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Abstract

Hurricane Katrina, a category four storm, made landfall on August 29, 2005, impacting both the De Soto Ranger District and the Chickasawhay Ranger District of the De Soto National Forest in Mississippi. Initial estimates of the affected areas on the De Soto Ranger District, in broad damage classes, included 142,000 acres of heavy damage, 108,000 acres of moderate damage and 132,000 acres of light damage. Similar estimates for the Chickasawhay District consisted of 39,000 acres of heavy damage and 116,000 acres of light damage. Due to forest health concerns regarding potential increases in insect, disease and non-native invasive plant activity in the aftermath of the hurricane, a general field assessment of the nature and extent of tree damage was conducted on the Districts during October 3-7, 2005. A total of 18 separate stands, representing a range of stand conditions and hurricane damage, were examined utilizing three, 1/10 ac plots per stand. Severe tree damage likely to result in eventual mortality, ranged from a low of 6% of the trees per acre (and 5% of the basal area per acre), to a high of 83% of the trees per acre (and 98% of the basal area per acre). Eleven of the 18 stands exhibited 30% or more severe tree damage on a trees per acre basis; ten of which showed greater than 40% of the basal area per acre as being severely damaged and likely to die in the near future (within two years). The widespread and abundant supply of highly susceptible host material for pine-infesting insects (e.g., bark beetles, weevils, and borers) suggests that populations of these potential pests will increase and possibly cause additional and undesirable tree mortality in the future. Recommendations for preventing and otherwise mitigating future tree mortality in the aftermath of hurricane damage are discussed. A preliminary report of this evaluation was provided to the Incident Command Team (ICT) on October 14, 2005.

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Introduction/Background

Hurricane Katrina, a category four storm, made landfall on August 29, 2005 and proceeded northward along a path west of the De Soto National Forest, impacting both the De Soto Ranger District to the south, and the Chickasawhay Ranger District to the north. Preliminary assessments of forest resource damage indicated that both Districts sustained abundant and widespread tree damage. Initial estimates of the affected areas on the De Soto Ranger District, in broad damage classes, included 142,000 acres of heavy damage, 108,000 acres of moderate damage and 132,000 acres of light damage. Similar estimates for the Chickasawhay District consisted of 39,000 acres of heavy damage, 24,000 acres of which occurred in major north-south oriented drainages, and 116,000 acres of light damage. The vast majority of the affected area was predominated by pine forest types, as 92% of the Forest is typed as either: longleaf (44%); slash (23%); loblolly, shortleaf or mixed yellow pine (14%); and pine and hardwood mixtures (10%); and only 8% as hardwood (Windham 2005).

Pine Bark Beetles: Storm-damaged trees, particularly pines, are more susceptible to insects and diseases, and subsequent mortality (Barry *et al.* 1998, Touliatos and Roth 1971). Insects of primary concern are the pine bark beetles, including the southern pine beetle (SPB) (*Dendroctonus frontalis*), the *Ips* engravers (IPS) (*Ips avulsus*, *I. grandicollis*, and *I. calligraphus*) and the black turpentine beetle (BTB) (*Dendroctonus terebrans*). These insects are attracted to host volatiles emitted from weakened, wounded and/or stressed trees. Successful attacks kill trees by the girdling nature of the galleries/tunnels that the beetles construct in the phloem tissue, and the blockage of water flow due to the introduction of blue-stain fungi into the xylem.

The SPB is the most aggressive tree killer of the above bark beetles, as well as the most destructive insect pest of pines in the southern U.S. (Thatcher and Barry 1982). Populations of SPB are capable of rapidly increasing and expanding into area-wide outbreaks, during which large numbers of apparently healthy trees are rapidly killed. However, SPB are attracted to vertical targets (*i.e.*, standing trees and not downed material) and historically have not exhibited outbreaks following major storm events (Clarke *et al.* 1999).

Although SPB populations were at epidemic levels as recently as 2004 on the Chickasawhay Ranger District, SPB activity during 2005 has been negligible. No new spots have been detected on either District since June of this year and only 12 new spots have been recorded since January on the entire Forest, all on the Chickasawhay Ranger District. Though there was a lack of SPB infestations prior to the storm, SPB populations are presumably present on both Districts, given the recent and routine catch of beetles at all trap locations on both Districts during the annual spring SPB pheromone trapping survey. Despite records/reports that SPB outbreaks historically have not materialized following major hurricane damage, populations can be explosive, and the threat of such occuring in the aftermath of Katrina should not be dismissed. In addition, the storm damage created many attractive and susceptible trees available to support successful infestations and increasing populations during the coming fall dispersal period of SPB.

Fortunately, spots that may develop in damaged trees in areas with low residual pine BA, will have little opportunity to expand. Many stands which were previously rated as high hazard for SPB (*i.e.*, 19,039 ac on the Chickasawhay and 24,380 ac on the De Soto), are now low hazard as much of the pine was blown over.

The *Ips* engravers prefer recently dead/downed material as well as severely damaged, stressed and dying pines, with relatively little host defenses (Conner and Wilkinson 1982). *Ips* engravers rarely infest and/or kill apparently healthy trees. Area-wide populations and associated infestations rapidly increase following major hurricane damage, as *Ips* engravers are the primary colonizers of the downed/dead pine material. Activity is typically evident within the first month following such storms. Undesirable infestations in residual surviving trees may be limited by the timing and extent of removal or destruction of susceptible host material (*i.e.*, rapid and thorough elimination of susceptible material). The BTB, typically attacks older, larger pines that have been weakened, wounded or are under stress, with the majority of attacks limited to the lower bole, root collar and large surface roots (Smith and Lee 1972). Trees may often survive limited attacks, but outbreaks following severe or multiple disturbances have caused widespread and abundant pine mortality. An outbreak of *Ips* and BTB populations, causing widespread mortality to relatively undamaged pines following a hurricane was reported in South Florida after Hurricane Andrew, when a severe drought occurred during the following growing season (Maguire 1995). Expected population increases of BTB and associated tree mortality may be mitigated by rapidly removing or treating susceptible host material prior to its colonization.

Ips and BTB populations were at relatively low, non-pest levels prior to Katrina on the Forest. Populations should, however, increase due to the amount and widespread distribution of downed and otherwise severely damaged host material available.

Other Bark Beetles, Weevils and Borers: Metallic wood-borers, long-horned wood-borers, ambrosia beetles, and other beetles associated with bark beetle infestations will begin to invade pines infested by SPB, *Ips*, and/or BTB. Unlike SPB, *Ips*, and BTB, which tunnel just underneath the bark, these beetles bore into the wood/xylem of pines (USDA Forest Service 1989). The speed of their attack is related to their background population level. As bark beetle populations climb, populations of these associates swiftly increase. At the tail end of outbreaks, borers are attacking the trees at the same time as the bark beetles and act as competitors for the same resources, initially, potentially having a limiting impact on bark beetle populations.

Eastern pine weevil (formerly Deodar weevil), *Pissodes nemorensis*, adults and larvae can kill small pines and often girdle terminals and lateral branches. They are attracted to and infest weakened, wounded and/or stressed trees. Populations can be expected to increase following summer hurricanes, when debilitated trees are available during the fall reproductive period of the weevil. This weevil is also a primary vector of the fungus which causes pitch canker disease of pines (USDA 1989).

The Pales weevil (*Hylobius pales*) and pitch-eating weevil (*Pachylobius picivorus*), together known as reproduction weevils, breed in the inner bark of recently dead, dying or damaged pine stumps and root sytems, and are attracted to host volatiles eminating from wounds or fresh stumps. Adults feed by debarking young, small diameter shoots, branches and seedlings, which can be lethal. These weevils are considered to be the most serious insect threat to newly planted pines in the south (USDA 1989). Populations of reproduction weevils expectedly increase following widespread pine mortality, including that which occurs with major hurricanes. As a result, areas reforested in the winter following such events may experience high levels of seedling mortality by summer, and result in possible planting failures the year following the hurricane. Populations may be limited by rapid and thorough removal of dead and likely to die trees in as short and continous a time frame as possible, so as to lessen the period and availability of suitable breeding habitat. Seedlings may also be protected with a nursery application of an appropriately labeled insecticide prior to outplanting in high risk areas.

Pitch Canker Disease: Pitch canker disease, caused by the fungus *Fusarium circinatum* (syn. = *F. moniliforme* var. *subglutinans*), causes crown dieback, stem deformity, reduced growth, and mortality of all species of pines in the South, particularly slash pine. The disease typically causes limited and scattered damage or mortality, most often in heavily stocked pole-sized stands, seed orchards, and ornamental pines, but on occasion may reach epidemic proportions. An increased incidence and severity of pitch canker disease occurs where trees have been damaged by natural and/or other types of wounding agents (Blakeslee et. al 1980). Wounds created by the hurricane, in addition to increased populations of the eastern pine weevil (a vector of the pitch canker fungus) and its feeding wounds, may lead to an increased incidence of pitch canker disease following the hurricane.

Hardwood Borers: Hardwood borers attack dead, dying, and severely stressed hardwoods (USDA Forest Service 1989). They generally have long life cycles, so their spread is slow. Most storm-damaged hardwoods will be invaded within 2 years.

Blue-stain fungi: Pines attacked by bark beetles are usually inoculated with blue-stain fungi. The fungi spreads into the heartwood of the tree, but heavy colonization usually takes 2-4 months, depending on weather conditions and the timing of the bark beetle attacks. While not affecting the structural integrity of the damaged trees, they adversely affect the appearance and marketability of the wood.

Due to the above concerns, a general field assessment and initial forest health evaluation was conducted on the Districts during October 3-7, 2005. An earlier, preliminary version of this evaluation report was provided to the Incident Command Team (ICT) on October 14, 2005.

Methods

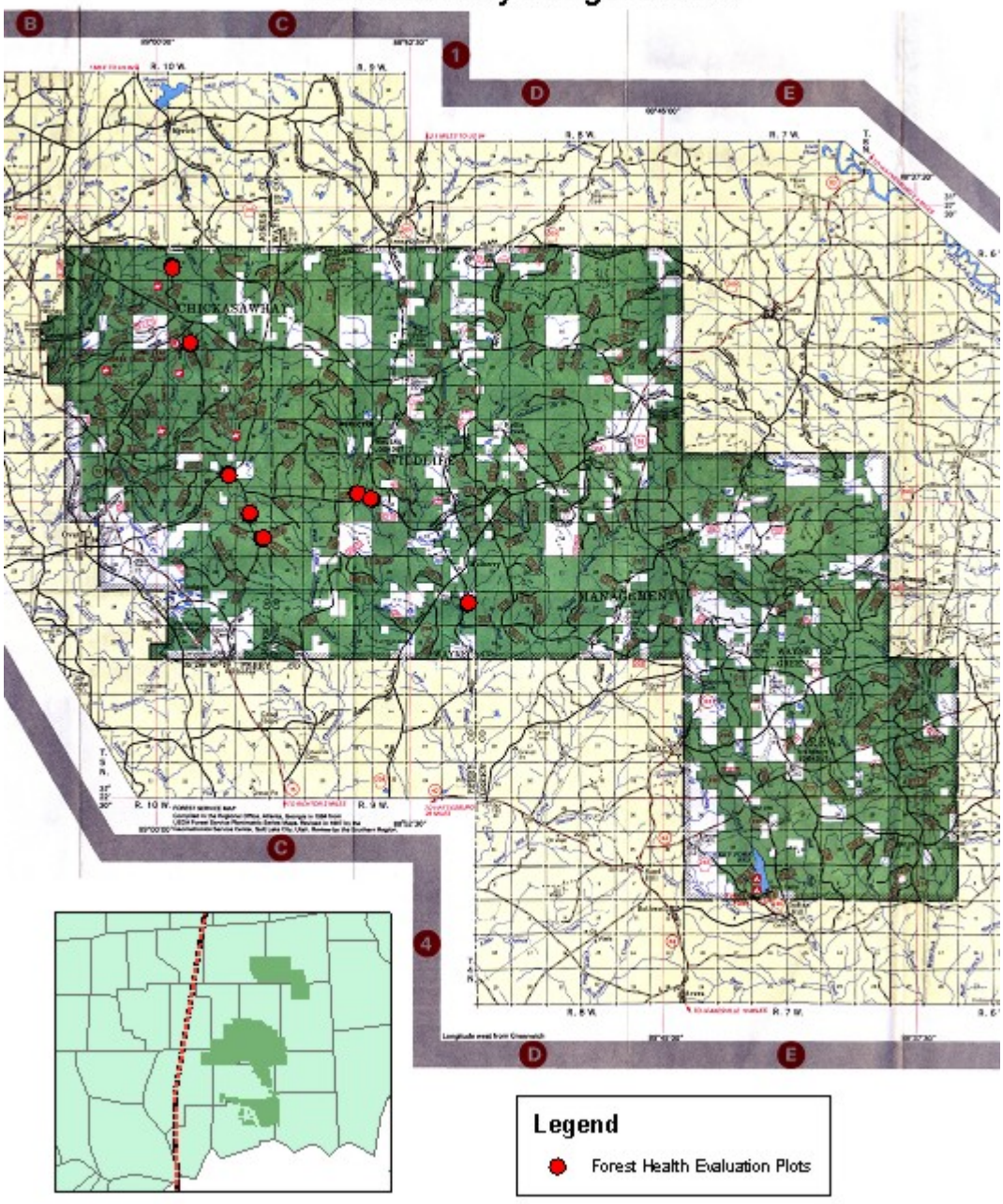
Following consultation with District personnel and members of the ICT, various areas/stands of each District were selected for classification and measurement of tree

damage/data, utilizing three (3), 1/10 ac plots per area/stand. Stands were selected which provided a representative range of: hurricane damage (*i.e.*, heavy, moderate, light) from initial District assessments; stand ages; stand/densities; pre-storm silvicultural treatments; threatened and endangered (T&E) species habitats; and other resource issues of concern (*i.e.*, drainages and associated floodplains). Eighteen different areas/stands were intensively sampled (Figure1A & 1B) utilizing 54, 1/10 ac plots. Numerous other stands were also observed throughout both Districts, indicating that these sampled stands were representative of the various types and degrees of evident hurricane damage.

Sample plots within each stand were located a minimum of two chains distance from roads, and two chains distance from each other. Waypoints (latitude and longitude) were recorded via a GPS device at each of the plot centers, for future monitoring and to determine corresponding Compartment and Stand parameters (Table 1). Within each plot, trees equal to or greater than 2.0 " dbh were identified, measured and classified as to the nature and extent of hurricane damage evident. The following types of hurricane damage were observed and recorded accordingly for each tree examined: snapped trunk (SP), windthrown (WT), horizontally root-sprung (trunk $>45^0$ from vertical with major root exposure) (RH), vertically root-sprung (trunk at 25^0-45^0 from vertical with evident root exposure) (RV), slightly leaning (trunk $<20^0$ from vertical) (SL), broken top (BT), bent $> 30^0$ from vertical (B+30), bent $<30^0$ from vertical (B-30), severe branch breakage (B-S), moderate branch breakage (B-M), light branch breakage (B-L), twisted trunk (TT), minor wounding (MW) and apparently undamaged (UN) (See attached Data Sheet and Key in Appendix). Damage types were then grouped into four categories representative of the risk of associated insect attack and tree mortality (*i.e.*, severe, moderate, light and none). The severe damage category included trees exhibiting a: snapped trunk, windthrow, root-sprung horizontally, root-sprung vertically, broken top, and/or bent $>30^0$. Moderately damaged trees included those that were slightly leaning, bent $<30^0$, had severe branch breakage, and/or twisted trunks. Lightly damaged trees were those exhibiting moderate or light branch breakage and/or minor wounding. Trees which outwardly exhibited no apparent damage were classified as none.

The 18 separate stands examined were then grouped into the following eight (8) similar stand structure by hurricane damage groupings, for comparing and contrasting results. These six groups were described in broad terms as: 1) heavily damaged sawtimber stands in drainages/floodplains (three stands); 2) heavily damaged pine sawtimber stands (four stands); 3) a heavily damaged and recently (within the last year) thinned pine sawtimber stand (one stand); 4) heavily damaged sparse pine sawtimber stands (two stands, including a seedtree and shelterwood harvest with residual overstory); 5) a moderately damaged red-cockaded woodpecker stand (RCW); 6) lightly damaged pine sawtimber stands (four stands, including another RCW stand); 7) lightly damaged and recently (within the last year) thinned pine poletimber plantations (two stands); and 8) a lightly damaged and recent (within the last year) precommercially thinned pine plantation (one stand) (See Tables 2 & 3).

Figure 1A. Forest Health Evaluation Plots:
Chickasawhay Ranger District



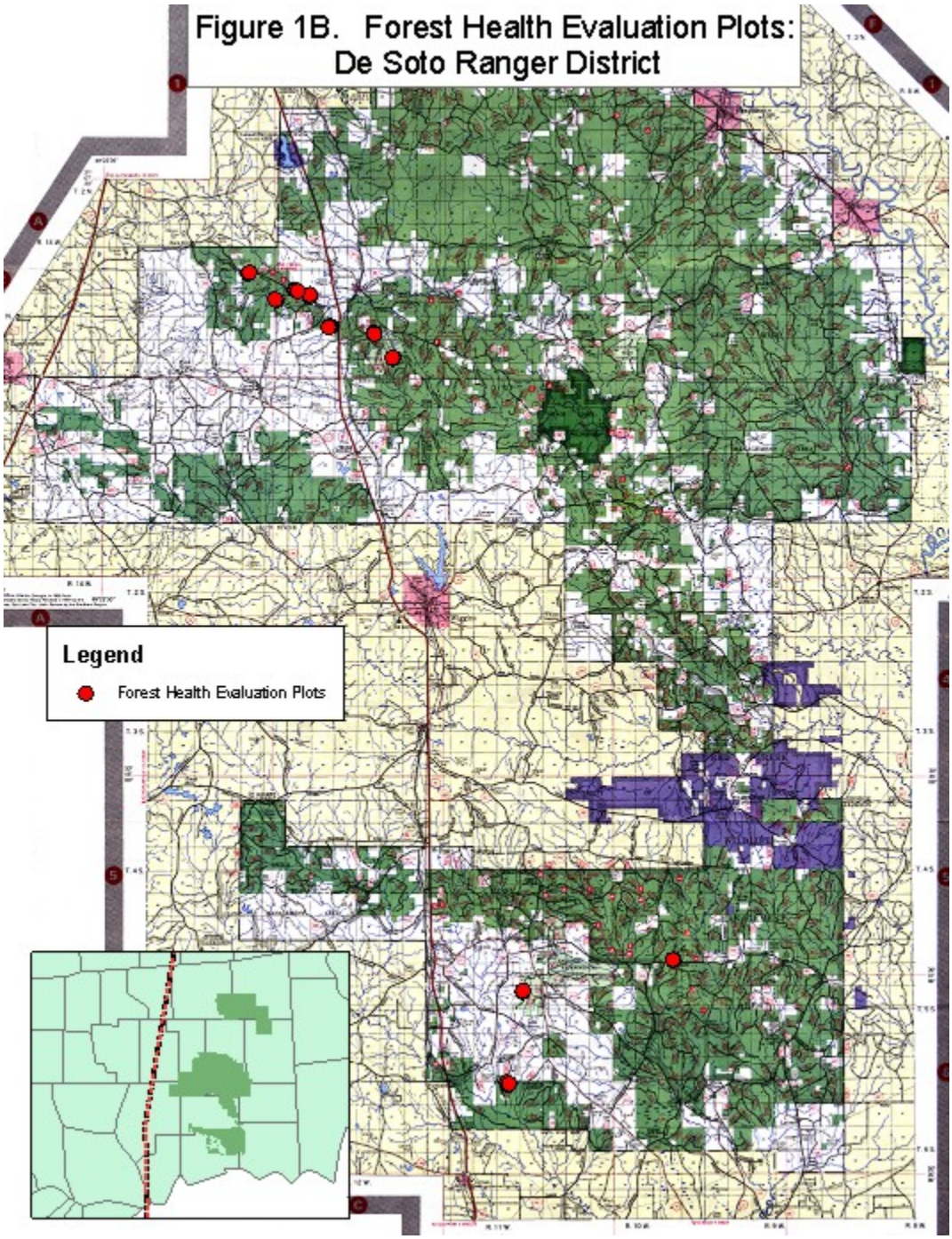


Figure 1B. Forest Health Evaluation Plots:
De Soto Ranger District
Legend
Forest Health Evaluation Plots

Table 1. Locations of Forest Health Evaluation plots, De Soto National Forest, October 3-7, 2005 (Datum = WGS84).

For.	Dist.	Comp.[a]	Stand[a]	Site #	Plot #	2004 SPB Hazard	N Latitude (dd)	W Longitude (dd)
7	2	296	13	1	1	Moderate	31.04984000	-89.24889000
7	2	296	13	1	2	Moderate	31.05019000	-89.24915000
7	2	296	13	1	3	Moderate	31.05035000	-89.24940000
7	2	295	13	2	1	Low	31.05244000	-89.22458000
7	2	295	13	2	2	Low	31.05226000	-89.22392000
7	2	295	13	2	3	Low	31.05345000	-89.22411000
7	2	297	8	3	1	High	31.06663000	-89.26922000
7	2	297	8	3	2	High	31.06685000	-89.26883000
7	2	297	8	3	3	High	31.06723000	-89.26851000
7	2	277	22	4	1	Low	31.01354000	-89.16266000
7	2	277	22	4	2	Low	31.01359000	-89.16313000
7	2	277	22	4	3	Low	31.01394000	-89.16345000
7	2	281	3	5	1	Moderate	31.02947000	-89.17737000
7	2	281	3	5	2	Moderate	31.02932000	-89.17700000
7	2	281	3	5	3	Moderate	31.02862000	-89.17670000
7	2	283	4	6	1	Moderate	31.03336000	-89.20885000
7	2	283	4	6	2	Moderate	31.03330000	-89.20973000
7	2	283	4	6	3	Moderate	31.03290000	-89.21010000
7	2	295	5	9	1	Moderate	31.05635000	-89.23508000
7	2	295	5	9	2	Moderate	31.05620000	-89.23457000
7	2	295	7	9	3	Moderate	31.05520000	-89.23283000
7	2	587	2	10	1	Low	30.55760000	-89.07870000
7	2	587	2	10	2	Low	30.55619000	-89.07751000
7	2	587	2	10	3	Low	30.55686000	-89.07684000
7	2	591	12	11	1	Moderate	30.61477000	-89.06721000
7	2	591	12	11	2	Moderate	30.61518000	-89.06711000
7	2	591	12	11	3	Moderate	30.61555000	-89.06680000
7	2	613	12	12	1	Moderate	30.63497000	-88.95705000
7	2	613	12	12	2	Moderate	30.63479000	-88.95741000
7	2	613	12	12	3	Moderate	30.63517000	-88.95749000
7	5	343	8	1	1	Moderate	31.60010000	-88.99253000
7	5	343	8	1	2	Moderate	31.59979000	-88.99240000
7	5	343	8	1	3	Moderate	31.59917000	-88.99239000
7	5	365	1	2	1	Moderate	31.49481004	-88.95386900
7	5	365	1	2	2	Moderate	31.49520022	-88.95389790
7	5	365	1	2	3	Moderate	31.49555480	-88.95386200
7	5	365	16	3	1	Moderate	31.48484879	-88.94798412
7	5	365	16	3	2	Moderate	31.48499331	-88.94753201
7	5	365	16	3	3	Moderate	31.48518126	-88.94710429
7	5	369	5	4	1	Moderate	31.51192778	-88.96473658
7	5	369	5	4	2	Moderate	31.51144943	-88.96422034
7	5	369	5	4	3	Moderate	XXXXXXXXXXX	XXXXXXXXXXX
7	5	378	18	5	1	High	31.50373726	-88.90123853
7	5	378	18	5	2	High	31.50358978	-88.90085824
7	5	378	18	5	3	High	31.50379048	-88.90049363
7	5	378	27	6	1	Moderate	31.50141602	-88.89339122
7	5	378	27	6	2	Moderate	31.50158845	-88.89376815

Table 1 (continued). Locations of Forest Health Evaluation plots, DeSoto National Forest, October 3-7, 2005 (Datum = WGS84).

For.	Dist.	Comp.[a]	Stand[a]	Site #	Plot #	2004 SPB Hazard	N Latitude (dd)	W Longitude (dd)
7	5	378	27	6	3	Moderate	31.50173123	-88.89146795
7	5	417	8	7	1	Low	31.45755761	-88.84614296
7	5	417	8	7	2	Low	31.45722648	-88.84637858
7	5	417	8	7	3	Low	31.45781315	-88.84585303
7	5	354	5	8	1	Low	31.56693000	-88.98331000
7	5	354	5	8	2	Low	31.56715000	-88.98357000
7	5	354	5	8	3	Low	31.56763000	-88.98354000

Footnote: [a] = taken from CISC data set.

Summary statistics for this report were then generated by tree damage class on a percent trees per acre basis and percent basal area per acre basis, for each of the 18 stands, and the eight, stand-structure by hurricane-damage groupings.

Results

Stands Initially Classified as Heavy Damage:
Severe tree damage (including those trees that were either: snapped, windthrown, horizontally and/or vertically root-sprung, bent >30^{o} and/or broken-topped) ranged from a low of 30% of the trees per acre (TPA), and 15% of the basal area per acre (BA) to a high of 83% of the TPA, and 98% of the BA, for the 10 sawtimber stands classified as heavily damage prior to our field assessment (Tables 2 & 3). These severely damaged trees were those that were dead, dying and likely to die as a direct or indirect result (*i.e.*, insect infestation) of the hurricane damage. *Ips* bark beetle and woodborer activity was already evident in many of the tops, branches and boles of downed and windthrown pine material throughout both Districts (Figure 2). The three sawtimber stands in the drainages/floodplains, which contained more hardwood trees than the other areas examined (20-76% hardwood), on average contained less severely damaged trees (42% TPA and 40% BA) than the other heavily damaged stands of pine sawtimber (56-74% TPA and 65-93% BA). On average, recently thinned and/or sparse pine sawtimber stands suffered the highest amounts of severe tree damage observed (71-74% TPA and 78-93% BA) (Tables 2 & 3).

Moderate tree damage (including those trees that were either: slightly leaning, bent < 30^{0}, had severe branch breakage and/or a twisted trunk), was relatively limited in the above heavily damaged sawtimber stands (<10 % TPA and 6% BA) (Tables 2 & 3). These moderately damaged trees are those that will likely survive the storm damage but will be at an increased risk of insect induced mortality in the months and years ahead.

Lightly damaged trees (those with light to moderate branch breakage and/or minor wounding) varied considerably among the heavily damaged sawtimber stands. These trees are also at an increased risk of insect induced mortality, but less so and for a shorter period than those with moderate damage. Lightly damaged trees can be expected to survive and fully recover in time, barring insect attacks in the short run and unforeseen disturbances in the future. Those trees in heavily damaged sawtimber stands that exhibited no outwardly apparent damage from the storm were also highly variable, ranging from 0-64% TPA and 0-75% BA (Tables 2 & 3). On average, the stand grouping with the most undamaged TPA and BA were those heavily damaged sawtimber stands in the drains/floodplains.

Of the 10 heavily damaged sawtimber stands, those with the fewest apparently undamaged trees (*i.e.*, relatively healthy trees) included a recently thinned longleaf stand and the stand surrounding the gopher frog pond, both of which were located on the De Soto Ranger District, and exhibited 0-4% undamaged TPA and 0-3% undamaged BA, respectively (Tables 2 & 3).

Stand Initially Classified as Moderate Damage:
The one stand classified as moderately damaged was in a stand containing an RCW cluster on the De Soto Ranger District. Although only 18% TPA and 26% BA were considered severely damaged, all of the other trees were either moderately or lightly damaged, with no apparently undamaged trees in the plots (Tables 2 & 3). Insect activity (IPS, BTB, sawyers and ambrosia beetles) was evident in a tree that had been snapped off in the storm and previously struck by lightning. This tree, in addition to the other severely damaged trees in the stand, poses an immediate threat to the survival of residual RCW cluster/cavity trees in the area.

Stands Initially Classified as Light Damage:
The stands initially classified as light hurricane damage all exhibited a substantial amount of severe individual tree damage, ranging from 6-30% TPA, and 5-42% BA. However, there were very limited amounts of moderately damaged trees and relatively high percentages of undamaged trees across all the stands, with one exception. The most severely damaged stand previously classified as lightly damaged was the Research Natural Area (RNA) on the Harrison Experimental Forest, where a high population of gopher tortoise burrows was mapped. This stand exhibited only 9% undamaged TPA, and 7% undamaged BA, and 30% TPA and 42% BA that was severely damaged. The rest of the trees incurred light damage, as there was no moderate tree damage evident in any of the plots (Tables 2 & 3).

On average the older, moderately stocked sawtimber stands exhibited similar levels of tree damage as the recently thinned poletimber stands. The recently thinned, young, mixed-pine plantation experienced substantially more severe tree damage than any of these six older and similarly open stands above (Tables 2 & 3).

Table 2. Summary statistics and trees per acre damaged; Forest Health Evaluation plots (1/10ac), De Soto National Forest, October 3-7, 2005.

										Pine			Trees per Acre					
For.	Dist.	Comp.[a]	Stand[a]	For. Type[a]	Cond. Class[a]	Site	Key Feature	# of Plots	Initial Damage Class	Avg. Dbh (in.)	Avg. Ht. (ft.)	Avg. Age (yrs.)	All Trees	% Pine	Damage by Severity Class (All Trees) Severe	Moderate	Light	None
Sawtimber Stands in Floodplains/Drains																		
7	2	297	8	31	10	3	Big Creek	3	Heavy	14.6	103	68	100	80%	63%	0%	27%	10%
7	5	369	5	21	12	4	Tiger Creek	3	Heavy	20.7		80[a]	140	31%	32%	0%	5%	64%
7	5	378	18	31	13	5	Bird Branch	3	Heavy	11.7	113	67	110	24%	30%	3%	6%	61%
							AVG.	9		15.7	108	68	117	45%	42%	1%	12%	45%
Pine Sawtimber Stands																		
7	2	296	13	32	12	1	RNA	3	Heavy	14.2	100	58	140	43%	43%	10%	36%	12%
7	2	295	5	31	16	9	Mixed Pine	3	Heavy	19.3	98	61	110	54%	52%	3%	33%	12%
7	5	378	27	21	12	6	Longleaf	3	Heavy	13.3	92	61	90	86%	59%	4%	0%	37%
7	2	587	2	21	6	10	Gopher Frog	3	Heavy	11.4	85	50	90	100%	71%	4%	27%	4%
							AVG.	12		14.6	94	58	108	71%	56%	5%	24%	16%
Recently Thinned Pine Sawtimber Stand																		
7	2	281	3	21		5	Longleaf	3	Heavy	14.5		80[a]	100	83%	71%	3%	26%	0%
Sparse Pine Sawtimber																		
7	2	295	13	31	13	2	Seed Tree	3	Heavy	22.1	107	61	50	53%	64%	7%	7%	21%
7	2	277	22	21	13	4	Shelterwood	3	Heavy	15.2	83	67	20	100%	83%	0%	0%	17%
							AVG.	9		18.7	95	64	35	77%	74%	4%	4%	19%
Red-cockaded Woodpecker Stand																		
7	2	613	12	21	10	12	RCW	3	Moderate	17.0	75	68[a]	40	100%	18%	27%	55%	0%
Pine Sawtimber Stands																		
7	2	591	12	21	10	11	Gopher Tortoise	3	Light	12.3	79	63	80	100%	30%	0%	61%	9%
7	5	365	16	21	12	3	RCW	3	Light	16.4	79	70	40	94%	9%	0%	0%	91%
7	5	365	1	21	12	2	Longleaf	3	Light	15.9	89	60	60	94%	12%	0%	0%	88%
7	5	354	5	21	12	8	Longleaf	3	Light	15.9	76		60	100%	6%	0%	12%	82%
							AVG.	12		15.1	81	64	60	97%	14%	0%	18%	68%
Recently Thinned Pine Poletimber Stands																		
7	2	283	4	22	11	6	Slash	3	Light	9.3	58	31	160	87%	21%	9%	57%	13%
7	5	343	8	21	11	1	Longleaf	3	Light	9.8	65	30	110	97%	9%	3%	3%	84%
							AVG.	6		9.5	62	31	135	92%	15%	6%	30%	49%
Recent Precommercially Thinned Pine Stand																		
7	5	417	8	21	13	7	Mixed Pine	3	Light	3.8	34	11[a]	480	90%	46%	29%	2%	24%

KEY:

Severe = trees (>5.0" dbh) exhibiting any of the following types of damage: snapped stem (SP), windthrown (WT), horizontally or vertically root-sprung(RH &RV), bent >30 degrees from vertical (B+30), and/or broken top (BT).

Moderate = trees (>5.0" dbh) exhibiting any of the following types of damage: slight lean (SL), bent < 30 degrees from vertical (B-30), severe branch breakage (B-S), and/or twisted trunk (TT).

Light = trees (>5.0" dbh) exhibiting any of the following types of damage: moderate or light branch breakage (B-M & B-L) or minor wounding (MW).

None = trees (>5.0" dbh) with no apparent storm damage.

Footnotes: [a] = taken from CISC data set.

Table 3. Summary statistics and basal area damaged; Forest Health Evaluation plots (1/10ac), De Soto National Forest, October 3-7, 2005.

										Pine			Basal Area (sq. ft.) per Acre					
For.	Dist.	Comp.[a]	Stand[a]	For. Type[a]	Cond. Class[a]	Site	Key Feature	# of Plots	Initial Damage Class	Avg. Dbh (in.)	Avg. Ht. (ft.)	Avg. Age (yrs.)	All Trees	% Pine	Damage by Severity Class (All Trees) Severe	Moderate	Light	None
Sawtimber Stands in Floodplains/Drains																		
7	2	297	8	31	10	3	Big Creek	3	Heavy	14.6	103	68	109	91%	65%	0%	24%	11%
7	5	369	5	21	12	4	Tiger Creek	3	Heavy	20.7		80[a]	150	68%	15%	0%	9%	75%
7	5	378	18	31	13	5	Bird Branch	3	Heavy	11.7	113	67	94	51%	40%	2%	5%	54%
							AVG.	9		15.7	108	68	118	70%	40%	1%	13%	47%
Pine Sawtimber Stands																		
7	2	296	13	32	12	1	RNA	3	Heavy	14.2	100	58	109	69%	53%	6%	32%	10%
7	2	295	5	31	16	9	Mixed Pine	3	Heavy	19.3	98	61	101	84%	69%	4%	17%	11%
7	5	378	27	21	12	6	Longleaf	3	Heavy	13.3	92	61	90	94%	59%	1%	0%	39%
7	2	587	2	21	6	10	Gopher Frog	3	Heavy	11.4	85	50	68	100%	77%	2%	18%	3%
							AVG.	12		14.6	94	58	92	87%	65%	3%	17%	16%
Recently Thinned Pine Sawtimber Stand																		
7	2	281	3	21		5	Longleaf	3	Heavy	14.5		80[a]	103	94%	78%	3%	19%	0%
Sparse Pine Sawtimber																		
7	2	295	13	31	13	2	Seed Tree	3	Heavy	22.1	107	61	42	72%	88%	3%	2%	6%
7	2	277	22	21	13	4	Shelterwood	3	Heavy	15.2	83	67	25	100%	98%	0%	0%	2%
							AVG.	9		18.7	95	64	34	86%	93%	1%	1%	4%
Red-cockaded Woodpecker Stand																		
7	2	613	12	21	10	12	RCW	3	Moderate	17.0	75	68[a]	60	100%	26%	23%	51%	0%
Pine Sawtimber Stands																		
7	2	591	12	21	10	11	Gopher Tortoise	3	Light	12.3	79	63	72	100%	42%	0%	51%	7%
7	5	365	16	21	12	3	RCW	3	Light	16.4	79	70	47	99%	13%	0%	0%	87%
7	5	365	1	21	12	2	Longleaf	3	Light	15.9	89	60	78	99%	12%	0%	0%	88%
7	5	354	5	21	12	8	Longleaf	3	Light	15.9	76		81	100%	5%	0%	8%	87%
							AVG.	12		15.1	81	64	70	100%	18%	0%	15%	67%
Recently Thinned Pine Poletimber Stands																		
7	2	283	4	22	11	6	Slash	3	Light	9.3	58	31	69	95%	23%	7%	56%	14%
7	5	343	8	21	11	1	Longleaf	3	Light	9.8	65	30	57	97%	9%	5%	2%	84%
							AVG.	6		9.5	62	31	63	96%	16%	6%	29%	49%
Recent Precommercially Thinned Pine Stand																		
7	5	417	8	21	13	7	Mixed Pine	3	Light	3.8	34	11[a]	57	74%	63%	18%	1%	18%

KEY:

Severe = trees (>5.0" dbh) exhibiting any of the following types of damage: snapped stem (SP), windthrown (WT), horizontally or vertically root-sprung(RH &RV), bent >30 degrees from vertical (B+30), and/or broken top (BT).

Moderate = trees (>5.0" dbh) exhibiting any of the following types of damage: slight lean (SL), bent < 30 degrees from vertical (B-30), severe branch breakage (B-S), and/or twisted trunk (TT).

Light = trees (>5.0" dbh) exhibiting any of the following types of damage: moderate or light branch breakage (B-M & B-L) or minor wounding (MW).

None = trees (>5.0" dbh) with no apparent storm damage.

Footnotes: [a] = taken from CISC data set.

Figure 2. Primary infestation by *Ips grandicollis* in upper bole of windthrown pine from Hurricane Katrina: De Soto Ranger District, October 6, 2005.

The two recently thinned pine poletimber stands (one slash and one longleaf) and one recent precommercially thinned mixed-pine plantation all contained a sufficient number of TPA classified as lightly damaged and undamaged (112, 96 and 125 TPA, respectively) to yield a residual stand following future anticipated mortality levels (Tables 2 & 3).

Initial FHP Recommendations

Based on the expectation of increasing bark beetle populations (and other potential pests mentioned earlier) as a result of the tree damage from Hurricane Katrina, the following recommendations are aimed at limiting the impacts of undesirable pest activity and additional tree mortality in storm damaged areas.

General forest area. Current and potential hazard trees (*i.e*., those trees that are dead, dying or otherwise so severely damaged that their survival is doubtful, and which pose a safety hazard) should be felled (if not already downed) at a minimum. Where feasible, these trees should also be salvaged, or otherwise removed and/or destroyed to eliminate future host material for *Ips* beetles and sources of potential pests. In high traffic areas where trees are subject to beetle attack, root disease and pending death, those severely damaged trees (*i.e*., those that were: snapped, windthrown, horizontally or vertically root-sprung, bent > 30^0, or broken topped) should also receive a high priority for cutting, removal, and/or destruction.

In other sections of the forest, protection of the remaining pines is important. Because of the uncertainties, hazard and risk of increased SPB activity and the potential for an outbreak to develop, a fall pheromone trapping survey should be conducted during mid

October through late November, to gain a better understanding of populations trends and projected activity levels. Storm-damaged stands in high hazard SPB areas should be routinely scouted and any actively enlarging SPB infestations suppressed promptly. The stands most likely to sustain high levels of SPB activity are those in areas categorized as having light or moderate damage, and which were rated as high SPB hazard prior to the storm. These stands will still have sufficient numbers of residual pines to support expanding SPB infestations, so attacks on damaged pines may soon spread to adjacent pines. Stands in areas of heavy damage should only support small, slow-moving infestations, due to the reduced density and increased spacing among residual pines. The regular program of aerial monitoring, detection, and suppression of SPB activity should commence earlier than usual with an initial flight this winter.

As part of a general salvage program, all of the trees in stands experiencing levels of severe damage where potential residuals (the moderate, light and undamaged trees) will constitute an understocked stand, or are insufficent to meet desired regeneration needs, should be removed as rapidly as possible. Removal of all trees in such areas will reduce the threat of undesirable and additional tree mortality from insect/disease activity, as well as aid in the reduction of suitable host material for increasing populations of potential insect pests and facilitate reforestation. Salvage efforts that result in partial removals and residuals (*e.g.*, severely damaged trees removed, but moderate, light and undamaged trees retained) will temporarily increase the threat of pest activity and additional mortality, due to the disturbance and damage of salvage operations on residuals, and the creation of attractive host odors and fresh breeding material (*e.g.*, slash and stumps). Where partial removals are dictated/appropriate (*e.g.* where the moderate, light and undamaged trees constitute a stocked stand), the leave trees or residuals should be clustered/grouped apart from disturbances of salvage operations, to minimize additional damage and reduce future tree losses. Similarly, where possible avoid retention of scattered individual residuals, where salvage operations would be conducted among and around these trees (*i.e.*, within root zones). Scattered individual residuals following salvage operations in the aftermath of major damage events, like hurricanes or wildfires, are often short-lived.

Additionally, in partial salvage operations, not all of the severely damaged and likley-to-die trees will be evident by residual stumps following salvage by the designation by damage provision. Trees that have been snapped, have broken tops or are bent more than 30^0 should be included/marked for salvage, in addition to those unmarked windthrown and root-sprung trees, as all such trees are likely to perish within two years.

General salvage operations should also target the larger/older pine sawtimber stands first, since similarly damaged stands of smaller/younger pine are: likely to be less susceptible to more of the most serious insect pests; more capable of recovering from sub-lethal damage; and will become unsuitable host material for many potential insect pests more rapidly.

Once the trees are on the ground and/or become infested by bark beetles, the wood borers, ambrosia beetles and blue-stain fungi will quickly work to degrade the wood. *Ips* beetles have begun initiating attacks and most downed trees should be infested by spring.

Blue-stain and wood borers will quickly follow, and most trees that were intitally downed by the storm will likely be severely degraded by spring if not salvaged.

RCW clusters. Within clusters, removal of all severely damaged trees and large pine material thereof, should be the first priority to mitigating additional tree mortality. Bark beetles are relatively strong flyers capable of flying appreciable distances (1/2 mi. and more), so the further away from residual cluster/cavity trees that the severely damaged material can be moved the better. Where appropriate, salvage operations are often the most effective and efficient means of removing such host material. The low pine BA in clusters usually prevents the development of large SPB spots, but trees (particularly those under stress) are infested one at a time, so undesirable tree loss over time may result. The downed trees and snapped tops will be attacked by *Ips* beetles, so branches of downed trees or tops in contact with the boles of relatively healthy trees, particularly cavity trees, should be cut or pulled away to prevent contact, if the damaged material cannot be otherwise removed. The standing boles of snapped and broken-top trees will also be colonized by BTB, as well as *Ips*, and should also be felled and dragged outside of the cluster, at a minimum. Once this initial work is complete, the clusters should be monitored routinely for evidence of bark beetle infestations. The remaining pines may be under stress, so monitoring should reveal which areas appear more susceptible. Early intervention once attacks are observed should limit further impacts.

Installing artificial cavity inserts in the residual pines adds additional stress to these trees and releases attractive host odors orienting searching beetles to such trees/areas. Observations have indicated that installing inserts from August-October may increase the tree's susceptibility to SPB attack during the fall dispersal period (Clarke 1999). Wherever possible, considering other factors bearing on maintaining critical RCW habitat, avoid installation of inserts during the above period to minimize the risk of additional tree losses due to insect attack.

RCW foraging habitat. RCW foraging habitat should be treated similar to the general forest area. Areas of high SPB hazard should be examined, and the susceptible, severely storm-damaged trees removed via salvage operations. Susceptible standing pines in stands with heavy damage, where pine BA is now low, may be removed or left standing (slightly leaning) as SPB infestations in these trees would have a low probability of spreading, and could provide food for RCW or snags if needed.

Conclusions:

In addition to the initial recommendations provided above, the Forest and Districts should also follow the guidelines and recommendations provided in Barry *et al*. (1998), Swain (1979), and Touliatos and Roth (1971). Beyond the issues and concerns associated with the potential insect and disease pests mentioned above, there will also be an increase in non-native invasive (NNI) plant problems, as a result of Hurricane Katrina. Though privet (*Ligustrum* sp.) and Japanese climbing fern (*Lygodium japonicum*) were the only NNI plants observed on the sample plots, cogongrass (*Imperata cylindrica*) was noted

within one of the RCW stands which was examined, and is a known problem on both Districts of the Forest. Salvage operations and other hurricane relief and restoration efforts should implement appropriate protocols and practices to minimize the spread and distribution of these noxious weeds. As time progresses and the Districts move from mitigating the storm damage and conducting salvage operations, into reforestation efforts, a plan for suppressing NNI plants in these areas should be developed and implemented to successfully achieve desired future conditions.

This initial evaluation will be followed up with future updates from additional field evaluations reporting on the re-inventory of established plots and the findings thereof.

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Appendix

HURRICANE KATRINA FOREST HEALTH EVALUATION: DESOTO NF

Ranger District: _____ **Damage Class:** _____ **Lat./Long.** _____

Compartment: _____ **Plot No.:** _____ **Plot Size:** _____ **Date:** _____

Stand: _____ **Stand Age:** _____ **Crew:** _____

					MAJOR DAMAGE TYPE												INSECTS/FUNGI				
TR	SPP	DBH	HT	LIVE/ DEAD	SP	WT	RH	RV	SL	B+30	B-30	BT	BL- L, M, or E	MW	TT	UN	BARK BEET	SAWY/ BORER	SAP ROT	BLUE STAIN	AMBRO
1																					
2																					
3																					
4																					
5																					
6																					
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NOTES:

Key to the Field Data Sheet for FHP Evaluation of Hurricane Katrina Damage on the DeSoto National Forest, MS

[October 2005]

Damage Type:

WT = Wind Thrown (tree blown over and lying on ground, only a few attached roots still in ground)
SP = Snap (pine with crown completely snapped off, usually 4-15 meters of bole remain)
BT = Broken Top (The upper portion of the crown broken–off from a snap - lying on the ground)
BL = Broken limbs (Broken limbs from crown - >3" diameter in size)
BLE = Extensive breakage – >40% of limbs broken
BLM = Moderate breakage – 20-40% of limbs broken
BLL = Light breakage - < 20% of limbs broken
RH = Root-sprung horizontal (tree now leaning at 46-75^{o} from vertical, most roots Exposed)
RV = Root-sprung vertical (tree now leaning at 20-45^{o} from vertical, some roots Exposed)
SL = Slight lean (tree leaning less than 20^{o} from vertical, no exposed roots but some breakage evident)
B+30 = Bend more than 30 degrees from vertical
B-30 = Bend less than 30 degrees from vertical
MW = Minor wounding (some damage to bark by falling trees, no other damage evident)
TT = Twisted trunk (twisting and separation of trunk or bole of tree)
UN = Undamaged (no visible sign of storm damage to the tree)

Insects/Fungi:

BARK BEET = evidence of bark beetle activity (signs and/or symptoms of SPB, *Ips* engravers, BTB, *Hylastes*)
SAWY/BORER = evidence (signs/symptoms) of sawyer and/or other wood borer activity
SAP ROT = evidence (signs/symptoms) of saprophytic wood-rotting organisms
BLUE STAIN = evidence of blue stain fungi activity
AMBRO = evidence (signs/symptoms) of ambrosia beetle activity

Initial Damage Classification:

Severe Damage = Stands losing 40% or more of the existing overstory
Moderate Damage = Stands losing 20-39% of the existing overstory
Light Damage = Stands losing <20% or more of the existing overstory