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

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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 waters 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-m^2 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 DISSCUSSION

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

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

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

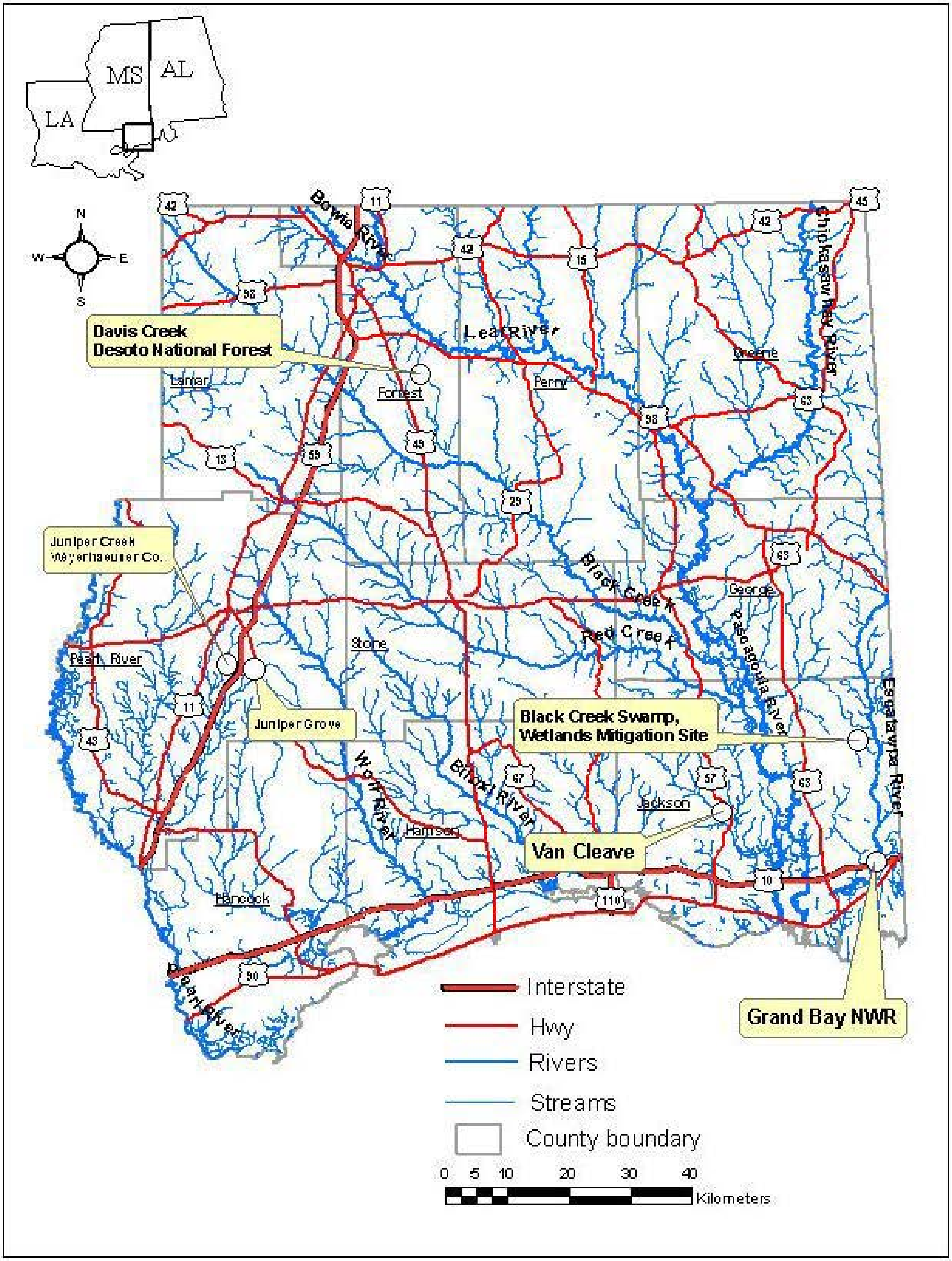

Figure 2—Locations of cedar trees at the Grand Bay NWR study site. Live, dead, and Hurricane Katrina damaged cedar trees are marked. The area mostly devoid of cedar is the cypress-tupelo swamp. The study area is ~ 4.7 ha. The relative size of the circles indicates relative dbh. Contour lines are at ~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

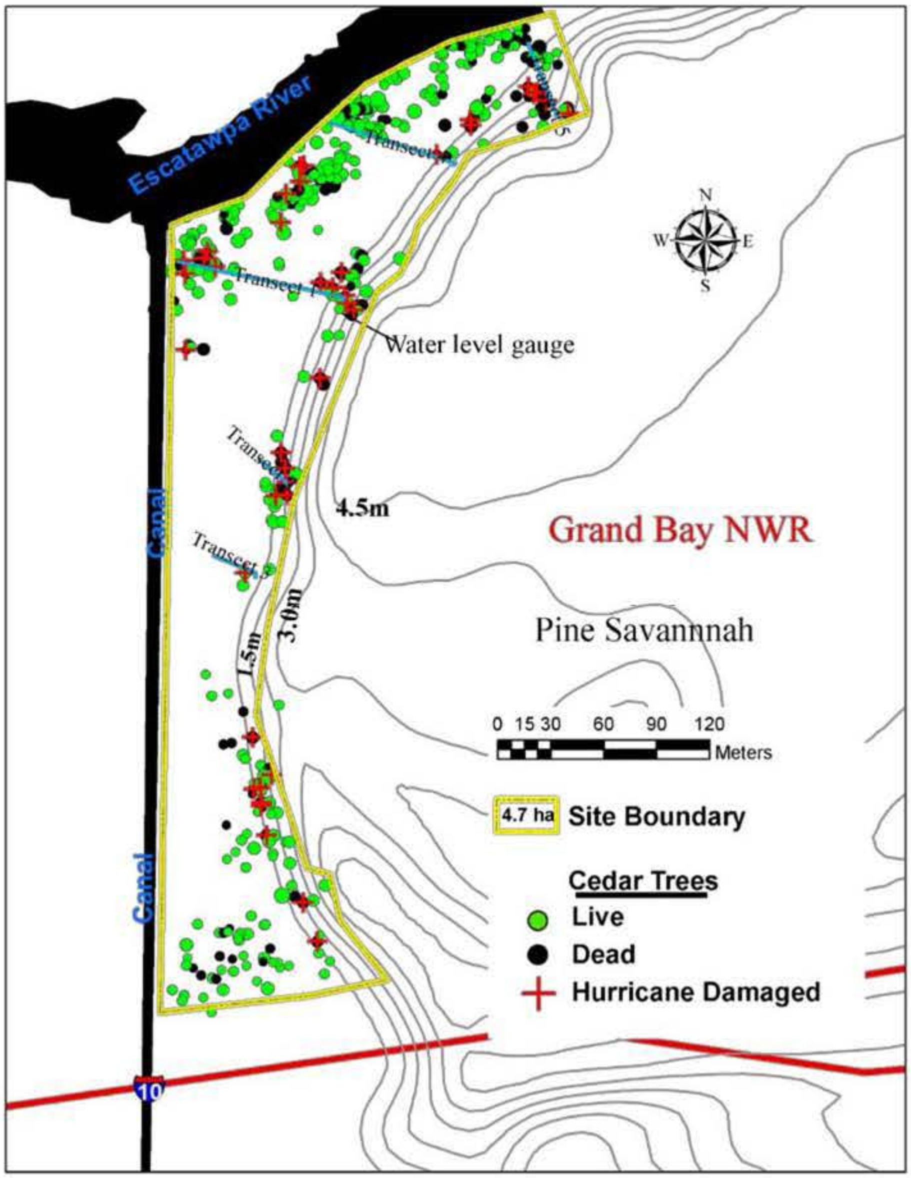

Figure 3--Water levels at the Grand Bay study site (black line) and at the Interstate 10 bridge over the Escatawpa River (gray line).

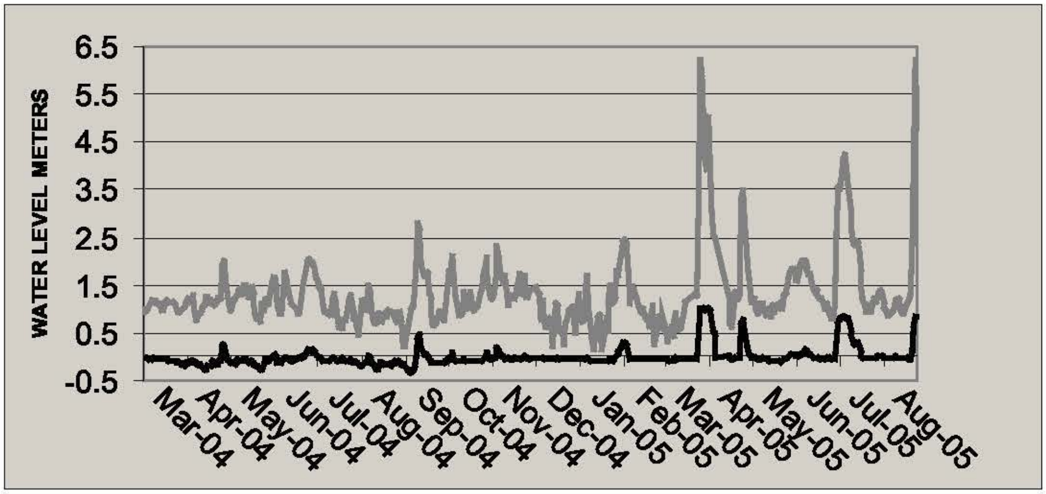

Figure 4--Diameter distribution of all living cedar trees at the Grand Bay study site.