EFFECTS OF HARVESTING TREATMENTS ON THE ANT COMMUNITY IN A MISSISSIPPI RIVER BOTTOMLAND HARDWOOD FOREST IN WEST-CENTRAL MISSISSIPPI

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Abstract—We assessed effects that harvesting treatments had on the ant community in a Mississippi River bottomland hardwood forest in west-central MS. Ants were collected on Pittman Island using pitfall traps from July to November in 1996, 1997, and 2000. The forest received three replicated harvesting treatments in 1995, including: 1) uncut controls (check), 2) selection treatments removing 50 percent of trees, and 3) clearcut treatments. The ant community was also affected by environmental extremes, including flooding and drought. A total of six subfamilies, 20 genera, 33 species, and 19,269 individuals were collected. Cluster analysis revealed little difference in ant community diversity between check and selection treatments, but clearcuts were very different. A multi-response permutation procedure and indicator species analysis of 18 species that dominated the site, showed these species were influenced differently by the treatments. No species preferred undisturbed sites exclusively, but three showed strong preferences. Eight species did equally well in all treatments, six "liked" selection harvests almost as well as checks, and one preferred selection harvests. Red imported fire ants, *Solenopsis invicta*, increased substantially with time in all treatments.

INTRODUCTION

Ant studies have been used to understand environmental changes brought about by human activities (Ambrecht and others 2005, Andersen 1990, Andersen and Sparling 1997, Corley and others 2006, Majer and Beeston 1996, Perfecto and Vandermeer 2002). For example, ant communities have been used to assess the success of mine restoration (Andersen 1997), the effects of introduced pine on the Patagonian steppes (Corley and others 2006), and recovery in tropical forest land conversion (Dunn 2004a). More specifically, the effects of harvesting on ants have been assessed in the United States with mixed effects (Jennings and others 1986, Palladini and others 2007, Stephens and Wagner 2006, Yi and Moldenke 2005, Zettler and others 2004). Thus, we hoped a survey of ants in a bottomland hardwood forest regeneration experiment might tell us something about how clearcut and selection harvesting affects the ant community.

METHODS

Site

Ants were collected in a bottomland hardwood forest at Pittman Island, MS (fig. 1) (32° 55' N latitude, 91° 08' W longitude) receiving several harvesting treatments in 1995. The island is located within the levee system of the Mississippi River and has typical ridge/swale topography with riverfront hardwood species associations. Year 1996 was the first growing season following harvest, and included a partial flood that did not cover the ridges. In 1997, there was a one month spring flood that covered the entire island with several meters of river water. In 2000, there was an extended fall drought that lasted into December. So, in addition to the effects of treatments, we also have the yearly effects of extreme weather confounding the adjustment of ant species to the harvesting disturbance. The forests were dominated by sugarberry (*Celtis laevigata*) before treatment and this species was also favored in the selection harvest.

Harvesting Treatments

Check is undisturbed forest; selection is the removal of about 50 percent of trees, leaving the most desirable commercial species to grow, with felled noncommercial trees and tops left on site; clearcut is harvesting of all trees, with felled noncommercial trees and tops left on site (fig. 2). Each treatment and control stand was about 20 ha in size, and the three treatments were replicated three times (nine total stands) in a randomized design (fig. 1).

Ant Collecting and Species Occurrence Calculation

Ants were collected using 20 pitfall traps per stand, with the traps spaced at 10-m intervals along a transect bisecting each stand and running along the ridge. Traps were serviced weekly from July to early November in 1996, 1997, and 2000. Because we were not interested in trap effects, all ants from each stand and week were pooled. Thus, quantitative data is the occurrence of a species within treated stands by weeks and years. For example, *Solenopsis invicta* was collected in 1996 in selection stand one in only nine of the 19 total weeks, so occurrence here is nine. The number of individuals collected was not used because traps placed close to colonies of some species typically collected hundreds of individuals (for example, *S. invicta*). Total occurrence for one species depends upon trapping weeks by year. Maximum occurrence is 19 trapping weeks for 1996 and 1997 and 23 weeks for 2000. Thus, for the nine stands, the maximum occurrence over all nine stands for 1996 and 1997 is 19 weeks x nine stands = 171, and for 2000, this number is 23 weeks x nine stands = 207. Likewise, maximum occurrence by treatment for one species is calculated as total occurrence over all three years (549) divided by three treatments (183).

Data Analysis

Species diversity measures were calculated using EstimateS (Colwell 2005), including: number of observed species, singletons (number of species where only specimen was

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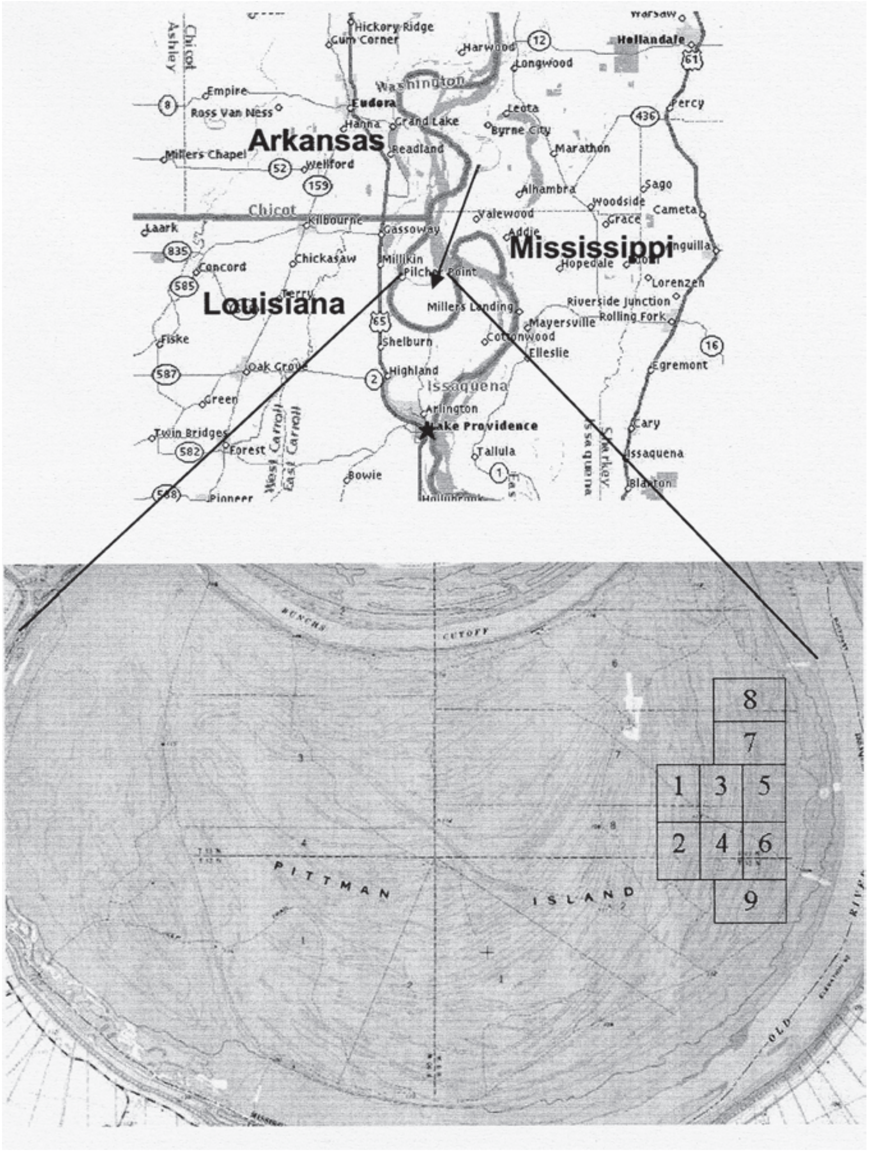

Figure 1—Location of Pittman Island (arrow), Mississippi, near the northeastern corner of Louisiana, and showing treatment layout with stands 1, 6, and 7 clearcut, 4, 5, and 8 selection, and 2, 3, and 9 control (check).

collected), doubletons (number of species where only two specimens were collected), and three richness estimators (Chao 2, Jack 2, and Bootstrap [Colwell 2005]) that, because of likely under-sampling by us, provide estimates of expected richness calculated from our data set. For more detail on these estimators see Colwell (2005).

To discover treatment effects, all stand replicates and years were pooled within treatments, then analyzed. All 33 species were included to assist interpretation. To assess the effects of treatments on the ant community, species presence/absence data and species occurrence data were both analyzed with the 2-way cluster analysis procedure in PC-ORD (McCune and Mefford 1999) using the flexible-beta linking method (beta = -0.25), and the Sorensen (Bray-Curtis) distance measure of the cluster routine, as recommended in McCune and Grace (2002). The presence/absence data were analyzed without transformation. However, for the occurrence data, treatments (rows) were first relativized using the maximum occurrence of the most abundant species in the treatment (that is, occurrence was transformed to a range of zero to one over each treatment, where one is maximum occurrence and zero is not collected), thus standardizing all treatments to the same starting point. The second clustering (columns) used the relativized totals for each species over all three treatments. The resulting image provides a two-dimensional picture of the combined relationships. To discover the yearly effects on treatments, only replicates of occurrence data were pooled, then relativized as described above, and analyzed. Because of the potential negative effects that rare species might have, only the 18 most common species were used. Rare species, those occurring in fewer than five percent of samples (McCune and Grace 2002) (in our case seven or fewer occurrences) were removed.

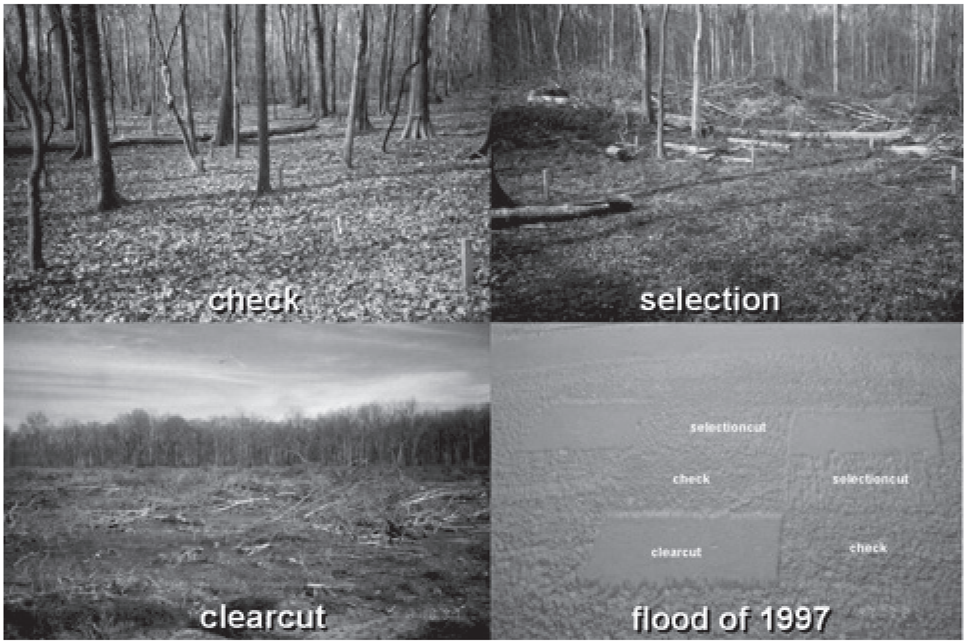

Figure 2—Images of treatments in winter of 1996 and flooding in 1997 at the Pittman Island, Mississippi, study site.

The occurrence data did not fit parametric statistics (transformations could not satisfy requirements), so non-parametrics were used (Clark 1993). The influence of treatments on the 18 most common species was analyzed by the multi-response permutation procedure (MRPP) in PC-ORD using occurrence by replicated treatment and year. Before analysis, the data set was relativized, as described above, for the treatments (rows) using the maximum occurrence of the most abundant species in the treatment stand. To tease out treatment effects, the analysis first compared all three treatments. If there were significant differences among any two, then multiple pairwise comparisons were done using a P = 0.05 significance level. The MRPP analysis used the Euclidean distance measure and Mielke group weighting (PC-ORD) to accommodate for the absence of ants in some treatment stands.

Indicator species analysis (PC-ORD) was used (by means of the procedure in Dufrene and Legendre 1997) to test faithfulness of ant species occurrence within treatments. A perfect indicator species would always be present in one treatment and never occur in other treatments; it would have a value of 100. As in the MRPP analysis, the data set was relativized within treatment stands using maximum occurrence of the most abundant species, thus standardizing all treatment stands to the same starting point. Significance was tested using a Monte Carlo method with 3,000 permutations and a significance level of P = 0.05.

RESULTS

Ants Found

Six subfamilies, 20 genera, 33 species and 19,268 individuals were collected. The occurrence of ant species by year and by treatment is shown in table 1. Of importance from this list is the absence of *Monomorium minimum*, and the single collection of *S. molesta*, both very common small ground-nesting species in AR, LA, and MS (Dash 2004, MacGowan and Hill 2007, Warren and Rouse 1969).

Ant Diversity

The number of observed species [species richness] (table 2) is lower in clearcuts over all years, and more similar in selection and check treatments. Year 1996 is very different because five species (*Camponotus pylartes, Dorymyrmex bureni, Brachymyrmex depilis, Stenamma meridionale*, and *Temnothorax curvispinosus*) disappeared in subsequent years. Other rare species (showing up only in single years) were *Cam. chromaiodes, Crematogaster missuriensis, Neivamyrmex opacithorax,* and *Trachymyrmex septentrionalis.* A measure of rare species is the number of singletons and doubletons (table 2), with singletons being much higher than doubletons within treatments in 1996 and 1997, and then reversing in 2000. The three richness estimators in table 2 show that the check treatments projected more species in 1997 and 2000.

The relationship between the ant community and treatments is shown in figure 3 (rows). The choice of data influenced the clustering results. When presence/absence data are used, the clearcuts and selections clustered together, but when occurrence data are used, the selections and checks clustered together. Although species richness data are useful, they do not provide enough information on the relative importance of each species in the community. Thus, because we have excellent occurrence data, we believe it provides a more reasonable picture of the treatment effects on our ant community. In this case, the clearcuts obviously affected the community and the selections had no effects.

The effects of treatments on individual species are shown in figure 3 (columns). When using presence/absence data

Table 1—Pittman Island, Mississippi, ant occurrence by year and treatment

SUBFAMILY/*Species*	1996	1997	2000	Clearcut	Selection	Check
ECITONINAE						
Neivamyrmex opacithorax (Emery)	0	0	2	0	0	2
DOLICHODERINAE						
Dorymyrmex bureni Trager	1	0	0	1	0	0
Tapinoma sessile (Say)	107	43	47	41	79	77
FORMICINAE						
Brachymyrmex depilis Emery	4	0	0	0	4	0
Camponotus americanus Mayr	6	4	11	3	3	15
C. castaneus (Latreille)	2	1	2	1	2	2
C. chromaiodes Bolton	0	0	1	0	1	0
C. decipiens Emery	35	17	0	2	25	25
C. discolor (Buckley)	1	0	3	0	1	3
C. pennsylvanicus (DeGeer)	101	85	32	37	84	96
C. pylartes Wheeler	1	0	0	0	0	1
Lasius alienus (Foerster)	124	65	26	53	77	85
Paratrechina terricola (Buckley)	2	1	91	52	35	7
Prenolepsis imparis (Say)	6	0	10	4	8	4
MYRMICINAE						
Aphaenogaster fulva Roger	2	10	2	2	6	6
A. tennesseensis (Mayr)	0	0	10	8	2	0
A. texana Wheeler	43	32	110	20	74	91
Crematogaster ashmeadi Mayr	21	21	17	4	31	24
C. lineolata (Say)	24	9	12	3	36	6
C. minutissima Mayr	26	8	7	0	26	15
C. missuriensis Emery	0	1	0	0	1	0
Myrmecina americana Emery	0	1	2	0	1	2
Myrmica spatulata M.R. Smith	141	87	72	41	95	163
Pheidole dentata Mayr	151	82	104	66	131	140
Solenopsis invicta Buren	67	97	142	160	108	38
S. molesta (Say)	1	1	0	0	1	1
Stenamma cf. meridionale	1	0	0	0	1	0
Temnothorax curvispinosus Mayr	1	0	0	0	0	1
Trachymyrmex septentrionalis McCook	0	0	1	0	0	1
PONERINAE						
Hypoponera opacior (Forel)	7	11	10	16	9	3
Ponera pennsylvanica Buckley	4	0	4	3	4	1
PSEUDOMYRMECINAE						
Pseudomyrmex pallidus (Fr. Smith)	3	1	0	0	0	4
TOTALS	**881**	**577**	**717**	**517**	**845**	**813**
Number of species	**26**	**20**	**23**	**19**	**26**	**27**

the rare species typically cluster together because they are usually absent from one or more of the three treatments. For the occurrence data, the species generally cluster based on occurrence within treatments. The left cluster in figure 3B shows the seven more abundant species in the clearcuts, the middle cluster shows the 21 species more abundant in selections and checks, and the right cluster the five species only present in the checks. Note that the rare species found only in the checks clustered together regardless of the data used (figs. 3A and B).

Because we also had yearly climate factors affecting the ant community, we used cluster analysis to help us separate out these effects on treatments and ants. Figure 4 shows the cluster analysis and the relative occurrence of species within treatments and years. Although all the clearcuts did not cluster together (rows), those in 1997 and 2000 did, along with selections in 2000. In addition, the selections and checks usually clustered together over all three years, and the extreme flooding year of 1997 did not appear to cluster differently than might be expected. Also, the left cluster of species (columns) is formed mostly by species more abundant in clearcuts, or those with no treatment effects (an exception is *Cam. americanus*, a species that seems to prefer checks). On the other hand, the right cluster of species is made up almost entirely of species more abundant in selection and check stands and those unaffected by treatments. From this analysis there is little evidence that the flooding in 1997 and drought in 2000 affected the ant community beyond the treatment effects noted before.

Treatment Effects on Individual Species

The analysis of treatment effects on individual species using MRPP is shown in table 3 (remember that MRPP is comparing relative species occurrence among and between treatments). Six species liked the selection and check treatments equally well (*Aphaenogaster picea, Cam. decipiens, Cam. pennsylvanicus, Cre. ashmeadi, Cre. minutissima,* and *Pheidole dentata*), and eight had no preferences at all (*A. fulva, A. tennesseensis, Cam. americanus, Hypoponera opacior, Lasius alienus, Ponera pennsylvanicas, Preolepis imparis*, and *Tapinoma sessile*). Although *Cam. americanus* showed no statistically significant preferences here, its three-treatment p-value was almost significant (0.0523), and in the ISA test below it showed

Table 2—Diversity estimates for ants by year and treatments at Pittman Island, Mississippi

	1996			1997			2000			
Diversity measure	Chk	Sel	CC	Chk	Sel	CC	Chk	Sel	CC	Comments
Occurrence	268	362	255	231	257	90	317	233	174	# of occurrences recorded
Species observed	17	19	15	16	16	11	20	18	16	# of species collected
Singletons	4	5	5	4	3	4	2	2	3	only 1 collected
Doubletons	2	1	1	0	0	2	3	3	4	only 2 collected
Chao 2	17.7	20.3	20.0	19.3	17.3	12.7	19.4	18.3	17.0	richness estimator
Jack 2	20.2	23.3	20.8	20.8	19.7	15.5	21.3	19.8	20.0	richness estimator
Bootstrap	18.4	20.6	16.8	17.5	17.3	12.6	20.0	19.2	17.7	richness estimator

Check = Chk, Selection = Sel, and Clearcut = CC.

preferences for checks. Of note, occurrence of the invasive *S. invicta* was significantly different among all treatments, being highest in clearcuts, intermediate in selections, and lowest in checks. *Crematogaster punctulata* showed clear preferences for selections. Finally, *Myrmica spatulata* and *Paratrechina terricola* showed no clear preferences, but gradients across treatments. *Myrmica spatulata* seemed to like checks over selections over clearcuts, while *P. terricola* showed the opposite trend, liking clearcuts over selections over checks.

Indicator Species Analysis

Only eight species were classified as indicators (table 4). The analysis over all three years is perhaps most revealing because it shows species responding to the three treatments consistently, but differently. Four species showed indicator value, *Cam. americanus* and *M. spatulata* for checks, *Cre. punctulata* for selections, and *S. invicta* for clearcuts. In 1996, the first growing season after disturbance, four species had indicator value, *Cre. minutissima* and *Cre. punctulata* for selections, and *H. opacior* and *S. invicta* for clearcuts. However, 1997 is also interesting, with no indicator species identified, perhaps due to the severe flooding that likely moved ants among treatments and affected population and or colony dynamics. Year 2000 shows that after the effects of treatments had stabilized, three species had indicator value, all for checks (*L. alienus, M. spatulata,* and *P. dentata*). Also of

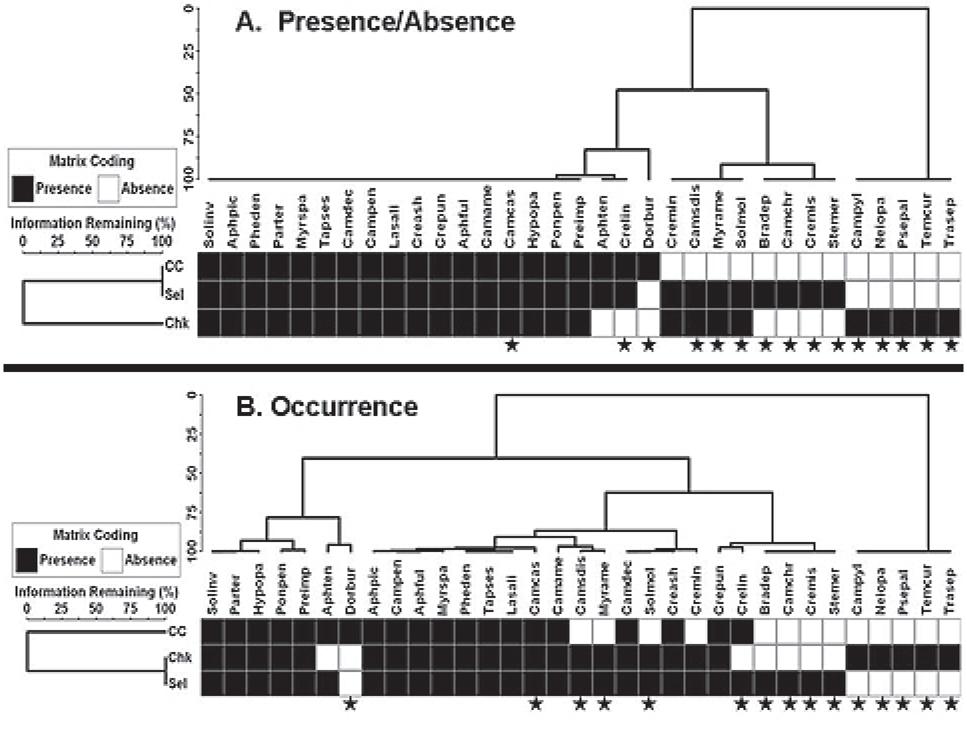

Figure 3—Dendrograms generated by 2-way cluster analysis showing ant diversity as a function of treatment, summed over all 3 collecting years and 3 replications: A) presence/absence data, and B) occurrence data. The 15 rare species are indicated with a star. Species abbreviations include the first 3 letters of the genus and the species. Table 1 has the scientific names. Treatment designations are Check = Chk, Selection = Sel, and Clearcut = CC. Cluster "breaks" are on a sliding scale with a value of 100 being most similar and 0 being very dissimilar. Natural groups have long stems in the dendrogram, and divergent groups are typically linked where the information remaining scale = 0.

importance here is that, by 2000, the invasive *S. invicta* was colonizing all treatments, and lost its ability to indicate severe disturbance (clearcuts), perhaps a clue to the power of this species to use disturbance to its advantage (in this case the ecotones resulting from our treatments).

DISCUSSION

Species richness was generally lower in the clearcuts than in selections and checks (table 2). This response in heavily disturbed sites is comparable to the only other study in the Southern United States on forest harvesting effects on ants. Zettler and others (2004) found decreased species richness following hardwood to pine conversions in South Carolina. Forest disturbance has produced variable results as it relates to species richness in tropical ant studies, decreasing (Schonberg and others 2004, Vasconcelos 1999), increasing (Watt and others 2002) and having no effect (Kalif 2001). Theoretically, opening up the forest may negatively affect forest specialists, while concurrently allowing generalist ants that like disturbance to colonize the sites. However, Palladini and others (2007) and Yi and Moldenke (2005), in studies in Douglas-fir (*Pseudotsuga menziesii*) in the Pacific Northwest, reported increased richness in cutover stands. This difference in the Pacific Northwest occurs because opening up the forest also heats up the ground so that the site is more habitable to cold intolerant ants (Yi and Moldenke 2005, Higgins and Lindgren 2006). Sanders and others (2007) proposed a similar idea, that warmer sites had more ant species along an elevational gradient in the Great Smokey Mountains National Park, U.S.A. Perhaps the opposite effect is true in the hot humid climate of the South, where the ants might instead be seeking shaded sites that are cooler and moister. Certainly the heat-loving *S. invicta* found the clearcuts excellent habitat. This was also the case in South Carolina (Zettler and others 2004), and *S. invicta* dominated the ant community in open grown longleaf pine (*Pinus palustris*) forests undergoing restoration in Louisiana (Colby and Prowell 2006).

Ant occurrence is a similar story. Checks and selections had similar numbers of ants (table 2, occurrence by treatment and year), with reduced numbers in the clearcuts. If it were not for *S. invicta*, the numbers in the clearcuts would have been even lower (table 1). Zettler and others (2004) reported similar results following hardwood to pine conversions in South Carolina. Studies conducted on the effects of forest regeneration in the tropics would suggest that ant abundance is affected little by moderate disturbance (Dunn 2004b, Watt and others 2002).

Even though we found no evidence that short term flooding affected the ant community at Pittman Island, studies in annually flooded Amazonian forests showed that ants were negatively affected (Majer and Delabie 1994, Ribas and Schoereder 2007), and a study of the ants in and around New Orleans, LA, showed species richness decreased by

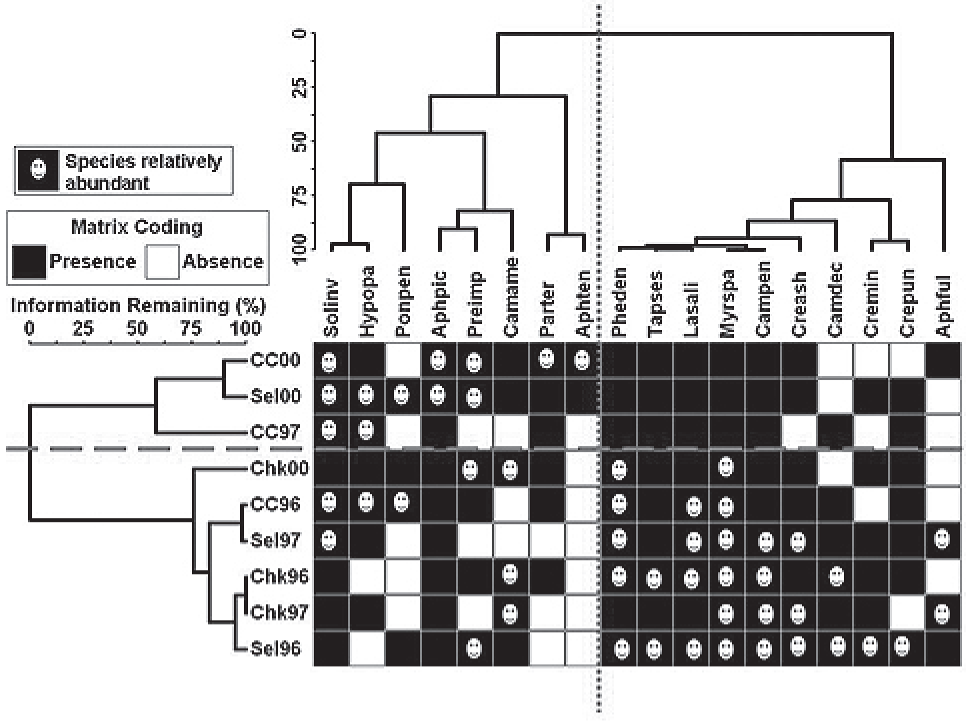

Figure 4—Dendrogram generated by 2-way cluster analysis showing ant diversity as a function of treatment and year (replicates pooled) using the 18 most abundant species. Open circles in the matrix coding shows species that are relatively abundant. Treatment-year designations are: (Check = Chk, Selection = Sel, and Clearcut = CC) followed by year (1996, 1997, and 2000). Cluster "breaks" are on a sliding scale with a value of 100 being most similar and 0 being very dissimilar. Natural groups have long stems in the dendrogram, and very divergent groups are typically linked where the information remaining scale = 0, and are shown here as dashed (- - - - -) and dotted (. . . . .) lines.

Table 3—Treatment effects on common ant species at Pittman Island, Mississippi, as analyzed using the Multi-Response Permutation Procedure

	Treatment Pairs						
	CC-Sel		CC-Chk		Sel-Chk		3 Treatments
Species	#	P	#	P	#	P	P
Aphaenogaster fulva	2 / 6		2 / 6		6 / 6		0.2024
A. tennesseensis	8 / 2		8 / 0		2 / 0		0.3775
A. texana	20 / 74	**0.0152**	20 / 91	**0.0030**	74 / 91	0.5218	**0.0196**
Camponotus americanus	3 / 3		3 / 15		3 / 15		0.0523
C. decipiens	2 / 25	**0.0088**	2 / 25	**0.0069**	25 / 25	1.0000	**0.0245**
C. pennsylvanicus	37 / 84	**0.0213**	37 / 96	**0.0107**	84 / 96	0.0828	**0.0183**
Crematogaster ashmeadi	4 / 31	**0.0024**	4 / 24	**0.0065**	31 / 24	0.5694	**0.0100**
C. lineolata	3 / 36	**0.0019**	3 / 6	0.6491	36 / 6	**0.0061**	**0.0006**
C. minutissima	0 / 26	**0.0047**	0 / 15	**0.0002**	26 / 15	0.2076	**0.0011**
Hypoponera opacior	16 / 9		16 / 3		9 / 3		0.0897
Lasius alienus	53 / 77		53 / 85		77 / 85		0.2288
Myrmica spatulata	41 / 95	0.0742	41 / 163	**0.0001**	95 / 163	**0.0136**	**0.0005**
Paratrechina terricola	52 / 35	0.1243	52 / 7	**0.0216**	35 / 7	**0.0217**	**0.0065**
Pheidole dentata	66 / 131	**0.0410**	66 / 140	**0.0188**	131 / 140	0.5630	**0.0191**
Ponera pennsylvanica	3 / 4		3 / 1		4 / 1		0.5147
Prenolepis imparis	4 / 8		4 / 4		8 / 4		0.4045
Solenopsis invicta	160 / 108	**0.0092**	160 / 38	**0.0000**	108 / 38	**0.0058**	**0.0000**
Tapinoma sessile	41 / 79		41 / 77		79 / 77		0.0934

Check = Chk, Selection = Sel, and Clearcut = CC.
Note: Occurrence (abundance) is represented by # in the treatment pairs, and bold indicates significant differences between treatments at P ≤ 0.05. Species nonsignificant when comparing all 3 treatments were not analyzed further using pairs.

more than 1/2 after flooding from Hurricane Katrina (Wiltz and others 2006).

The cluster analysis of occurrence data showed that the ant communities in the selections and checks were very similar, but differed from the clearcuts. Thus, the act of harvesting is not as important as the degree of tree removal. In our case, cutting all trees (clearcuts) removed food and other habitat resources for ground-active ants that forage on the trunk and in the canopy (Hölldober and Wilson 1990). If standing trees are available for colonization (in our case mostly sugarberry, the same tree species that dominated the uncut check forests) then the ant community appears to be much less affected. Most of the studies on the effects of selection harvesting on ants were done in tropical forests and showed similar results, few effects (Dunn 2004b, Oliver and others 2000, Vanderwoude and others 2000, Vasconcelos and others 2000, Watt and others 2002). In a study of the canopy ants of longleaf pine in Florida, Tschinkel and Hess (1999) found that the ant community responded to increasing tree size, except where a dominant ant species occurred. Likewise, Schonberg and others (2004) discovered that relict trees in pastures were just as species-rich as trees in primary tropical forests in Costa Rica. In addition, rain forest studies (Longino and Colwell 1997) have shown that tree species is not a strong predictor of arboreal ant species richness. So, it is the presence of trees that is important to the ant community, and perhaps the larger the trees the better.

Table 4—Indicator species values of ants with significant values by year for Pittman Island, Mississippi, receiving several harvesting treatments in 1995

				Year								
	All 3 years			1996			1997			2000		
Significant Species	Value*	P	Trt	Value	P	Trt	Value	P	Trt	Value	P	Trt
Camponotus americanus	**47.6**	**0.039**	**Chk**	55.6	0.462		33.3	1.000		54.5	0.532	
Crematogaster minutissima	42.3	0.110		**76.9**	**0.029**	**Sel**	50.0	0.305		71.4	0.139	
C. lineolata	**62.2**	**0.005**	**Sel**	**87.5**	**0.035**	**Sel**	59.3	0.245		38.9	0.418	
Hypoponera opacior	44.4	0.073		**100**	**0.036**	**CC**	42.4	0.502		60.0	0.167	
Lasius alienus	39.5	0.301		36.3	0.612		47.7	0.205		**92.3**	**0.017**	**Chk**
Myrmica spatulata	**54.6**	**0.002**	**Chk**	38.6	0.285		59.8	0.075		**80.6**	**0.032**	**Chk**
Pheidole dentata	41.2	0.183		35.9	0.549		56.1	0.100		**59.0**	**0.036**	**Chk**
Solenopsis invicta	**52.1**	**0.002**	**CC**	**71.6**	**0.023**	**CC**	53.6	0.102		42.2	0.318	

Check = Chk, Selection = Sel, and Clearcut = CC.
Note: Bold indicates significant at p ≤ 0.05. A perfect indicator species would always be present in one treatment and never occur in other treatments, and would have a value of 100.

The MRPP showed that 14 of the 18 ant species analyzed could not differentiate between selections and checks. No species preferred the undisturbed checks exclusively in the MRPP analysis, but when using data over all three study years, the ISA showed two species (*Cam. americanus* and *M. spatulata*) liked the checks. Both the MRPP and ISA showed that *Cre. punctulata* liked the selections, and *S. invicta* liked the clearcuts. By 2000, *L. alienus, M. spatulata,* and *P. dentata* showed preferences for checks. Thus, it would appear that the clearcuts negatively affected three species, and positively affected one. The selection harvesting had little effect on 14 of 18 species analyzed, but benefited *Cre. punctulata*.

Evidently, for those species showing preferences, the checks provide suitable soil moisture and texture, and the downed rotten wood used for nesting. *Camponotus americanus* is reported to nest in soil under logs (Creighton 1950), which is where we have found it nesting in forested sites in Arkansas (unpublished data). *Lasius alienus* and other species in this genus tend root coccids and aphids, preferring well drained soils for nests. We have found it in open and forested sites in bottomland habitats. *Myrmica spatulata* is reported by Creighton (1950) to nest in the soil under objects and to avoid areas of high temperatures and dry conditions. We have not found it in an intensively studied bottomland hardwood site in southeastern Arkansas. We have collected a sister species, *M. punctiventris*, in oaks, but not other forest types at the site. *Pheidole dentata* occurs in a wide range of habitats from forest to beaches, and is one of the most abundant species in the genus in the Southeastern United States (Wilson 2003). It often nests in rotten logs and stumps (Creighton 1950). Why it showed preferences for checks in 2000 is unclear. We have sampled it in open and forested sites in Arkansas.

We have found little information in the literature that would help us understand why *Cre. punctulata* liked the selections. However, the literature is full of information on the preferences for open places by *S. invicta* (Vinson 1997).

Our collecting experience from Arkansas showed us that the presence of a good supply of downed twigs, branches, and logs that are sufficiently rotten, or have lots of “worm holes” inside, provides improved nesting habitat for many species of ants. Although we did not measure the amount of coarse woody debris (CWD) on these treatments, we can generalize that there was much more in the selection and clearcut sites (see fig. 2). This is important because over time this CWD should eventually become suitable nesting habitat for ants. In a study in British Columbia, Higgins and Lindgren (2006) examined the physical attributes of CWD (>10 cm diameter and including stumps) in unharvested and eight to 10 year old harvested pines, as it related to ants. They found no difference in CWD volume among treatments, but in harvested stands CWD was somewhat smaller in diameter, shorter, had less bark, less decay, and was mostly in contact with the forest floor. They reasoned that these factors would likely increase the decay rate and might provide less CWD available to ants over the long run, as compared with unharvested forests.

There is often speculation about how long it might take for the ant community in cutover stands to return to normal. We have no personal experience to support an opinion, but, Palladini and others (2007) argue that in Douglas-fir in Oregon, it might take 100 years for the ant community in a clearcut to return to that of older natural stands. Dunn (2004a) reviewed the ant literature on this issue and concluded that the range is 13 to 40 years in the tropics. In a disturbance study in central Amazonia, Vasconcelos (1999) commented that recuperation of the ground-foraging ant community appeared to be faster than recuperation of the woody-plant community. Although the study of Heneghan and others (2004) was not directly related to ants, they report that it took 21 years for the microarthropod community in a clearcut Appalachian hardwood forest to return to uncut forest conditions. One could surmise that this might indicate the recovery time for ant habitat at our site may be less than 40 years, but will likely be faster than recuperation of the woody-plant community. Only a long-term, or short-term chronosequence study, is likely to assess recovery of ant communities from harvesting disturbances like those in our study.

In conclusion, harvesting affected the ant community somewhat, reducing richness and abundance of some species and increasing it for a few others. The effects from selection cutting were few as compared with clearcutting. Most important, however, was that the red imported fire ant (*S. invicta*), an invasive and exotic species, increased substantially with time in all treatments and may affect the native ants (Lubertazzi and Tschinkel 2003) until the surrounding disturbed treatments grow to the point where the opened forest floor becomes heavily shaded by the growing vegetation, cutting off the heat source to the *S. invicta* colonies. To keep their colony exposed to the sun, we have personally found *S. invicta* nests at Pittman Island on the tops of rotting cut tree trunks lying 1 m off the ground as the ants tried to elude the encroaching shade produced by the vegetation growing from below.

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