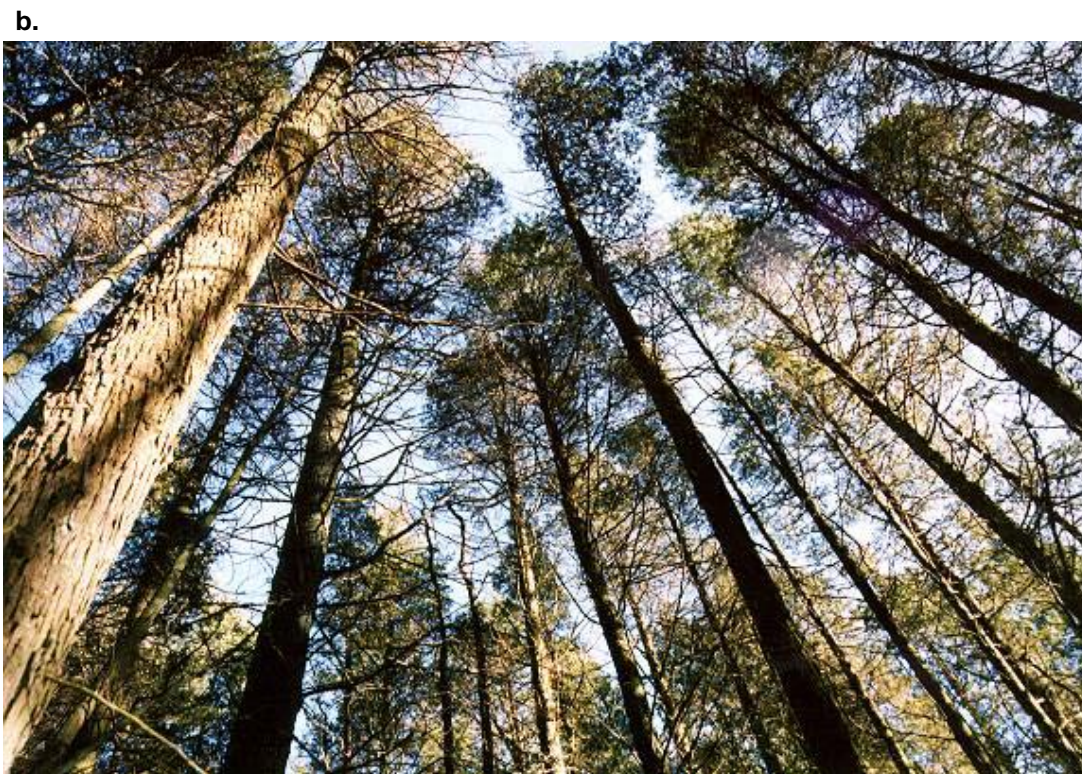
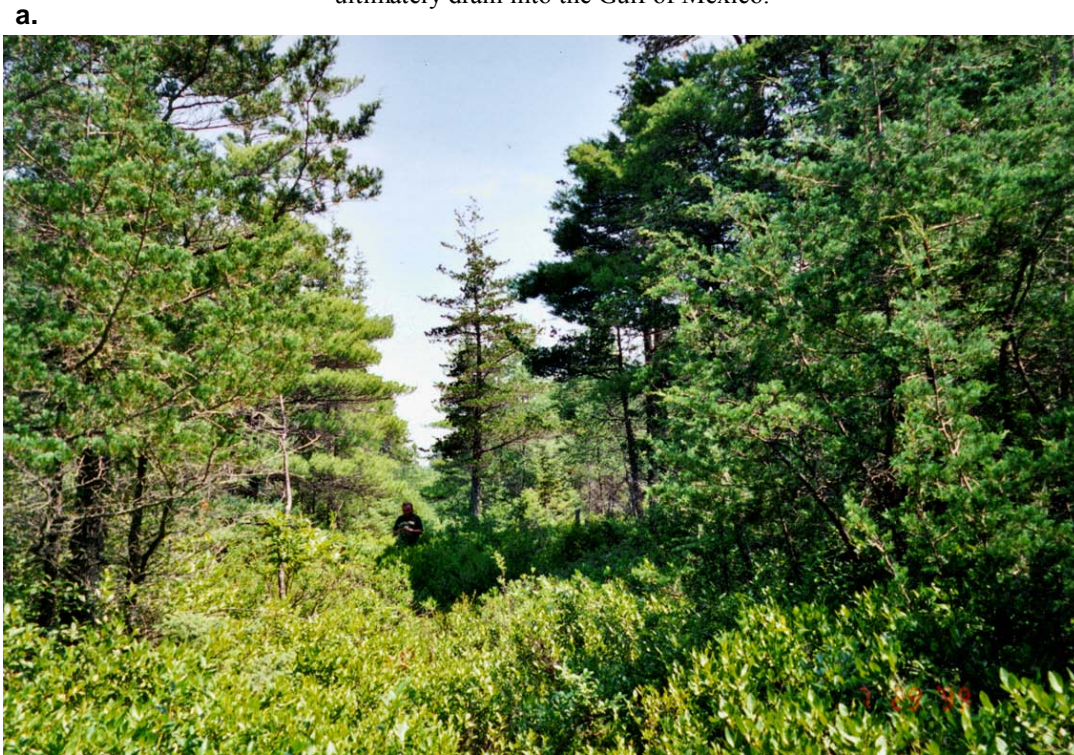
c. Typical *C. t.* var. *henryae* seed cones



d. Typical *C. t.* var. *thyoides* seed cones



Figure 3 --Variation in Atlantic white-cedar habitats: (a) Saco Heath, Maine (Region 1b): AWC is found with a number of ericaceous shrubs and boreal species, such as black spruce; (b) dense, monospecific stand of AWC typical of many mid-Atlantic (Region 1b) populations; (c) Ocala National Forest, Florida (Region 2): AWC is found along clear, sand-bottomed, neutral to slightly alkaline streams, with a variety of southern species, including cabbage palmetto; (d) example of the large *C. t.* var. *henryae* individuals occurring in the western Florida panhandle (Region 3b); (e) typical stand of *C. t.* var. *henryae*, occurring mixed with a number of species along streams that ultimately drain into the Gulf of Mexico.



c.



d.



e.



MANAGING ATLANTIC WHITE CEDAR AT DARE COUNTY BOMBING RANGE: HISTORY, HOPES AND ASPIRATIONS

Scott B. Smith

Installation Forester, Dare County Bombing Range, NC, P.O. Box 1659, Nags Head, NC 27959

Abstract--The North Carolina Chapter of The Nature Conservancy (TNC) and the North Carolina Natural Heritage Program (NCNHP), hereafter referred to as non-government organizations (NGOs); and other stakeholders have a strong interest in protecting and conserving Atlantic white cedar (AWC) forests present on Dare County Bombing Range (DCBR). Correspondence from the NGOs occurred, as draft forest management plans were distributed for public comment. During September 2003, Hurricane Isabel destroyed nearly 7,000 acres of forested ecosystems on DCBR, including 104 acres of mature AWC forest stands. An additional 112 acres of mature AWC was converted to hardwood forest types during the time period from 1989 to 2004. The Air Force sponsored a stakeholders meeting in September 2005 to address the hurricane damage, review the draft DCBR Forest Management Plan and renew communication between the DCBR natural resources staff and the NGOs. A series of meetings are planned to work toward consensus with the stakeholders on restoring the damaged AWC and future management goals of the AWC present on DCBR.

Keywords: Atlantic white cedar, NGO, The Nature Conservancy, North Carolina, Dare County Bombing Range, Hurricane Isabel, damage, management

INTRODUCTION

Dare County Bombing Range was established in northeastern North Carolina in 1964 to provide bombing and gunnery training for fighter pilots in the Air Force, Navy, Marine Corps and Air National Guard. DCBR is situated on a peninsula bordered by the Alligator River, the Pamlico Sound and the Croatan Sound, and is completely surrounded by the Alligator River National Wildlife Refuge, which is administered by the U.S. Fish and Wildlife Service ([figure 1](#)). Ordnance delivery and strafing are restricted to two impact areas; each area is approximately 2,500 acre in size. The balance of 42,000 acres is managed under ecosystem management principles in conjunction with multiple-use and sustained yield policies, in accordance with United States Air Force Instruction 32-7064 “Integrated Natural Resources Management” (USAF 2004).

Several species of concern occur within DCBR including the following animals (some protected): red cockaded woodpecker (*Picoides borealis*), red wolf (*Canis rufus*), American alligator (*Alligator mississippiensis*), and black bear (*Ursus americanus*). Dominant plant communities include Atlantic white-cedar (*Chamaecyparis thyoides*) and old-growth pond pine (*Pinus serotina*) forests. There are a total of 8,907 acres of AWC within DCBR. This forest community naturally regenerated following extensive clear-cut logging that occurred during the late 19th and early 20th centuries. The North Carolina Chapter of TNC designated the AWC on DCBR as a “globally rare Peatland AWC forest community” and, along with other NGOs, has a strong interest in protecting and conserving the AWC forests on DCBR.

HISTORY

In 1984, a cooperative agreement was signed between the Fourth Fighter Wing Commander at Seymour Johnson Air Force Base (AFB) and the NC Natural Heritage Program. This agreement registered 19,000 acres as Significant Natural Heritage Areas ([figure 2](#)). This agreement specified that there would be no change in title or loss of ownership rights by the Air Force; however, the Air Force agreed to limit any activities that would negatively impact those designated areas. At the time this agreement was executed, there was no forest management program

in place at DCBR. The Air Force established a forest management program in 1985, and communication between DCBR natural resources managers and the stakeholders has been sporadic over the years.

In 1992, the Department of Defense Legacy Resource Management Program provided multi-year funding authority to restore 3,000 acres of AWC ecosystems at DCBR and the adjacent Alligator River National Wildlife Refuge. The U.S. Air Force Air Combat Command provided additional funding from Forestry and Conservation programs. In order to achieve this complex and challenging goal, a steering committee was formed by representatives from the U.S. Air Force (USAF), Alligator River National Wildlife Refuge (ARNWR), North Carolina Division of Forest Resources (NCDFR) and North Carolina State University (NCSU), and the following tasks were identified: inventory remnant and cutover AWC stands, promote and enhance natural regeneration, develop seed and seedling sources, develop artificial regeneration methods, restore previously high-graded stands, implement a geographic information system (GIS), and establish water control and management to restore a more natural hydrologic regime. This eight-year, one million dollar project produced the most extensive and applicable information since the 1950s. Christopher Newport University, Newport News, VA produced a compendium on compact disk, which represents the current body of knowledge guiding AWC restoration efforts on DCBR (Belcher and others, 2000).

Daniels Consulting Forestry was contracted to perform a cruise of 1,261 acres of mature stands of AWC on DCBR (Daniels 1999). At the time of the inventory, Daniels found that most of the AWC trees were over 50 years old; some were up to 110 years old. Heart rot and wind throw were common in the older stands, especially those over 60 years old. The gross annual growth of AWC in the study area was estimated to be 607,000 board feet of saw timber and 727 cords of pulpwood. The AWC was not regenerating and was being replaced by lesser valued species (both financially and biologically) such as red maple (*Acer rubrum*) and sweet gum (*Liquidambar styraciflua*). Daniels recommended that the oldest AWC stands be harvested and regenerated back to AWC on a perpetual basis to prevent the eventual loss of this species.

Alion Science and Technology Inc. (1000 Park Forty Plaza, Suite 200, Durham, NC 27713) used orthorectified color infrared aerial imagery, GIS and three-dimensional heads-up digital photogrammetry to classify the vegetation on DCBR (figure 3). The vegetation was delineated at the Alliance Level of the national vegetation classification system as specified by the Federal Geographic Data Committee. A total of 8,907 acres of AWC were classified and delineated; these stands are comprised of 3,046 acres of pure AWC (forest stands with an AWC component of 75 percent or greater) and 5,667 acres of mixed AWC forest. Alion Science and Technology Inc. also compared color infrared aerial photographs to determine the extent of change in a contiguous stand of AWC on DCBR between 1989 and 2004 (Mickler and Bailey 2006a). The photographs were collected under leaf-off conditions on November 11, 1989 and on April 17, 2004. The photographs were converted to digital images, orthorectified and classified. The forest stand boundaries were digitized and plotted. Damage from Hurricane Isabel in 2003 was the most significant driver of change, converting 104 acres from mature-pure AWC forest to blowdown (figure 4). It is too early to assess regeneration in these areas. There were an additional 49 acres of pure AWC and 75 acres of mixed AWC forest types that were converted to predominantly hardwood forest types by 2004 (figure 5). The change in the stands of pure AWC stands that occurred during this same time period was also plotted (Mickler and Bailey 2006b). The 1989 stands (colored red) and the overlay of the 2004 stands (colored green) illustrate the loss of 151 acres of pure AWC shown in the map as the underlying 1989 red polygon areas (figure 6). Hurricane damage occurred in the interior of the stand, and loss of AWC by way of conversion to pine and hardwood occurred on the edges. The overall trends suggest a declining number of AWC trees, with a mixture of red maple, swamp black gum (*Nyssa sylvatica*), loblolly pine (*Pinus taeda*), pond pine (*Pinus serotina*) and bald cypress (*Taxodium distichum*) trees replacing them.

Former AWC stands that were clear-cut prior to Air Force ownership were inventoried and classified as to their relative stocking of AWC regeneration to determine their suitability for release (Van Druten and Eagle 2000). In 1998 and 1999, the Air Force hired a contractor to aerial spray 518 acres with Arsenal[®] herbicide. Arsenal[®] is a member of the Imidazolinone family manufactured by the Baden Aniline and Soda Factory (BASF). It is approved for release of AWC and may be applied on wetlands in accordance with Environmental Protection Agency regulations. During 2004, an additional 233 acres were sprayed for release. In 2006 Alion Science and Technology Inc. remeasured plots in an unsprayed control stand, the 1999 Arsenal[®] treated stands, and the 2004 Arsenal[®] treated stands to assess the success of AWC regeneration (Mickler and Bailey 2006c). The resurvey showed a substantial increase in hardwood competition and a decrease in AWC in the untreated control stand. The resurvey of the 1999 and 2004 Arsenal[®] treated stands showed an increase of AWC following hardwood herbicide application. Approximately 780 acres remain to be sprayed for release from hardwood competition.

The Air Force and Alion Science and Technology Inc. hosted a meeting in September 2005 of federal and state land management administrators and environmental groups interested in natural resources on the Dare County peninsula (Mickler and Bailey 2006d). The meeting brought together forestry experts from throughout the eastern U.S. to discuss historical, current forest management practices and restoration of AWC damaged by Hurricane Isabel. The meeting was attended by more than 50 people, including representatives from TNC, NCNHP, The Sierra Club, North Carolina Coastal Federation, NCDFR, the Southern Environmental Law Center and the U.S. Fish and Wildlife Service.

The main topic of discussion at the two-day meeting was the summary of comments provided to the Air Force on the draft Findings of “No Significant Impact” and the draft Environmental Assessment of the Supplemental Forest Management Plan for the DCBR. Attendees all agreed that the DCBR contained unique holdings of AWC that needed ecological management. The group discussed the first six of 44 comment items. There was some disagreement over what constituted AWC tree maturity. Some forest managers suggested a harvest rotation of 60 years, while some stakeholders preferred 200 years. Some NGOs objected to the proposed harvesting of old growth AWC and construction of new roads and ditches to access the hurricane-damaged stands because the hurricanes are a natural phenomenon and part of the ecological process, while some forest managers suggested that hurricane blowdown should be removed immediately to facilitate natural regeneration. It was agreed that further discussion was needed, preferably with smaller stakeholder groups.

Atlantic white cedar regeneration and harvesting sites on the DCBR were featured on the field trip on the second day of the meeting. One 32-acre stand of AWC blowdown was salvage logged during January 2005. On the day of the field trip, AWC seedlings were scarce. A seedling survival check performed in April 2006 showed an excellent survival rate of nearly 4,000 free-growing AWC seedlings per acre.

HOPES

Correspondence from the NGOs occurred, as Air Force draft forest management plans were distributed for public comment. During the past 18 years there have been misunderstandings and misgivings among the respective organizations. Differences in terminology also hindered communication between the DCBR natural resources managers and the NGOs. Examples of forestry terms and their corresponding ecology terms are listed in Table 1.

In April 2006, the DCBR natural resources management staff and Alion Science and Technology Inc. held a scoping meeting with the NGOs to discuss the DCBR Integrated Natural Resources Management Plan (INRMP) currently being drafted. After being presented with the most accurate vegetation map to date, the NGOs were open to redrawing the boundaries of the Natural Heritage Areas based on that map. The old boundaries seemed to have been based on anecdotal information and some old aerial photos, and are seriously in error. The NGOs recommended that the INRMP should include restoration and conservation of the AWC forest community as a high priority objective.

The Nature Conservancy has purported that if restoration and conservation of the AWC forest community are consistent with and supported by strategies for sustainable harvesting of AWC, then they can support such strategies. At the conclusion of this meeting, the Nature Conservancy representative stated he was pleased with the current relationship between the Air Force and TNC and the NCNHP, and that he thought we were all working toward the same goals.

ASPIRATIONS

With the advent of the 2004 color infrared imagery and recent vegetation classification accomplished by Alion Science and Technology Inc., we can now better manage AWC at DCBR. A forest inventory is planned which will provide a current description of the AWC community to include age, rate of growth and mortality. Our goals are to restore the AWC damaged by Hurricane Isabel, expand the presence of AWC by removing above-ground biomass and planting AWC seedlings, and aerial spray Arsenal[®] to release the remaining 780 acres of previously clear-cut AWC stands.

CONCLUSION

In the past, the DCBR natural resources managers and the NGOs seemed to hold opposing interests in what constituted proper management of AWC. We are now committed to working towards general consensus with the NGOs and other stakeholders on restoring and conserving AWC at Dare County Bombing Range and across the Dare County peninsula.

ACKNOWLEDGEMENTS

I appreciate Robert Mickler and Andrew Bailey for their GIS support and professional insights.

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Figure 1--Dare County Bombing Range Location Map.



Figure 2--Current Natural Heritage Areas for the Dare County Bombing Range.

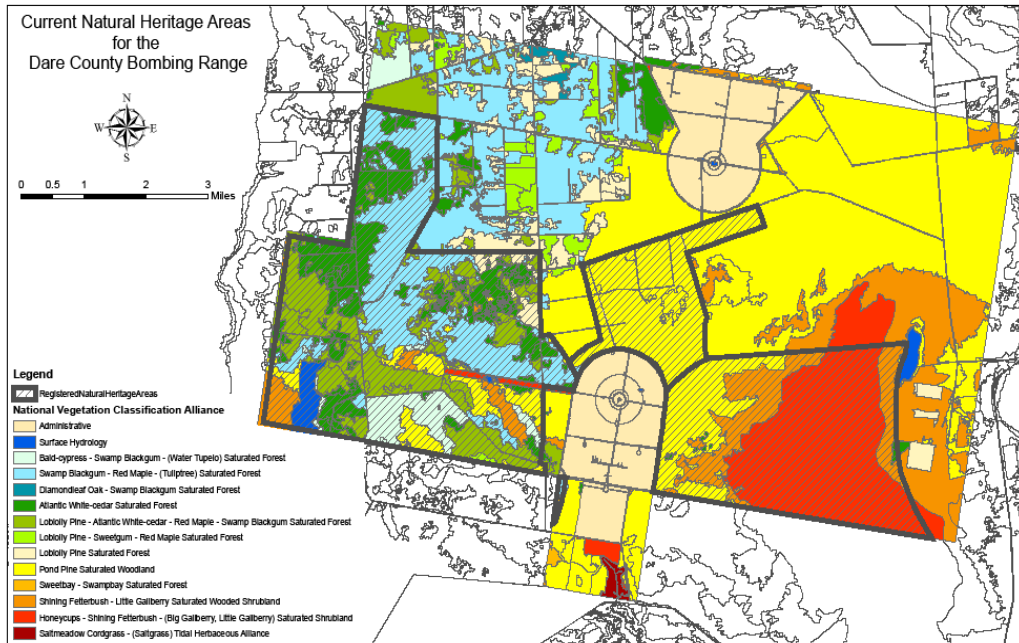


Figure 3--Dare County Range Vegetation Classification.

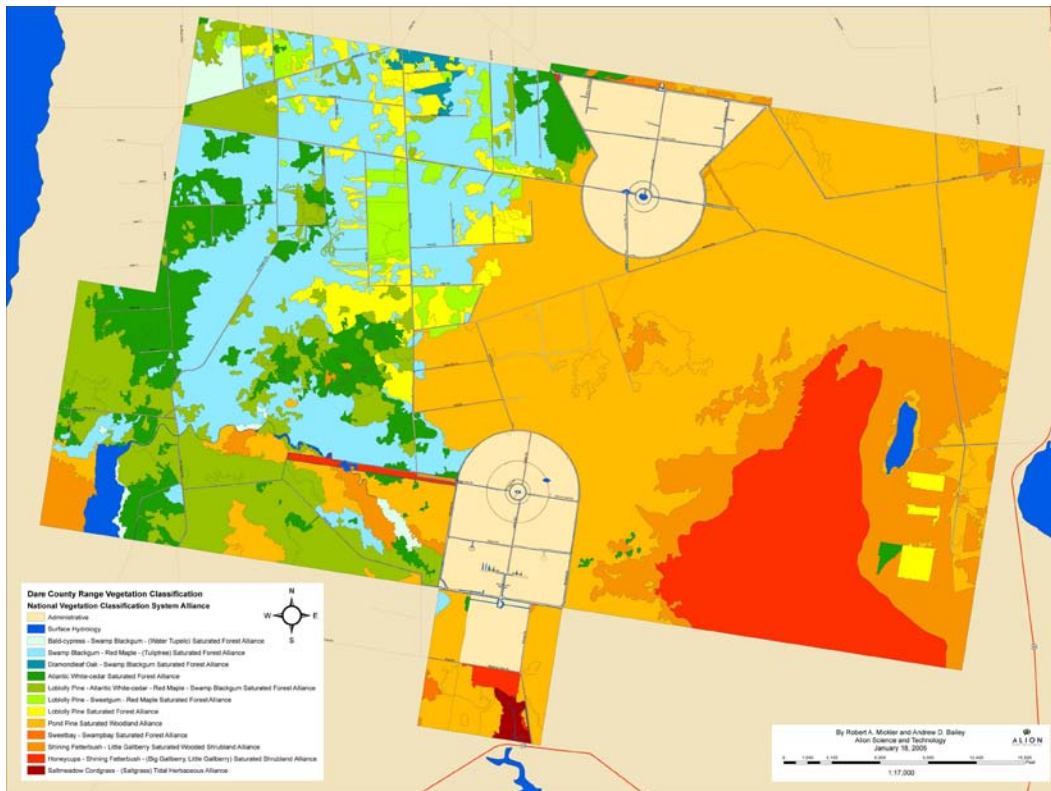


Figure 4--Extent of Hurricane Isabel Damage to Pure Atlantic White Cedar Stands.

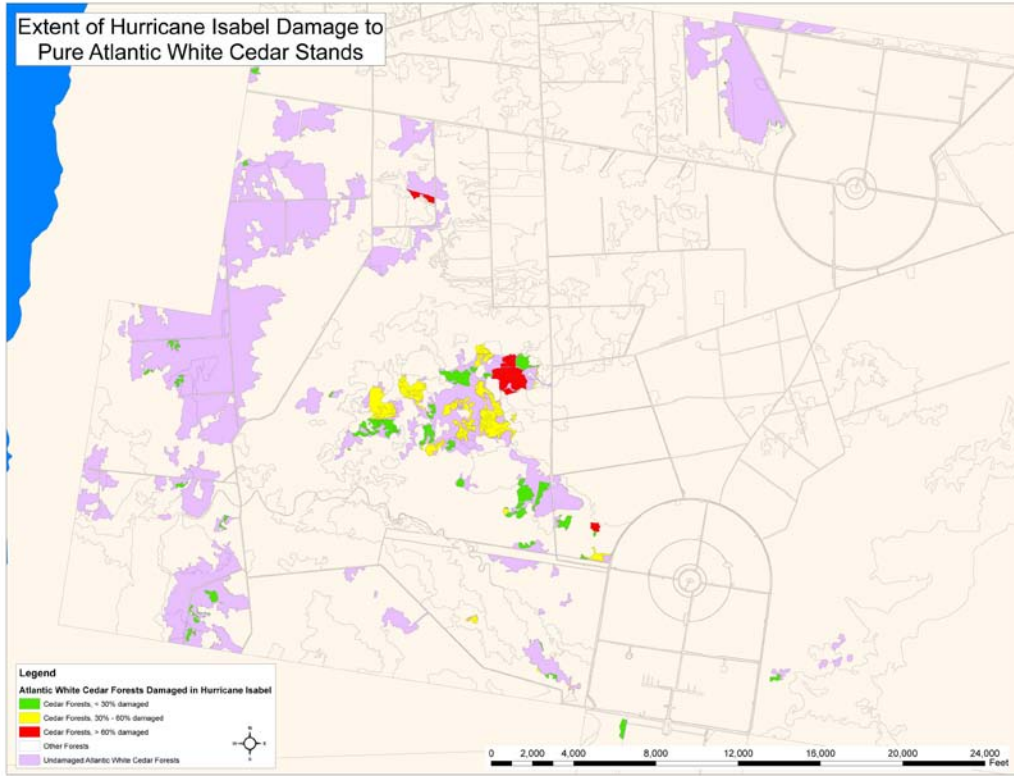


Figure 5--Change Analysis for Pure and Mixed Atlantic White Cedar Stands West of Beechland Road.

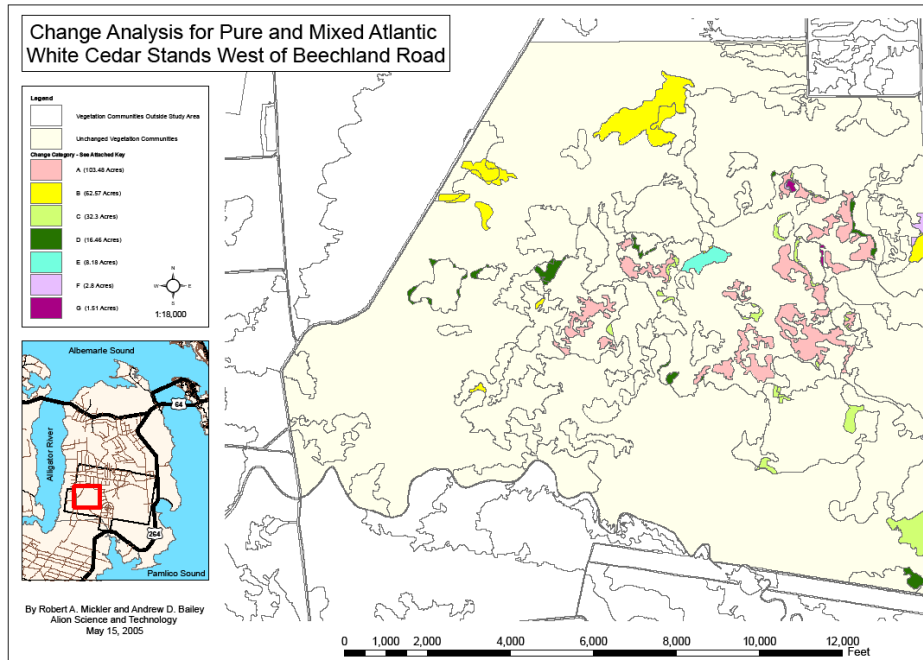


Figure 6--Change Analysis of the Pure Atlantic White Stand West of Beechland Road.**Table 1**--Forestry Terms and Corresponding Ecology Terms

Forestry terms	Ecology terms
Forest type	Vegetation community
Rotation age	Life span of species
Board feet	Biomass
Net annual growth	Net primary productivity
Unmerchantable timber	Mixed hardwood forests
Forest stands	Large, small patches
Unmanaged stands	Biological diversity

ATLANTIC WHITE CEDAR SALVAGE EFFORTS IN THE GREAT DISMAL SWAMP FOLLOWING HURRICANE ISABEL

Robert T. Belcher¹ and Bryan Poovey²

¹*Robert T. Belcher, Project Scientist, Malcolm Pirnie, Inc., Newport News, Virginia 23606*

²*Bryan Poovey, Forester, U.S. Fish and Wildlife Service Great Dismal Swamp National Wildlife Refuge, Suffolk, Virginia 23434*

Abstract: On September 18, 2003, Hurricane Isabel made landfall near Drum Inlet on the Outer Banks of North Carolina, and inflicted considerable damage to forests throughout North Carolina and Virginia. Some of the most severe damage occurred within the mature stands of Atlantic white cedar (AWC) in the Great Dismal Swamp National Wildlife Refuge (GDSNWR). No mature stands of AWC within the GDSNWR escaped without significant damage. The thick layer of debris including a tangled mat of uprooted, snapped and standing storm damaged trees prohibited natural regeneration of AWC and represented a severe fuel loading situation. Between the spring of 2004 and fall 2006, the GDSNWR conducted two timber sales to reduce the fuel loads and create an environment suitable for the establishment, survival and growth of cedar. This report discusses available information on Hurricane Isabel, the damage to cedar and cedar restoration efforts to date.

Keywords: Atlantic white cedar, Great Dismal Swamp, Hurricane Isabel, establishment, *Chamaecyparis thyoides*

INTRODUCTION

Many coastal forests are subject to recurrent, large scale perturbations due to hurricanes, fire or other catastrophic events (Wright and Heinselman 1973, White 1979). Hurricanes are a major factor controlling ecosystem structure, function, and dynamics in coastal forest (Boose and others 2001). Very little is actually known about the long term impact of hurricanes on forested ecosystems (Lugo and others 1983).

High winds, torrential rains and storm surges are usually associated with hurricanes. The storm surge and heavy rains associated with a hurricane may cause flooding in coastal systems, tributaries, floodplains and headwater systems. Hurricane force winds may cause defoliation, breakage and windthrow in the forest. Weaver (1989) reported the severity of damage related to the storm intensity, forest structure and soil conditions.

Extensive research has been conducted on the hurricane damage to several coastal forested communities including hardwood, pine and cypress forests (Touliatos and Roth 1991, Hedlund 1969, Craighead and Gilbert 1962, Stoneburner 1978, Duever and others 1984, Hook and others 1991, Peart and others 1992, Boose and others 2001). However, very little has been written about the effect of hurricanes on AWC swamps.

AWC is susceptible to wind damage, because of its shallow root system and spongy characteristics of the peat (Little 1950). Korstian and Brush (1931) suggested cedar that has grown in dense stands on peat soils never become wind-firm. Mylecraine and Zimmermann (2000) reported cedar as being especially susceptible to windthrow when a stand is opened from a disturbance.

Cook (1857) provided some of the earliest documentation of cedar stands that had been damaged by winds. He noted that cedar trees that were being mined from in the peat had blown down and their upturned roots were still present. Hawes (1939) reported that extensive stands of cedar near Voluntown, Connecticut were heavily damaged by a hurricane in 1938. Several acres were completely leveled, while in other places the trees were pushed only partly over.

In September 2003, Hurricane Isabel struck portions of eastern North Carolina and southeastern Virginia. The objective of this report is to describe the damage to AWC in the GDSNWR; and summarize current restoration efforts.

HURRICANE ISABEL

Hurricane Isabel made landfall as a Category 2 storm on September 18, 2003 ([figure 1](#)) with the eye of the storm passing near Drum Inlet, NC (Beven and Cobb 2004). Estimated maximum sustained winds were 157 - 166 km/hr and a 1.8 – 2.4 m storm surge was recorded over the eastern portions of the Pamlico and most of the Albemarle Sounds. Isabel weakened as it moved inland and became a tropical storm as it moved northwestward over southern Virginia and lost its tropical characteristics on September 19th as it moved across western Pennsylvania.

Widespread damage from wind and storm surge occurred throughout Isabel's path. Estimated insured property damage for Isabel was \$1.7 billion and the total damage was estimated to be \$3.4 billion. Isabel was the twelfth most costly hurricane to make landfall in the United States. Isabel was one of the most significant hurricanes to affect portions northeastern North Carolina and southeastern Virginia since Hurricane Hazel in 1954 and the Chesapeake-Potomac Hurricane of 1933.

IMPACT TO CEDAR

Historically, AWC formed one of the two dominant forest types in the GDSNWR; however, past harvesting practices, changes in hydrologic regime, and fire suppression, have promoted the establishment of communities dominated by red maple (*Acer rubrum*). Prior to Hurricane Isabel, the GDSNWR contained approximately 1,000 ha of mature AWC stands and approximately 4,000 ha of cedar mixed with hardwood and pine forest (Carter 1997, USFWS 2004).

As Hurricane Isabel passed to the southwest of the GDSNWR, it inflicted considerable damage to the forest throughout the GDSNWR especially within the mature pure AWC stands. USFWS (2004) estimated 85 percent of the mature cedar-dominant stands were destroyed and numerous individuals and clusters of trees that appeared to have survived the storm have since died. Storm damage included snapping and uprooting trees, which left the forest floor littered with a thick layer of debris ([figures 2](#) and [3](#)). Debris created by Isabel would prohibit natural regeneration of AWC and presented fuel loading problems for the GDSNWR.

CEDAR RESTORATION

GDSNWR forest management programs are directed towards restoring and enhancing the natural habitat diversity by mimicking the natural forces that once maintained habitat and wildlife diversity. Historically, cedar was regenerated by catastrophic fires occurring every 50-300 years (Frost 1995). However, the use of fire to regenerate cedar after Hurricane Isabel was not practical. Therefore, a salvage logging program was developed to promote cedar regeneration and reduce fuel loading by removing debris left by Isabel.

In the spring of 2004, salvage logging began within the Blackwater Cut. The 28-ha site was selected because of its close proximity to Corapeake Road. Salvage logging operations, using an excavator mounted with a grapple saw and skidder, continued until spring 2005. DeBerry and others (2003) estimated the pre-Isabel stocking level of cedar at the site was 1,006 stems/ha and comprised 180 MT/ha of dry biomass. Habitat[©] was applied via aerial spraying in September 2004 to release the cedar seedlings that germinated since the beginning of salvage operations. Belcher and others (These Proceedings) provide additional information and quantify the number of cedar seedlings within the Blackwater Cut as of the winter of 2006.

Much of the severely damaged cedar was far from existing roads (USFWS 2004). These stands were inaccessible to conventional equipment used to harvest and transport timber because of the instability of the deep organic soils. To reduce impacts to soils and water quality the GDSNWR required timber removal to be conducted by helicopter logging and specialized low-pressure equipment. Carson Helicopter Services, Inc. was awarded the second salvage logging contract for 445 ha. Between March 2005 and November 2006, a total 260 ha of cedar were harvested and yielded an estimated 3 million board feet of timber. In addition to the saw timber, Carson removed approximately 4

million kg of fuel and has an additional 4-8 million kg stockpiled and awaiting removal ([figure 4](#)). These fuels consisted primarily of splintered cedar logs and material discarded due to extensive heart rot.

Carson used a combination of ground based equipment and a Super S-61 logging helicopter. In a few stands within close proximity to an existing road, an excavator mounted with a processing head was used to cut and process trees ([figure 5](#)). The excavators worked off of barge mats and a road constructed from slash. A tracked forwarder then collected the processed logs and carried them back to an existing road ([figure 6](#)).

For more remote sites, excavators were used to cut and pile trees for whole tree skidding by helicopter. A grapple was initially used to remove the cedar, but it was unable to hold the trees once airborne. Carson then switched to a choke cable system ([figure 7](#)).

DISCUSSION

Conner (1997) suggested, since coastal forest developed in areas prone to hurricanes, it is likely that these forests have developed mechanisms to reestablish themselves rapidly following a disturbance. However, anthropogenic degradation at a landscape level has affected species composition and the self-maintenance potential of cedar within the GDSNWR. (Belcher and others, These Proceedings). Without salvage logging operations cedar stands damaged by Isabel would be replaced by hardwood swamps dominated by red maple (USFWS 2004).

Salvage logging operations to date have been very successful in reducing fuel levels and exposing the underlying seedbed to an increased level of light. Belcher and others (These Proceedings) assess cedar regeneration associated with three discrete areas (salvage logged areas, skidder trails, and control) in the Blackwater Cut. To date, no formal estimates have been made on cedar regeneration within sites salvaged logged by Carson.

Additional monitoring of competition control, cedar seedling germination, survival and growth is needed prior to fully assessing the effects of salvage logging on cedar regeneration.

ACKNOWLEDGEMENTS

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Figure 1 - Isabel's path based on Beven and Cobb 2004.

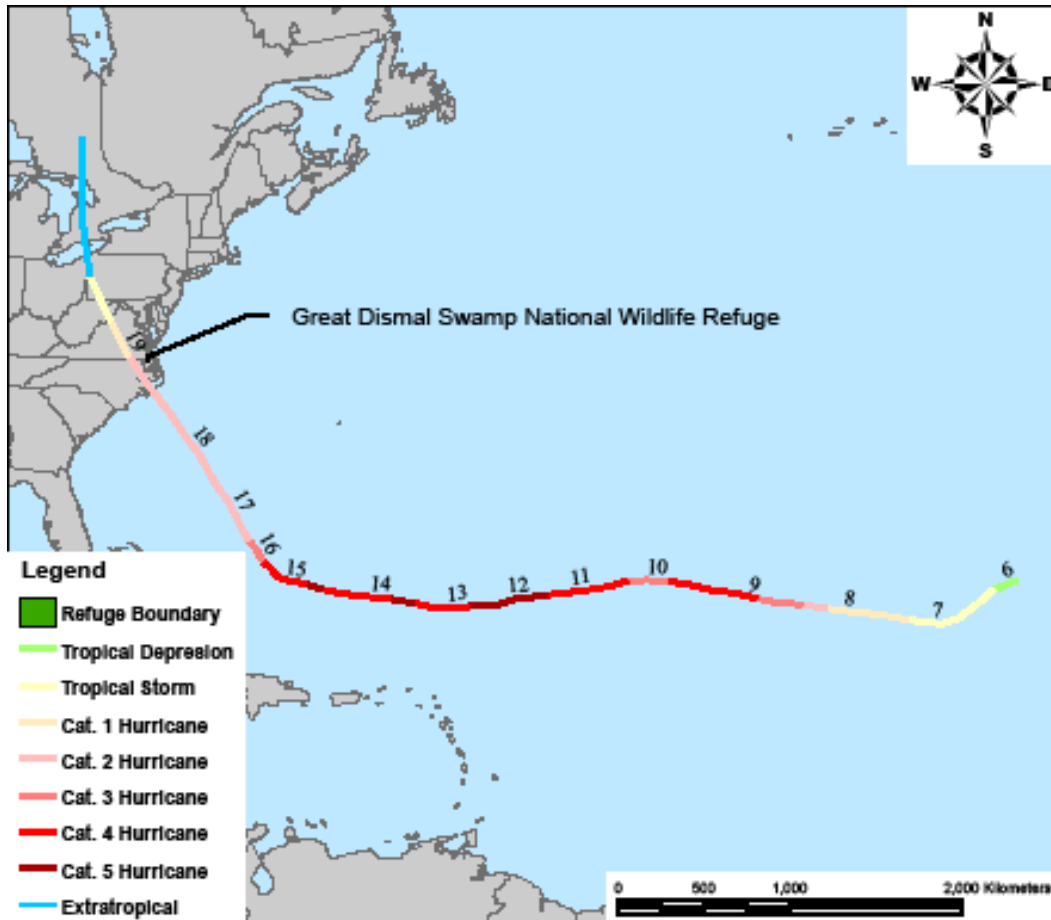


Figure 2 - Aerial photographs showing damage caused by Hurricane Isabel, a) pre-Isabel conditions, b) post-Isabel conditions, photo courtesy of USFWS.

a.



b.



Figure 3 - Bryan Poovey, Refuge Forester assessing cedar damage from the ground, photo courtesy of USFWS.



Figure 4 - Scattered, split and rotten logs awaiting removal from the GDSNWR. During a conventional logging operation these logs would have remained within the site.



Figure 5 - Daewoo excavator with processing head.



Figure 6 - Tracked forwarder collecting processed cedar logs



Figure 7 - Carson's helicopter after dropping its load at the logging deck, photo courtesy of USFWS.



A PRELIMINARY ANALYSIS OF THE HYDROLOGIC REGIME AND WETLAND PLANT COMMUNITIES OF THE MANCHESTER CEDAR SWAMP

Kimberly P. Hall

Kimberly P. Hall, President, and Senior Wetland Scientist, Green River Ecological Services, LLC.
575 Bullock Rd, Guilford, VT 05301

Abstract—Preliminary data was obtained to document existing hydrologic conditions and plant community composition for Atlantic white cedar (*Chamaecyparis thyoides*) (cedar), cedar/giant rhododendron, black gum, and red maple wetlands at the Manchester Cedar Swamp. Twenty-three piezometers were installed in eight transects located throughout each plant community. Water level was measured bi-weekly for one year. Hydroperiod, mean water level, and water table fluctuation were determined. At each of the piezometer locations ground cover and shrub strata were sampled using one and three meter box plots, respectively, and the tree stratum was sampled using a five-factor prism. Species were sampled and dominant species were used to calculate a Wetland Site Index for each piezometer. R^2 regression analysis was used to correlate this data with mean water level. This study will make it possible to observe the long-term effects of development on the hydrology and plant community composition of the Manchester Cedar Swamp.

Keywords: Atlantic white cedar, Manchester Cedar Swamp, hydrology, disturbance, community composition, stratum, water level

INTRODUCTION

Hydrology and the Cedar Community

Hydrology is a critical environmental parameter regulating, in part or in entirety, many wetland functions and variables such as moisture availability, supply of nutrients, substrate aeration, export of metabolic products, and the temperature regime of the soil (Hemond and others 1987). In turn, those same functions and variables largely determine the biotic composition, structure, and function of wetland ecosystems (Richter and others 1996). As such, hydrology has often been cited as the dominant factor determining wetland plant species composition (Golet and Lowry 1987, Gosselink and Turner 1978, Laderman 1989, Lowry 1984); therefore, hydrologic studies are becoming an integral component of ecological research (Hemond and others 1987).

Sperduto & Ritter (1994) believe that the hydroperiod and mean water level are the primary determinants of species composition and canopy density in the cedar community, and it is thought that the hydroperiod is one of the most essential of the hydrologic parameters in maintaining the integrity of the biotic environment (Gosselink and Turner 1978) as the hydroperiod is one of the factors responsible for controlling seed germination. Although adapted to saturated soil conditions, cedar seedlings appear to be intolerant of prolonged inundation (Rodgers and others 2003) so may not survive such conditions.

Throughout its geographic range, the cedar community is adapted to a wide variety of hydrologic conditions, however, cedar is intolerant of changes in hydrologic conditions specific to its locale. Cedar has a hydrologic regime that is characterized by seasonal inundation and a shallow water table (Laderman 1989). The hollows surrounding the hummocks upon which cedar typically grow have a water level that ranges from approximately 1.2 meters above ground surface (AGS) to 0.3 meters below ground surface (BGS) (Laderman 1989). Ehrenfeld & Schneider (1993) determined that hummocks are on average 50 to 75 cm above the low points in the hollows. Hummock and hollow topography in the cedar community is pronounced and hollows are often wet throughout the growing season (Sperduto and Nichols, 2004). Sphagnum and cedar find their own niche in this environment, based upon soil moisture, creating the undulating surface characteristic of cedar wetlands. Hanks (1985) found that depth to the water table, or depth of surface water, in large part determines plant community composition. Since hydrologic

regime varies from year to year and from wetland to wetland, documenting hydrologic regime for each wetland basin is ideal, but in most cases is not practical due to the time required to collect many years of data.

Few studies have been completed that quantitatively document the hydrologic regime of cedar wetlands (Laderman 1989); however, several studies have qualitatively documented the effect of altered hydrologic regime on the cedar community (Baldwin 1965; Motzkin 1991; Ahrens 1997). The findings of these studies indicate that there is a high likelihood for degradation of the cedar community following human or other disturbance adjacent to the wetland basin or upgradient within the watershed. Since the establishment and continued success of the cedar community is largely dependent upon a consistent hydrologic regime, even subtle changes in hydrologic regime can impede the ecological success of the cedar community (Ehrenfeld & Schneider 1991).

Ehrenfeld & Schneider (1993) concluded that urbanization alters hydrology. Schneider and Ehrenfeld (1987) studied 18 cedar wetlands located in the New Jersey Pinelands in undisturbed watersheds. Data from this study suggests that along a gradient ranging from undisturbed sites to disturbed sites, in undeveloped watersheds, there is a gradient of impact indicated in species composition, water level, and water quality that corresponds to the gradient of disturbance. This same study also found that human modifications to swamp drainage or stream channels have a major influence on water table dynamics in cedar wetlands. In the absence of these modifications, there was a slight trend toward drier conditions (lower water tables) as proximity of the wetland to development increased. This study concluded that urbanization has a substantial impact on the cedar community. Urbanization alters hydrologic regime by changing drainage pathways and creating increased impervious surface area. Both altered drainage and increased impervious surface area will alter hydrology, change the source of input and channel flow. In addition, even minimal placement of roads in proximity to wetlands can impact the condition of those wetlands by altering water levels and allowing invasive plant species to colonize the site (Ehrenfeld & Schneider 1983).

Site Description

Within the study area are approximately 16 hectares of wetland. The general topography of the study area is characterized by steep slopes and rocky ledges that protrude through shallow soil. The steep slopes and shallow soils increase the likelihood of flash flows during storm events. The slopes form ridges that divide the study area into three subwatersheds, each containing the wetland basins included in the study. The topography within each wetland basin is characterized by extensive and well-defined hummocks and hollows characteristic of cedar wetlands. The wetland basins are located at an elevation of approximately 106 m above mean sea level approximately 60 km inland from the Atlantic coast.

METHODS

Hydrologic Monitoring

Twenty-three piezometers were installed within the study area to document the existing hydrologic regime of each plant community, as shown in [figure 1](#). The piezometers were installed in eight transects located within three subwatersheds. Within each transect individual piezometers were placed approximately 30 m apart within the hollows of the hummock and hollow topography. The elevational gradient between the hollows and surrounding hummocks was not measured. Transects were located within the wetland basins on the downgradient side of potential development locations. Piezometers were distributed as follows: seven in the cedar/giant rhododendron community (Watershed 1); six in the cedar community and five in the northern black gum community (Watershed 2); three in the southern black gum community and two in the red maple community (Watershed 3).

The water level at each piezometer was obtained bi-weekly for one year (24 monitoring events) to obtain data representing one complete hydroperiod. Water level monitoring commenced on January 2, 2000, and culminated on December 17, 2000. Water level measurements were obtained using either a Seattle Co. Water Level Indicator Model 51453, or a Solinst Water Level Indicator Model 101. During each monitoring event, three measurements were recorded: depth to water (DTW), depth to ground (DTG), and, if surface water was present, depth of surface water.

It has been observed in this study, and others, that piezometers float up and down with the sphagnum mat. As sphagnum expands and contracts with the raising and lowering of the water table, the skin friction of the sphagnum

on the outside of the piezometer causes it to move up and down accordingly (Hemond et al. 1987). The piezometer cannot be considered a stable reference point since it has a tendency to “float”; therefore, it may be inaccurate to obtain DTW without obtaining DTG, under similar conditions in the absence of some form of reference datum, to account for possible vertical movement of the piezometer.

Vegetation Sampling

On June 16 and 17, 2000, all herbaceous growth, tree seedlings, shrubs, and saplings were sampled at each piezometer. Box plots were placed around each piezometer. The piezometer was used as the plot centrum to obtain vegetation data from the same location as water level data. Herbaceous and low woody vegetation were grouped and collectively called ground cover. Individuals within a one m² box plot were sampled. All woody vegetation over 0.91 m in height within a three m² box plot was sampled. All individuals within the box plots were identified to species and percent areal cover was estimated, with the exception of sphagnum.

Percent areal cover was determined based upon the methods set forth in the “1987 U.S. Army Corps of Engineers Federal Manual for Delineating and Identifying Jurisdictional Wetlands” (the Manual) and dominance was identified based upon the “50/20” rule, which is stated in the Manual as follows: “for each stratum in the plant community, dominant species are the most abundant plant species (when ranked in descending order of abundance and cumulatively totaled) that immediately exceed 50 percent of the total dominance measure for the stratum, plus any additional species that individually comprise 20 percent or more of the total dominance measure for the stratum. The list of dominant species is then combined across strata.” However, for the purposes of this study I did not complete the final step of combining dominant species across strata as I wanted to compare variation among strata.

On September 24, 2000, and October 8, 2000, tree species were sampled using a basal area prism with a factor of five. All individuals within the plot determined by the prism were identified to species, diameter at breast height (DBH) was measured, and health was assessed. Sampled trees were put into one of three health categories: healthy tree, less vigorous tree, and dead tree. A healthy tree was defined as a tree with a visual estimation of a live crown ratio (LCR) greater than 30 percent. A less vigorous tree was defined as a tree with a LCR less than 30 percent. A dead tree was defined as a tree with a LCR of zero. The LCR was determined based upon a visual estimation of the measured height of the live branches divided by the total measured height of the tree multiplied by 100.

Plant Communities and Water Level

To define the relationship between vegetation and mean water level, vegetation sampling results for the ground cover and shrub strata were correlated with the mean water level for each piezometer. To correlate the data, the Region 1 wetland indicator status (R1IND), a representation of occurrence frequency based upon the likelihood of occurrence in a wetland, was obtained for each species included in the sample for both the ground cover and shrub strata. Dominant species were determined according to the method outlined in the Manual. An Ecological Site Index (ESI) was assigned to each R1IND category then applied to all dominant species based upon the midpoint of the category’s range. The ESI was then used to derive the Wetland Site Index (WSI). The WSI is a 100- point scale that measures the propensity for a species to occur in a wetland, or “wetlandness,” with 1 representing a dry site and 100 representing a wet site. The WSI was determined for each dominant species by multiplying the midpoint value by the ESI and then dividing the result by the sum of the midpoint values for all dominant species. The WSI for all dominant species was then summed to derive a WSI representative of each piezometer location.

RESULTS AND DISCUSSION

Hydrology

To quantify hydrologic regime three parameters were analyzed: hydroperiod, mean water level, and water table fluctuation. Piezometer A1 was excluded from any calculation involving mean water level as it was determined to be an outlier due to its location on the wetland boundary. Also, data obtained at piezometer D1 on May 21st was not used in calculations of water table fluctuation due to the extreme low measurement.

Hydroperiod— The hydroperiod represents the rise and fall of the water table in a wetland over time with one year representing one complete hydroperiod. Using the modifiers presented in Cowardin (1979), the wetlands in this

study are defined as Seasonally Flooded and Seasonally Flooded/Saturated. According to Cowardin, Seasonally Flooded wetlands are those in which surface water is present for extended periods, especially early in the growing season, but is absent by the end of the growing season in most years. When surface water is absent, the water table is often near the ground surface. Saturated wetlands are those in which the substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present. The results show that water levels in piezometers located within the same watershed fluctuate together, and when graphed they depict a similar hydroperiod, indicative of a strong hydrologic connection. [figures 2 - 6](#) illustrate the hydroperiod for each watershed.

Mean water level—Differences in mean water level between plant communities were statistically significant ($P = .22 \times 10^{-9}$) among all plant communities. Comparisons between each plant community are shown in [table 1](#). Mean annual water level for each plant community was calculated as follows: cedar/giant rhododendron (1.0 cm BGS); cedar (9.4 cm BGS); northern black gum (4.3 BGS); southern black gum (1.3 BGS); and red maple (10.4 BGS). In Lowry (1984), the mean annual water level over the 6 year period for the 6 cedar swamps was 0.7 cm AGS. The annual mean, maximum, and minimum water levels for each piezometer are shown as [figure 7](#).

Water table fluctuation— To obtain mean annual fluctuation, the mean water level for each monitoring event was calculated for each piezometer. From this the mean annual water level was calculated for each plant community. The lowest mean annual water level within the community was then subtracted from the highest mean annual water level to yield mean annual fluctuation. When analyzed, differences in water table fluctuation were found to be statistically significant overall ($P = 0.7702$); however, comparisons between the northern black gum community and the cedar/giant rhododendron, southern black gum, and red maple communities were not ([table 2](#)).

Mean annual fluctuation for each plant community was as follows: cedar/giant rhododendron (23.2 cm); cedar (24.5 cm); northern black gum (33.2 cm); southern black gum (27.6 cm); and red maple (28.3 cm). The range of fluctuation for each plant community was as follows: cedar/giant rhododendron (26.8 cm BGS to 21.3 cm AGS); cedar (42.7 cm BGS to 0.9 cm AGS); northern black gum (56.1 cm BGS to 16.2 cm AGS); southern black gum (20.7 cm BGS to 13.4 cm AGS); and red maple (28.7 cm BGS to 2.7 cm AGS).

Vegetation Sampling

Species Richness/Structure— Fifty one vascular plant species were identified in the study. Of those, 33 species were identified in the ground cover stratum, 21 in the shrub stratum, and 13 in the tree stratum. There were 32 species identified in both the cedar/giant rhododendron and the cedar community. In the northern and southern black gum communities there were 28 and 18 species identified, respectively. Nineteen species were identified in the red maple community. This data is summarized in [table 3](#).

Dominant ground cover species were identified for each of the plant communities. In the cedar/giant rhododendron community dominant species included *Pteridium aquilinum* (bracken fern), *Trientalis borealis* (starflower), *Osmunda cinnamomea* (cinnamon fern), and *Coptis groenlandica* (goldthread). In the cedar community dominant species included *C. groenlandica*, *O. cinnamomea*, and *Kalmia latifolia* (mountain laurel). In the northern black gum community dominant species included *O. cinnamomea* and *Symplocarpus foetidus* (skunk cabbage) *C. groenlandica*, *Gaultheria hispidula* (creeping snowberry) and *Thelypteris simulata* (Massachusetts fern). In the southern black gum community dominant species included *O. cinnamomea* and *Vaccinium vacillans*. In the red maple community dominant species included *O. cinnamomea*, *C. groenlandica*, and *T. simulata*.

Dominant shrub species were identified for each of the plant communities. In the cedar/giant rhododendron community, dominant species included *Vaccinium corymbosum* (common highbush blueberry), *Gaylussacia baccata* (black huckleberry), *Rhododendron maximum* (Giant rhododendron) and *Lyonia ligustrina* (maleberry). In the cedar community dominant species included *K. latifolia*, *Acer rubrum* (red maple), and *Betula alleghaniensis* (yellow birch). In the northern black gum community dominant species included *V. corymbosum* and *G. frondosa*. In the southern black gum community dominant species included *V. corymbosum* and *A. rubrum*. In the red maple community dominant species included *V. corymbosum* and *Kalmia angustifolia* (sheep laurel).

Dominant tree species were identified for each of the plant communities. In the cedar/giant rhododendron community dominant species included *C. thyoides* and *A. rubrum*. In the cedar community dominant species

included *C. thyoides*. In the northern black gum community dominant species included *Nyssa sylvatica* (black gum), *A. rubrum*, *Pinus strobus* (Eastern white pine), and *Tsuga Canadensis* (Eastern hemlock). In the southern black gum community dominant species included *N. sylvatica* and *P. strobus*. In the red maple community dominant species included *A. rubrum* and *P. strobus*.

Complete results of vegetation sampling are shown in [table 4](#).

Plant Communities and Water Level

Linear regression analyses were performed for the ground cover and shrub strata to determine if a relationship exists between the WSI and mean water level. The tree stratum was not included in the analyses since basal area was used to determine dominance instead of percent areal cover. Both r^2 values indicate that there is not a strong correlation between the WSI and the mean water level: ground cover $r^2 = 0.0062$, and shrub $r^2 = 0.0737$. The r^2 for the ground cover strata is slightly stronger, but is not statistically significant ($P = 0.002106$). The low r^2 values suggest that there is a great deal of variability in water table preference. It is notable that each vegetative stratum has a different level of correlation with the water table. Many of the shrubs sampled in the study had a lower R1IND Status than much of the ground cover sampled. This is apparent in the linear regression model, as the WSI was not higher at piezometers with higher mean water levels for the shrub stratum. In contrast the WSI was higher at piezometers with a higher mean water level for the ground cover stratum. Therefore, the notion that the wettest plots would have the highest WSI values does not hold true. The weakness of these correlations indicates that as a method, the Routine on-site method, the most widely practiced standardized method for wetland delineation, may be inadequate in yielding a determination of "wetlandness" in terms of vegetation analysis. Linear regression results are shown as [figures 8](#) and [9](#).

CONCLUSIONS

These wetland basins support a broad vegetative assemblage of species with highly variable water requirements. Species were identified with R1IND Status assignments ranging from Obligate to Facultative Upland. Although, topography was not measured as part of this study, it seems that topography plays a role in enabling such a wide variety of species to colonize these wetlands by providing an elevational gradient (from wet to dry) upon which to colonize.

Lowry's (1984) study showed a wide disparity in water level data between years and among wetland types emphasizing the need for long-term hydrologic monitoring. The monitoring plan set forth in this study and the data collected now serves as the foundation upon which long-term hydrologic and ecological monitoring of the Manchester Cedar Swamp has been based. Continuance of this study is an ongoing effort of The Nature Conservancy. This study will make it possible to observe the long-term effects of development on hydrology and plant community composition and subsequently, strategies can be implemented to minimize adverse effects resulting from future development in the surrounding upland. Maintaining a stable hydrologic regime should be integral to any protection plan if the goal of protecting the cedar community is to succeed.

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Figure 1—Project area map showing plant communities and piezometer locations.

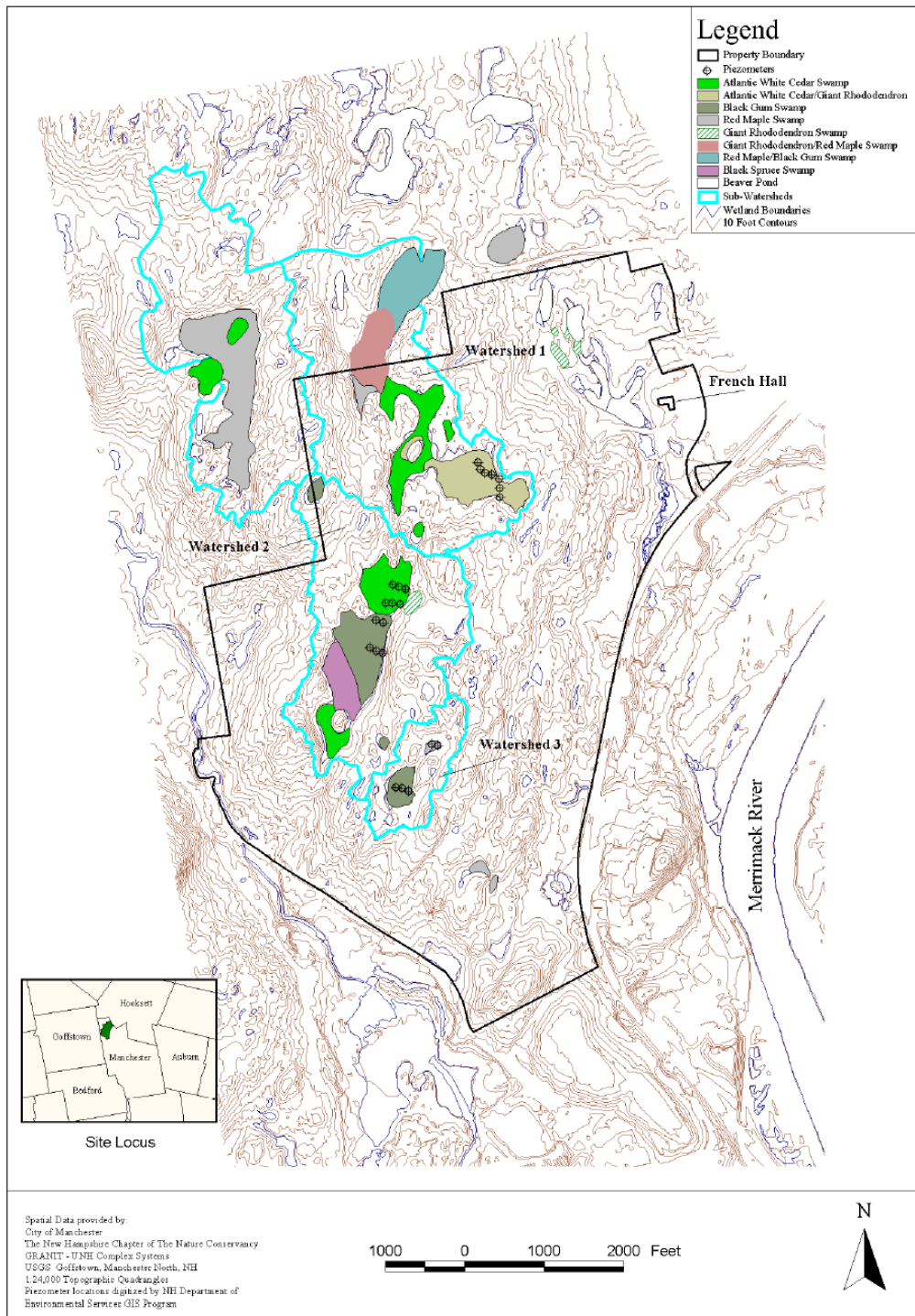


Table 1— P Value Analysis of Mean Water Level between Plant Communities.

Plant Community	AWC/GR	AWC	NBG	SBG	RM
AWC/GR	--	7.85E-14	1.22E-05	0.668	1.33E-11
AWC	7.85E-14	--	4.67E-08	2.47E-09	0.983
NBG	1.22E-05	4.67E-08	--	3.45E-04	3.18E-07
SBG	0.668	2.47E-09	3.45E-04	--	4.79E-11
RM	1.33E-11	0.983	3.18E-07	4.79E-11	--

Table 2—P Value Analysis of Water Table Fluctuation between Plant Communities.

Plant Community	AWC/GR	AWC	NBG	SBG	RM
AWC/GR	--	0.43	0.24	0.55	0.63
AWC	0.43	--	0.84	0.51	0.59
NBG	0.24	0.84	--	0.30	0.38
SBG	0.55	0.51	0.30	--	0.86
RM	0.63	0.59	0.38	0.86	--

Table 3—Summary of Species Richness/Structure for each Plant Community.

Plant Community	Ground Cover	Shrub	Tree	Species Richness /Plant Community
AWC/GR	20	7	11	32
AWC	21	12	6	32
NBG	16	8	9	28
SBG	11	11	4	18
RM	11	4	4	19
Species Richness/Strata	33	21	13	51

Table 4—Results of vegetation sampling for each plant community.

Genus/Species	Common Name	AWC	AWC/GR	RM	NBG	SBG
GROUND COVER						
<i>Chamaecyparis thyoides</i>	Atlantic white cedar	1	--	--	--	--
<i>Nyssa sylvatica</i>	Black gum	2	--	--	--	--
<i>Gaylussacia baccata</i>	Black huckleberry	2	--	--	--	--
<i>Pteridium aquilinum</i>	Bracken fern	4	--	--	--	--
<i>Cornus canadensis</i>	Bunchberry	--	1	--	--	--
<i>Maianthemum canadense</i>	Canada mayflower	--	1	--	--	--
<i>Osmunda cinnamomea</i>	Cinnamon fern	--	1	--	--	--
<i>Ilex verticillata</i>	Common winterberry holly	--	1	--	--	--
<i>Gaultheria hispidula</i>	Creeping snowberry	1	1	--	--	--
<i>Dalibarda repens</i>	Dewdrop	2	1	--	--	--
<i>Vaccinium vacillans</i>	Early low blueberry	2	1	--	--	--
<i>Glyceria striata</i>	Fowl manna grass	1	5	--	--	--
<i>Coptis groenlandica</i>	Goldthread	--	--	1	--	--
<i>Vaccinium angustifolium</i>	Late low blueberry	--	--	--	1	--
<i>Thelypteris simulata</i>	Massachusetts fern	1	--	--	1	--
<i>Kalmia latifolia</i>	Mountain laurel	--	1	--	1	--
<i>Trillium undulatum</i>	Painted trillium	--	1	--	1	--
<i>Aster lanceolatus</i>	Panckled aster	1	1	--	1	--
<i>Acer rubrum</i>	Red maple	2	--	1	1	--
<i>Quercus rubra</i>	Red oak	--	1	1	1	--
<i>Kalmia angustifolia</i>	Sheep laurel	1	1	2	3	--
<i>Symplocarpus foetidus</i>	Skunk cabbage	1	--	--	4	--
<i>Trientalis borealis</i>	Starflower	--	--	--	--	1
<i>Lysimachia terrestris</i>	Swamp candles	1	--	--	--	1
<i>Rubus hispidus</i>	Swamp dewberry	--	1	1	--	1
<i>Carex trisperma</i>	Three seed sedge	1	--	--	1	1
<i>Lycopodium obscurum L.</i>	Tree clubmoss	5	2	1	1	1
<i>Aster acuminatus</i>	Whorled aster	3	1	1	2	1
<i>Uvularia sessifolia</i>	Wild oats	5	2	2	2	1
<i>Aralia nudicaulis</i>	Wild sarsaparilla	--	--	1	--	2
<i>Gaultheria procumbens</i>	Wintergreen	2	5	2	4	2
<i>Betula alleghaniensis</i>	Yellow birch	1	2	1	1	3
<i>Clintonia borealis</i>	Yellow clintonia	5	6	--	3	3
SHRUBS						
<i>Nyssa sylvatica</i>	Black gum	--	--	1	--	1
<i>Gaylussacia baccata</i>	Black huckleberry	--	2	--	1	--
<i>Amelanchier canadensis</i>	Canada shadbush serviceberry	--	--	1	--	--
<i>Vaccinium corymbosum</i>	Common highbush blueberry	2	5	2	3	3
<i>Ilex verticillata</i>	Common winterberry holly	1	1	--	2	2
<i>Amelanchier arborea</i>	Downy serviceberry	--	--	--	--	1
<i>Vaccinium angustifolium</i>	Early low blueberry	1	--	--	--	1
<i>Rhamnus frangula</i>	European buckthorn	1	--	--	--	--
<i>Rhododendron maximum</i>	Giant rhododendron	--	3	--	--	--
<i>Vaccinium angustifolium</i>	Late low blueberry	1	--	--	1	1
<i>Lyonia ligustrina</i>	Maleberry	--	2	--	--	--
<i>Nemopanthis mucronata</i>	Mountain holly	1	--	--	--	--

<i>Kalmia latifolia</i>	Mountain laurel	1	--	--	--	--
<i>Rhododendron nudiflorum</i>	Pink azalea	--	--	--	1	--
<i>Acer rubrum</i>	Red maple	3	1	--	1	2
<i>Quercus rubra</i>	Red oak	1	--	--	--	1
<i>Kalmia angustifolia</i>	Sheep laurel	1	--	1	--	1
<i>Gaylussacia frondosa</i>	Tall huckleberry	--	--	--	1	--
<i>Pinus strobus</i>	White pine	--	--	--	--	1
<i>Hammamalis virginiana</i>	Witch hazel	1	--	--	--	--
<i>Betula alleghaniensis</i>	Yellow birch	2	1	--	1	1
TREES						
<i>Chamaecyparis thyoides</i>	Atlantic white cedar	78	56	--	1	--
<i>Betula lenta</i>	Black birch	--	1	--	--	--
<i>Nyssa sylvatica</i>	Black gum	--	10	--	9	12
<i>Quercus velutina</i>	Black oak	--	1	--	--	--
<i>Picea mariana</i>	Black spruce	--	--	--	5	--
<i>Tsuga canadensis</i>	Eastern hemlock	--	4	--	15	--
<i>Pinus rigida</i>	Pitch pine	2	--	--	--	--
<i>Acer rubrum</i>	Red maple	11	60	17	21	12
<i>Quercus rubra</i>	Red oak	10	5	--	3	--
<i>Betula papyrifera</i>	White birch	--	3	1	--	--
<i>Quercus alba</i>	White oak	--	1	1	4	--
<i>Pinus strobus</i>	White pine	18	7	6	18	11
<i>Betula allegheniensis</i>	Yellow birch	1	2	--	4	3

Figure 2—Hydroperiod for the Atlantic White Cedar/Giant Rhododendron Community by transects A and B.

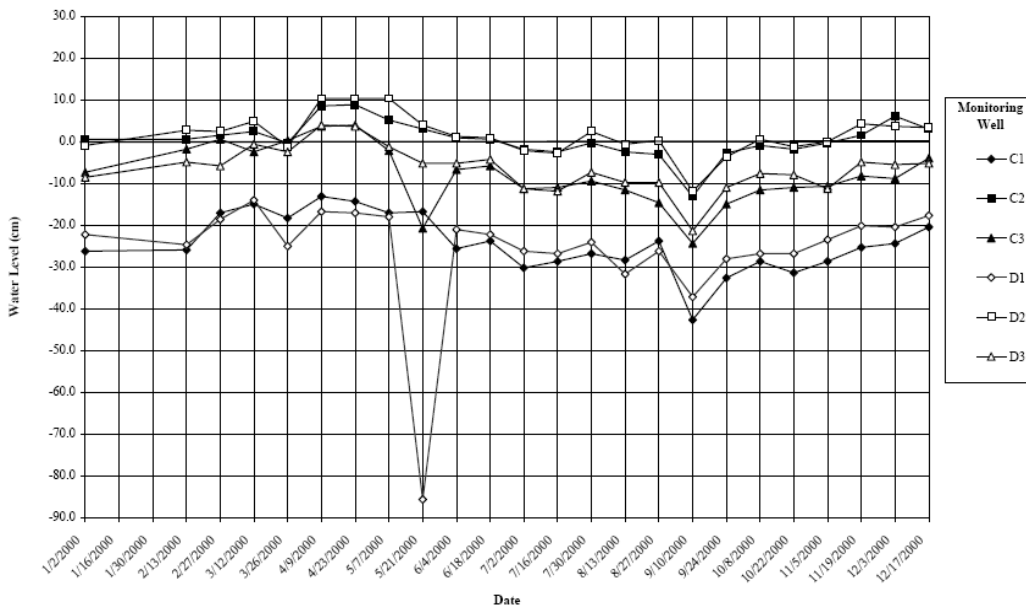


Figure 3—Hydroperiod for the Atlantic White Cedar Community represented by transects C and D.

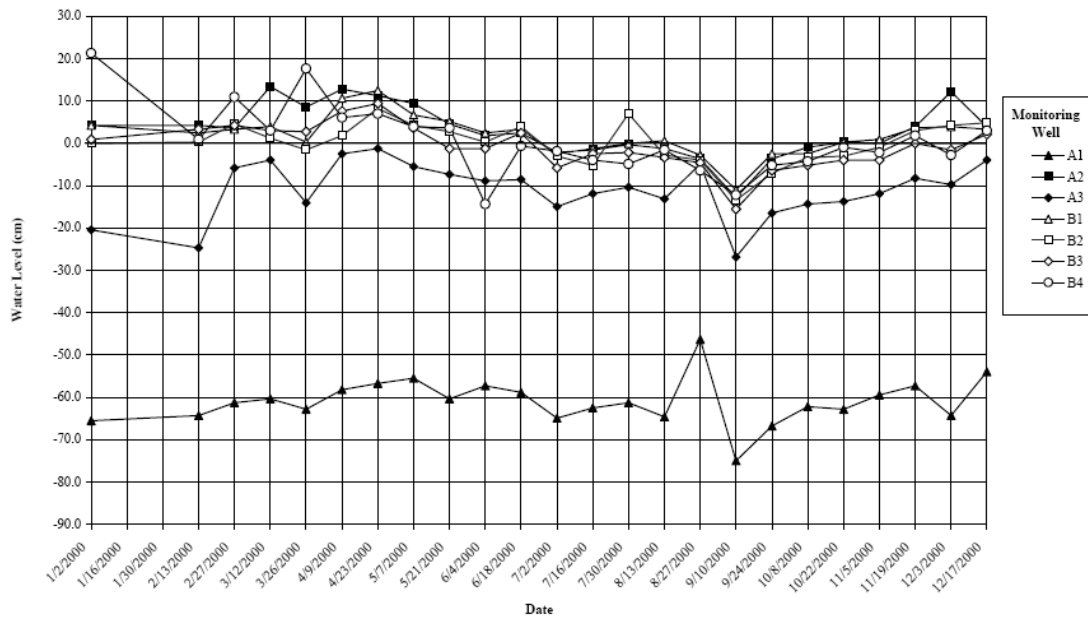


Figure 4—Hydroperiod for the Northern Black Gum Community represented by transects E and F.

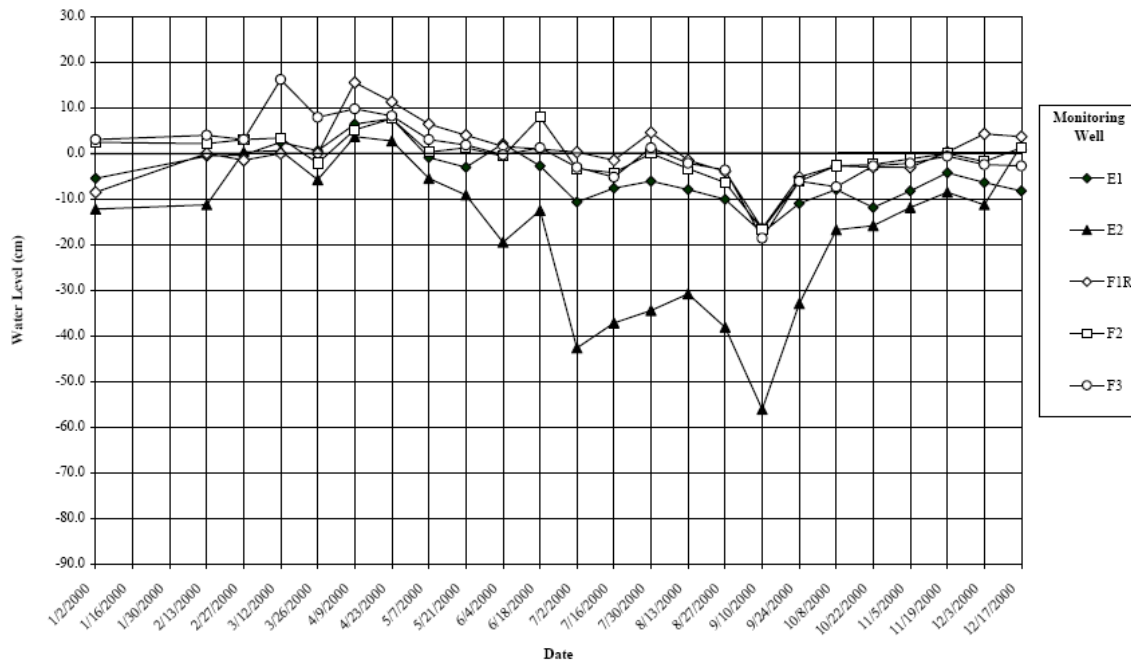


Figure 5— Hydroperiod for the Southern Black Gum Community represented by transect G.

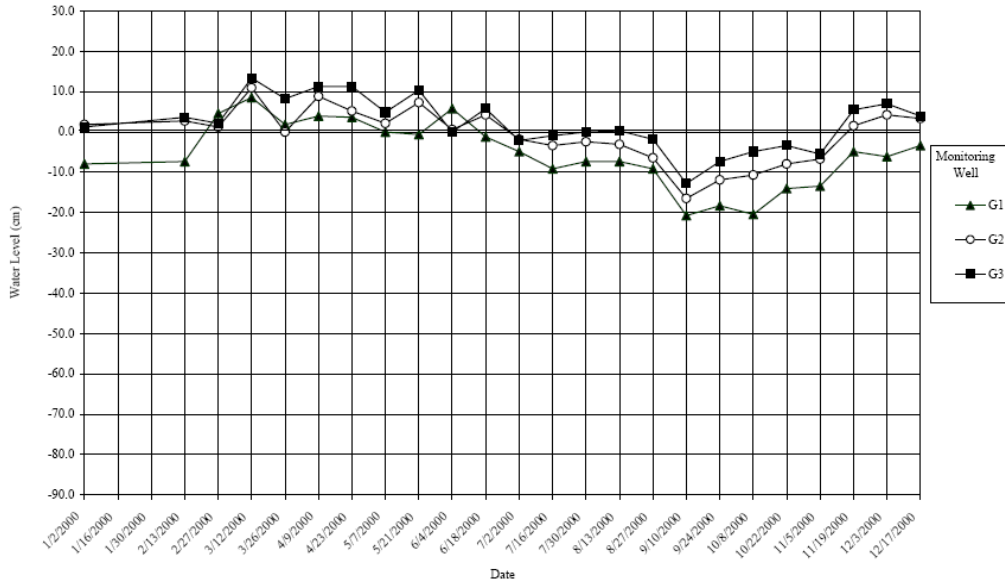


Figure 6— Hydroperiod for the Red Maple Community represented by transect H.

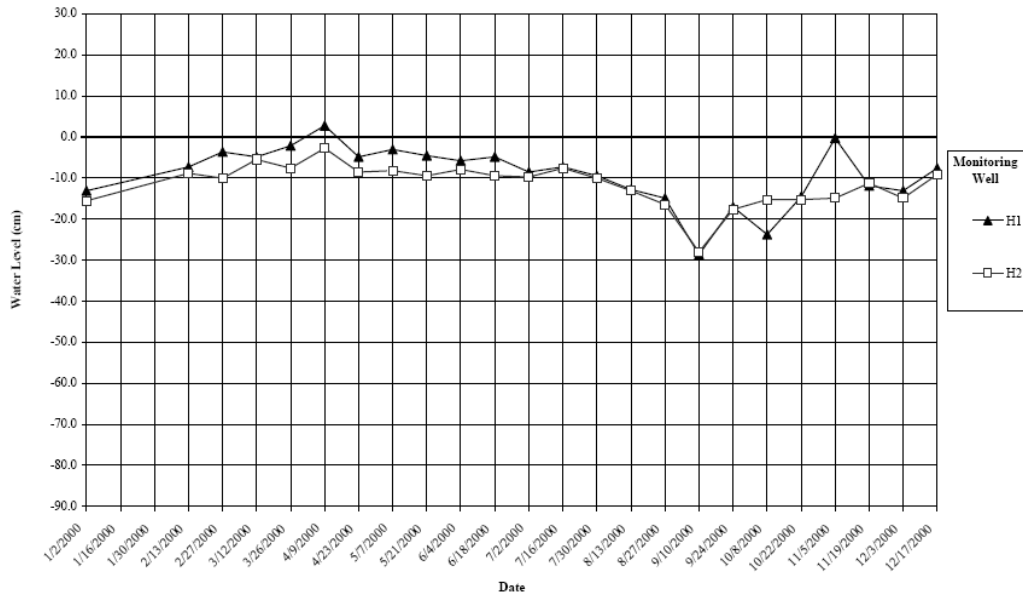


Figure 7—Mean, maximum, and minimum water levels for all piezometers.

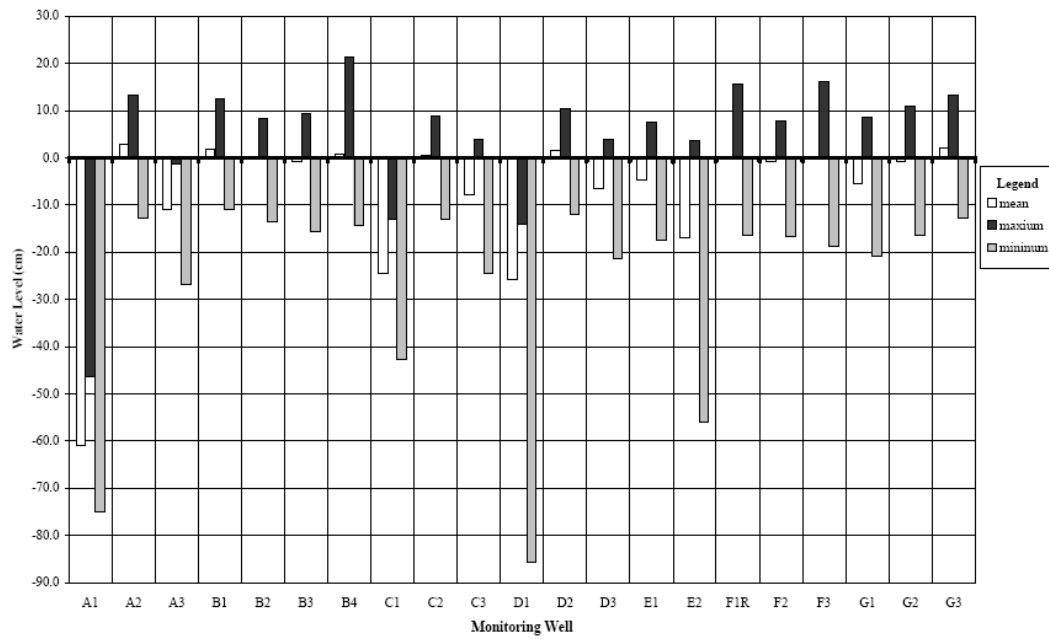


Figure 8—Results of regression analysis for the ground cover stratum.

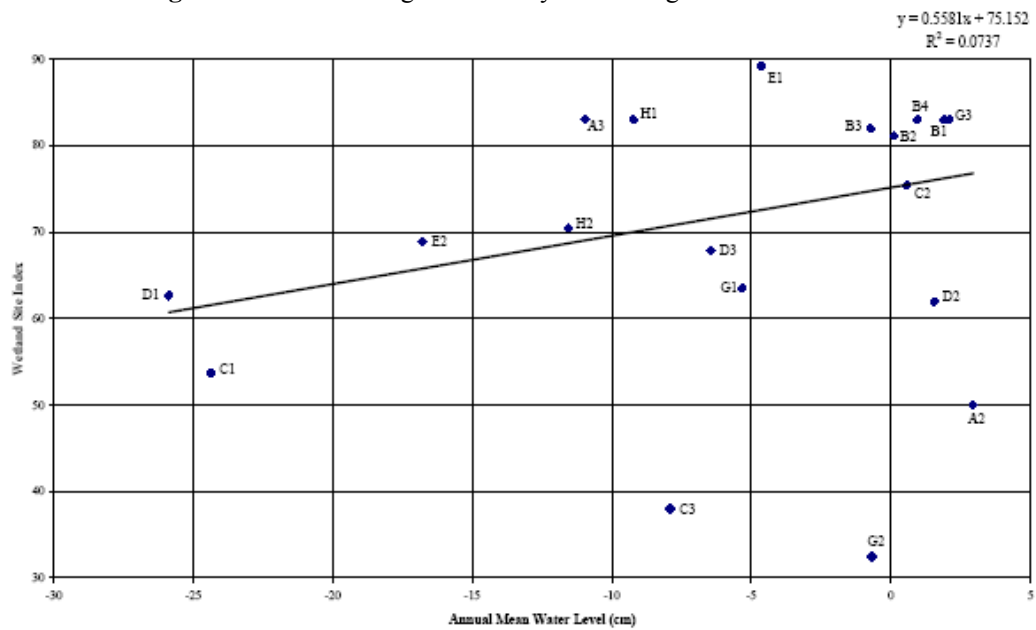
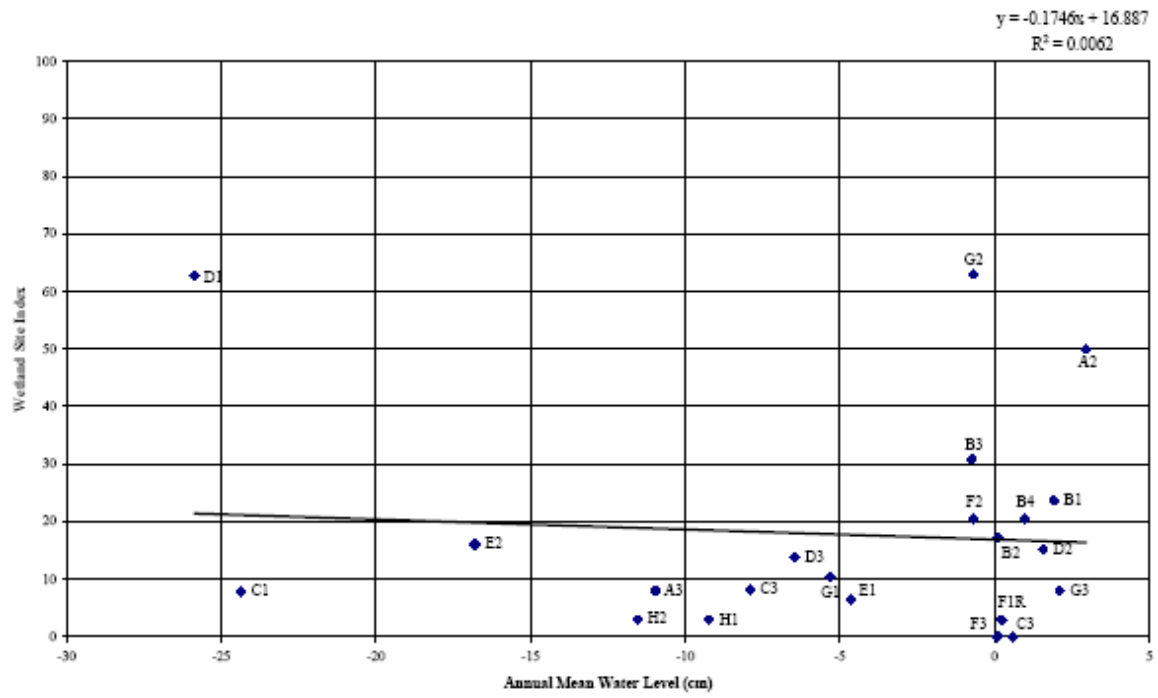


Figure 9—Results of regression analysis for the shrub stratum.



CYPRESS CREEK SAVANNA: A HISTORY OF VEGETATIVE CHANGES

David E. Walbeck¹, Keith R. Underwood² and Karl D. Benedict³

¹David E. Walbeck, Wetlands Specialist, Maryland Department of the Environment,
1800 Washington Blvd., Baltimore, MD 21230

²Keith R. Underwood, Ecologist, Underwood and Associates, 1753 Ebling Trail, Annapolis, MD 21401

³Karl D. Benedict, Plant Biologist, Underwood and Associates, 1753 Ebling Trail, Annapolis, MD 21401.

Abstract-- Atlantic white cedar (AWC) and associated peatland species have been reported at Cypress Creek Savanna in Severna Park, Maryland for one hundred years. Historical records of site vegetation indicate a relatively recent significant decline in AWC and other locally rare plant species, along with an increase in *Phragmites australis*. The decline in the AWC population was first recorded in 1988 and has continued through 2006. We compared AWC count data collected in 1997, 2003 and 2006 to predict the fate of the AWC population. It is likely that all of the rare species will be extirpated unless there are dramatic efforts to restore the site. We concluded that increases in salinity at the site were most likely the main cause of the loss of AWC and other peatland plants.

Keywords: Atlantic white cedar, *Chamaecyparis thyoides*, Cypress Creek Savanna, salinity, invasive, brackish, *Phragmites*, propagules, Maryland

INTRODUCTION

Cypress Creek Savanna is located on the east side of Maryland Route 2 at a tidal interface of the Magothy River in Severna Park, Maryland. The site has been characterized as a sea level fen (Sipple 1999). Over one hundred years of historical accounts of the site report the presence of rare plant species, including an AWC (*Chamaecyparis thyoides* (L.) BSP) population.

In 1904, Dr. Charles Plitt began describing Cypress Creek Savanna and recording his observations of the plant species occurring at the site (Sipple 1999). Dr. Plitt described “many” white cedar and a “large” sphagnum swamp that contained three orchid species, pitcher plants, and “great patches” of the native cranberry (*Vaccinium macrocarpon* Ait.) in 1907 (Sipple 1999).

During the twentieth century the Cypress Creek area became highly developed, with many new roads and buildings. Located at the narrowest part of the peninsula separating the Severn and Magothy Rivers, development separated the AWC population into 4 current sites (Cypress Creek Swamp, Cypress Creek Savanna, Dill Road, and Sullivan Cove) as identified by Sheridan and others (1999). Other sites were eliminated, such as the AWC on the North Fork of (or Big) Cypress Creek, which received runoff from large impervious areas associated with roads and shopping centers.

Beginning in 1977, William S. Sipple and others conducted a series of studies at Cypress Creek Savanna. In 1977, Sipple (1977) stated that the number of cedar trees probably easily exceeded one hundred, although many were small saplings and most of the larger ones were only 3 to 6 inches diameter at breast height (dbh). Sipple and Klockner (1980) described the site as a two-acre wetland with an open savanna, surrounding AWC swamp, deciduous swamp and tidal marsh. The open savanna was dominated by *Cladium mariscoides* and *Rhynchospora alba* with small (one to six feet tall) AWC scattered throughout, and the AWC swamp included a few specimens up to 1 foot dbh (Sipple and Klockner 1980). Unlike the other AWC sites in Maryland, Cypress Creek Savanna contained many vigorous AWC seedlings (Sipple and Klockner 1984).

Sipple visited the Cypress Creek site in 1982, 1983, 1986 and 1987 and did not notice any problems with the cedars (Sipple 1999). On July 9, 1988, however, Sipple (1999) was disappointed that almost all of the AWC appeared dead

and there was no evidence of *Drosera*, *Sarracenia*, *Eleocharis flavescens*, orchids, and other interesting plants that he had previously found. On June 10, 1992 Sipple noted that many of the small cedars had died and that he did not see any sundews or orchids. Similarly, his June 18, 1993 report indicated that much of the AWC was dead, particularly the smaller trees. He did find one remaining yellow-fringed orchid (formerly *Habenaria ciliaris*, now *Platanthera ciliaris*) on August 13, 1998 (Sipple 1999).

In 1997, a census of AWC in Anne Arundel County, Maryland quantified the number and diameters of AWC trees at ten sites (Sheridan and others 1999). The Cypress Creek Savanna site included 501 dead trees, 125 living trees and 24 seedlings. Of the ten sites sampled, the Cypress Creek Savanna had the fourth largest number of living trees and the fourth largest number of seedlings.

The purpose of this study was to resample AWC at Cypress Creek Savanna in an effort to continue the long-term evaluation of changes that are occurring at the site. We compared AWC count data collected in 2003 and 2006 to the 1997 data to predict the fate of the AWC population. We also considered some of the possible reasons for the decline of the population.

METHODS

Site visits were made in April and May 2003 and in May and June 2006 to count the number of living AWC trees and seedlings at Cypress Creek Savanna. We used the same protocol as in the 1997 census (Sheridan and others 1999). Live cedars measuring over 1.2 m in height were recorded as trees and individuals measuring less than 1.2 m were recorded as seedlings. Salinity measurements were taken in ten shallow pools of standing water dispersed around the Savanna and in the adjacent tidal creek on May 17, 2006 using a Model REF211ATC Salinity Refractometer from Mannix Testing & Measurement.

RESULTS

A total of 650 AWC were counted in 2003, but most of them were dead - only 85 living trees and 23 seedlings were found. In 2006, the number of live trees and seedlings had declined to 56 and 7, respectively. [Figure 1](#) shows the changes that have occurred since the 1997 census. The number of living AWC has declined from 149 to 63 between 1997 and 2006. There has been a continuous decline in the number of living trees from 125 in 1997 to 85 in 2003 and to 56 in 2006. The number of seedlings was similar in 1997 and 2003, but there was a sharp decline between 2003 and 2006 (from 23 to 7).

Salinity measurements within the Savanna ranged from five to six parts per thousand, compared to eight parts per thousand in the adjacent tidal creek. Seven pools of water had salinity readings of five parts per thousand, and three pools had readings of six parts per thousand.

DISCUSSION

Long-term records of AWC at the Cypress Creek Savanna clearly demonstrate that dramatic changes have occurred. While not specifically sampled in this study, historical records demonstrate that almost all of the locally rare acidophilic bog/fen species (e.g., *Drosera*, *Platanthera*, *Sarracenia*) have been eliminated. The site has also been invaded by common marsh species that can tolerate higher pH and brackish conditions, especially the invasive common reed (*Phragmites australis*), which is expanding rapidly in mid-Atlantic brackish wetlands. AWC and perhaps a few individual orchids or cranberries are the last of the rare species remaining. The decline of the AWC population and the disappearance of the other rare species indicate a change in the ecosystem, probably related to long term changes to the hydrology of the site (Sheridan and others 1999).

Cypress Creek Savanna is occasionally exposed to tidal water from adjacent estuarine areas (Whigham 1981, Whigham and Richardson 1988, Sipple 1999). Hull and Whigham (1987) predicted that sea level rise and the subsequent rise in salinities threatened the future existence of AWC in Anne Arundel County, Maryland. The 2006 salinity measurements clearly demonstrate that brackish water has entered the site, and increasing evidence shows that AWC can be killed by exposure to high salinities (Personal communication. George Zimmermann. 2006. Richard Stockton College of New Jersey. P.O. Box 195. Pomona, NJ 08240-0195). Increased frequencies of tidal flooding in the future as a result of sea level rise will likely continue to stress and kill the remaining cedars.

Competition from common species that invade the site as a result of changes in soil salinity may be another possible contributing cause of the decline of AWC. AWC recruitment generally occurs in habitat formed over open water as grasses and deadfalls create hummocks in sunlit areas. Common reed and other species invade this habitat and will compete with AWC. For example, a large number of AWC that had established on hummocks along a tidal pond edge at Sullivan Cove in 1996 were out-competed by common reed over the subsequent two years (Personal communication. Keith Underwood. 2003. Ecologist, 1753 Ebling Trail, Annapolis, MD 21401). At Cypress Creek Savanna, Sipple and Klockner (1984) considered the common reed to be restricted to two small areas and doing poorly in 1977 and 1978. In his June 18, 1993 journal notes, Sipple (1999) noted that the patches of common reed had spread, but he did not give an indication of the extent of the spread.

CONCLUSIONS

Extinction of the Cypress Creek Savanna AWC population would occur within the next 5 to 10 years if the rate of decline between 1997 and 2006 continues. Although the definitive reasons for the decline of rare plants cannot be determined without extensive monitoring, the increase in salinity is likely the most important factor. Increasing competition from common reed may also be important, especially for seedlings and saplings.

Hull and Whigham (1987) concluded that, because of their age and natural origins, the Cypress Creek sites were the main source of propagules for colonization of five other, younger, man-influenced bogs studied. As the historic main source of propagules of rare species for the nearby peatlands (Hull and Whigham 1987), Cypress Creek Savanna should be preserved and restored. Hull and Whigham (1987) and Sipple (1999) argued for the acquisition and preservation of the peatlands on the western shore of Maryland, including Cypress Creek Savanna. There has been significant progress in purchasing some of the peatlands and in regulatory protections (Broersma-Cole 2005), but Cypress Creek Savanna is still declining in quality. It seems likely that all of the rare species will be extirpated unless there are dramatic efforts to restore the site. The portion of the property encompassing the Cypress Creek Savanna could be purchased, or a stewardship agreement could be formed with the private landowner. A successful project could then be conducted that would restore the native peatland biota by recreating a fresh water system and seeding and planting the site with propagules from the Savanna and other local sites.

For existing populations of rare fresh water plant species that occur just above sea level to persist as sea level rises, these species must be able to move to suitable habitat available at adjacent higher elevations, or brackish waters must be physically kept at bay. Projects to enhance and create suitable habitat for these species can make significant contributions to preserving and increasing local and regional native biodiversity (Underwood and others 2005).

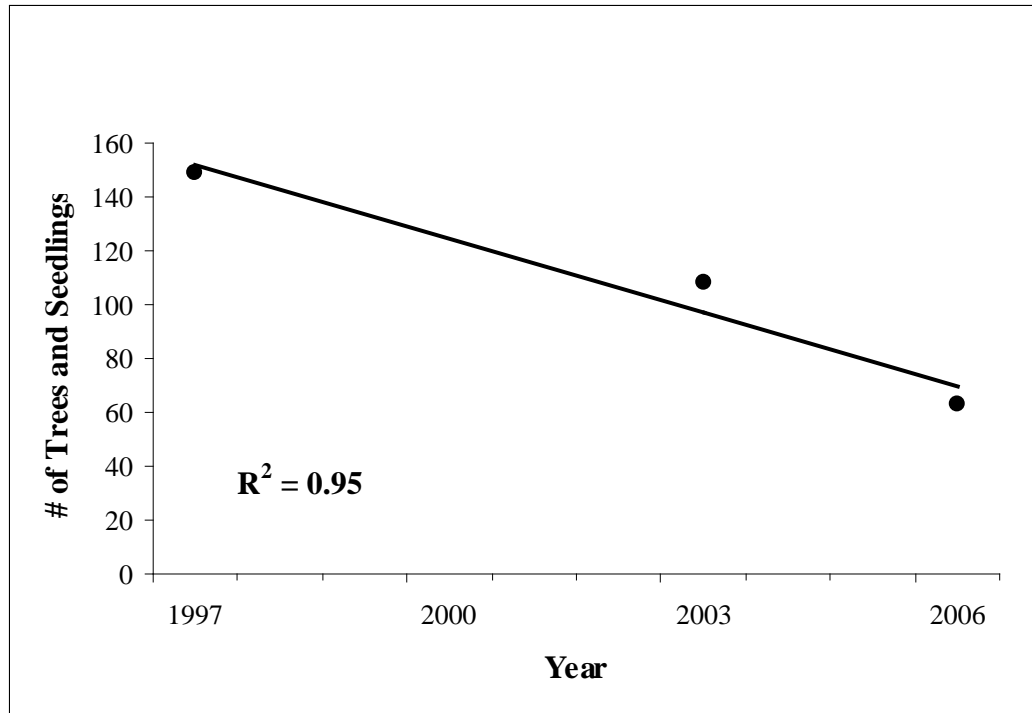
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Figure 1—Living Atlantic white cedar trees and saplings by year.



ATLANTIC WHITE CEDAR RESTORATION IN SOUTH CAROLINA: EFFECT OF FALL PLANTING DATE ON GROWTH AFTER 2 YEARS IN THE FIELD

Johnny Stowe¹, Eric Hinesley², Mike Wicker³, Jamie Dozier⁴, and James Sizemore⁵

¹Johnny Stowe: Region 2 Heritage Preserve Manager, South Carolina Department of Natural Resources
Columbia, SC 29224.

²Eric Hinesley: Professor, Department of Horticultural Science, North Carolina State University
Raleigh, NC 27695.

³Mike Wicker: Biologist, U. S. Fish & Wildlife Service
Raleigh, NC 27606.

⁴Jamie Dozier, Region 4 Heritage Preserve Manager, South Carolina Department of Natural Resources
Georgetown, SC 29440.

⁵James Sizemore, South Carolina Department of Natural Resources Heritage Preserve Stewardship Committee
Prosperity, SC 29127

Abstract—Six thousand Atlantic white cedar (AWC) transplants were established in October 2002 in a recently-drained 4-ha man-made impoundment in Aiken County, South Carolina. Survival was close to 100%. In a small replicated experiment (120 trees), growth the following year was significantly better for transplants established in September and October compared to November and December. This advantage was attributed to a shorter time of root confinement in containers during the fall. After 2 years in the field, transplants were about 1.3 m tall, and those planted in September were significantly taller than those planted in October or later. Planting throughout the fall appears feasible if soil moisture is adequate.

Key Words: Atlantic white cedar, *Chamaecyparis thyoides*, transplants, survival, seedlings, restoration, Sandhills

INTRODUCTION

In the Southeast, Atlantic white cedar (AWC: *Chamaecyparis thyoides*) often grows within the once extensive longleaf pine ecosystems that dominated the Coastal Plain from Virginia to Texas. Bill Boyer (USFS, retired; personal communication) has asserted that longleaf enthusiasts should pay closer attention to unique ecosystems embedded within longleaf pine forests. He mentioned cane (*Arundinaria* spp.) specifically, but his point is also germane to AWC swamps in much of the Southeast. Atlantic white-cedar occupies only a small fraction of its former extent, mostly because of overharvesting, lack of regeneration, drainage and filling of wetlands, and alterations in fire regimes (Davis et al. 1997, Frost 1987). Juniper communities are classified by the United States Fish and Wildlife Service (USFWS) as critically endangered (Noss et al. 1995), and by The Nature Conservancy as globally threatened (G2). Juniper tends to occur in blackwater swamps, most often along streams, but also in isolated swamps such as Carolina Bays. In the Carolinas, it typically grows in frequently saturated peat soils atop sand, or in wet sandy soils near streamheads. Factors such as soil and other seedbed requirements, hydrologic dynamics, competing vegetation and past fire history of the site all play critical roles in regeneration of AWC. Pure AWC stands can maintain up to twice as many healthy trees per acre as other forest tree species. Juniper wood has always commanded a premium price relative to pine and many other species. Our objective was to evaluate various planting dates (September to December) to facilitate restoration efforts with AWC in ecosystems where it grew in earlier times.

METHODS

On 28-30 October 2002, about 6,000 AWC seedling transplants ([figure 1](#)) were hand-planted in a recently drained, 4-ha man-made impoundment along Spring Branch, a first-order blackwater stream on Aiken Gopher Tortoise Heritage Preserve and Wildlife Management Area in Aiken County, SC. Seedlings had been raised for 1 year in

Ropak Multi-Pots (39-cm³ cell), and a second year in Anderson deep tree bands (7.5 x 7.5 x 23.5 cm)(Anderson Die & Manufacturing Co., Portland, Oregon). Planting conditions ranged from firm sand to muck almost 1.3 m deep. To determine if temporal variation in planting date affected seedling survival and growth, we also conducted a small replicated experiment by planting AWC transplants in mid-September, -October, -November, and -December. Thirty transplants were planted on each date. The experimental design was a randomized complete block with 30 blocks, four treatments (planting dates), and single-tree plots. Plants were placed in two adjacent rows, with 15 blocks in each row. The two rows ran along a set contour. Spacing was 2.4 m in rows and between rows. During the fall, plants that were still in containers were watered as needed. Total height of the experimental plants was measured at the end of the first (Fall 2003) and second (Fall 2004) years in the field. Data were subjected to analysis of variance, and 1-df contrasts were used to compare planting dates.

RESULTS

After one year in the field, survival was 100 percent for the 120 experimental seedlings, and seedlings planted in September and October were significantly taller than those planted later. All planting dates yielded good results ([table 1](#)), possibly because the site was constantly wet and rainfall was abundant. Differences in height were judged to result from a longer period of root confinement in containers during the fall of 2002 for seedlings outplanted in November and December. Survival after 2 years in the field was virtually 100 percent, with almost all trees healthy and some trees 1.5 to 1.8 m tall. After 2 years in the field, total height was significantly greater for the September planting date (131 cm) compared to an average of 119 to 124 cm for the other planting dates. A similar study with Fraser fir seedlings (*Abies fraseri*) showed that planting in irrigated transplant beds early in the fall yielded more growth the following year compared to later planting dates (Hinesley 1986). [Figures 2](#) and [3](#) show aspects of the restoration.

CONCLUSIONS

AWC transplants can be established successfully throughout the fall if soil moisture is adequate and competition not limiting. Based on total tree height, there was a small advantage to earlier planting (September) that was still evident after 2 years in the field.

ACKNOWLEDGEMENTS

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Table 1--Growth of Atlantic white-cedar planted on various dates in the fall of 2002, Aiken Gopher Tortoise Heritage Preserve, South Carolina. Measured in 2003 and 2004

Planting date - 2002	Number	Initial height (cm)	Total height growth (cm) Dec 2003	Total height growth (cm) July 2004	Total height (cm) Dec 2003	Total height (cm) July 2004
September	30	47.4	44.8	92.1	84.0	131.4
October	30	53.0	35.6	89.2	65.0	118.6
November	30	56.5	29.3	85.7	67.4	123.9
December	30	57.3	31.3	85.4	68.3	122.5
Sept vs. Oct		**	**	NS	**	**
Oct vs. Nov		*	NS	NS	NS	NS
Nov vs. Dec		NS	NS	NS	NS	NS
NS, *, ** Non-significant or significant at $P \leq 0.05$ or 0.01, respectively						

Figure 1— AWC transplants grown in Anderson deep tree bands (7.5 x 7.5 x 23.5 cm). Containers were removed to show the root systems.



Figure 2 -- Two-yr-old AWC transplant typical of those planted on Aiken Gopher Tortoise Heritage Preserve and Wildlife Management Area (Aiken County, SC). Seedlings had been grown 1 year in Ropak Multi-Pots (39-cm³ cell), and a second year in Anderson deep tree bands (7.5 x 7.5 x 23.5 cm)(Anderson Die & Manufacturing Co., Portland, Oregon). Shown in picture is Johnny Stowe.



Figure 3 -- Drained impoundment on Aiken Gopher Tortoise Heritage Preserve and Wildlife Management Area (Aiken County, SC) that was planted with 2-yr-old AWC transplants in October 2002. The two flagged rows were used to plant AWC on different dates in the fall (mid- September to mid-December). Shown in picture is Johnny Stowe.



ABSTRACT

CULTURAL PRACTICES FOR CONTAINERIZED ATLANTIC WHITE CEDAR

L. Eric Hinesley and Scott Derby

Dept. of Horticultural Science, North Carolina State University, Raleigh, NC 27695

Note: This is a brief summary of two presentations at the 2006 Research Conference in New Jersey. Readers can access pdf's of related journal articles at:

<http://www.fws.gov/nc-es/coastal/plnwrawc/awcindex.html>

Efforts to restore Atlantic white cedar [*Chamaecyparis thyoides* (L.) B.S.P.] (AWC) to former sites in North Carolina in the last 20 years have had limited success owing, in part, to a lack of quality planting stock. Production of bare-root seedlings in outdoor nursery beds has been inconsistent, and vegetative propagation, although easy, is costly and has considerable risk. Our objective was to develop a protocol for producing containerized seedlings. Newly germinated seedlings were grown in factorial combinations of four container volumes (98 cm³ to 530 cm³), two substrates [North Carolina Forest Service (NCFS) container mix (3 peat: 2 vermiculite: 1.5 perlite, by volume) and 3 pine bark: 1 peat], two controlled-release fertilizers (Osmocote[®] 15N-9P₂O₅-12K₂O, 12-14 month southern formulation, with micros; and Polyon[®] 18N-6P₂O₅-12K₂O with micros, 9-month formulation), and three irrigation frequencies (2, 3, or 4 times daily). Growth increased with container volume up to 530 cm³ (32 cubic inches), but the optimum was 164 to 262 cm³ (10 to 16 cubic inches). The NCFS substrate was best, probably owing to higher peat content and water holding capacity. Osmocote[®] yielded larger and heavier plants than Polyon[®], apparently owing to more available phosphorus. Irrigation frequency was flexible, but the optimum was 3X daily, especially later in the season when plants were large in relation to container volume. Manipulation of container volume, substrate, fertilizer, and irrigation should yield high quality containerized Atlantic white cedar seedlings.

AWC seedlings were grown in 3:1 composted pine bark and peat (v/v), and fertilized with five rates (0.0, 2.4, 4.8, 7.2, and 9.6 kg/m³) of controlled-release fertilizers (CRF) [Osmocote[®] 15N-9P₂O₅-12K₂O, 12-14 month southern formulation, with micros; and Polyon[®] 18N-6P₂O₅-12K₂O, 9-month formulation, with micros]. In general, the response to increasing fertilization was quadratic, and Osmocote[®] yielded larger plants than Polyon[®], probably owing to its higher P content. Osmocote[®] (4.8 to 7.2 kg/m³) or Polyon[®] (7.2 kg/m³) is suggested for container-grown seedlings the first year. Most of the potential height growth and plant dry weight were realized with 2.4 kg/m³ and 4.8 kg/m³, respectively, of CRF incorporated in the substrate.

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