EFFECTS OF SILVICULTURAL OPERATIONS IN A MISSISSIPPI RIVER BOTTOMLAND HARDWOOD FOREST ON GROUND BEETLES IN THE GENUS *BRACHINUS*

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ABSTRACT—Little information is available on how insects are affected by anthropogenic influences in the bottomland forests of the West Gulf Coastal Plain. This study investigates one genus of ground beetles that lives in managed forested landscapes to discover which species are positively and negatively influenced by human disturbances. Ground beetles (Carabidae) were collected from a bottomland hardwood forest in the Mississippi River floodplain that received three harvesting treatments in 1995 (three replicates each of clearcut, selection, and control). Beetles were analyzed to assess the effects of forest disturbance over time. Four species in the genus *Brachinus* accounted for about 66 percent of all specimens collected. *Brachinus* larvae are ectoparasites on the pupae of water beetles, and the adults prefer moist habitats. In 1996, the year after applying treatments, the selection cuts yielded almost three times as many *Brachinus* (63 percent of 3,696 total) as the control (19 percent) and clearcut (19 percent) treatments. One year later, in 1997, both the control (45 percent of 2,572 total) and selection cuts (40 percent) yielded almost three times the number of *Brachinus* than the clearcuts (14 percent). In 2000 (an exceptionally dry summer), both the control (44 percent of 465 total) and selection cuts (45 percent) yielded four times the number of *Brachinus* than the clearcuts (11 percent). The steady loss of beetles during the study is believed to be due to several summer floods followed by several summer droughts. Nonetheless, this study demonstrates that the selection cuts continued to provide the habitat needs of these beetles, and the clearcuts continued to provide less suitable habitat, despite a lush growth of plants in 2000.

INTRODUCTION

According to Elzinga (2000), about 40 percent of all insects are beetles, and they provide a wide range of functional roles within forests, such as herbivores, predators, scavengers, decomposers, and fungivores. Ground beetles (family Carabidae) are a large, very diverse group of about 25,000 species worldwide, with about 2,200 species in North America; it is the fifth largest beetle family (Elzinga 2000). Ground beetles are found under litter, stones, and debris, mostly associated with damp habitats. When disturbed, ground beetles run quickly but seldom fly. Most adults and larvae are generalist predators, but some are highly specialized on specific hosts. A few are herbivorous on seeds. These beetles are active searchers in soil litter. Because of their ease of collection, ground beetles have been used in the past as indicators of habitat conditions and/or change (Niemela and others 1993, Thiele 1977).

Studies of ground beetles in bottomland hardwoods are few, with most being faunal surveys (Allen and Thompson 1977, Goff 1952). Two recent studies from the south-central United States provide more analytical information on the effects of disturbance on these beetles. Thompson and Allen (1993) studied the beetles in the Saline River bottom in south-central Arkansas, and Warriner and others (2002) documented beetle diversity from two stream bottoms: one in the Delta National Forest in west-central Mississippi and the other in Monroe County in northeastern Mississippi. Ground beetles in the genus *Brachinus* were recovered in both these studies.

The genus *Brachinus* are colorful insects, with orangish head and prothorax and metallic black or dark blue-green wing covers that appear cut-off at their ends. They have the common name bombardier beetles because they defend themselves by squirting a hot, toxic liquid from their anus. Little is known of their biology and ecology. They are typically found near all sorts of water bodies. They hide under stones, logs, debris, and so forth during the day and come out to forage at night. The adults are general scavengers on dead and dying arthropods; the larvae are probably parasites on water beetle pupae. Some of the beetles in this genus cannot fly but many can and are attracted to lights. Adults usually overwinter and become active between March and October (Erwin 1970).

Little information is available on how ground beetles are affected by anthropogenic influences in bottomland forests of the West Gulf Coastal Plain. The *Brachinus* were studied because they dominated the ground beetle fauna, and little is known about them or their response to forest disturbance.

METHODS

Study Site

The study site is located on Pittman Island in Issaquena County, MS, on lands owned by Anderson-Tully Company (fig. 1). The island is located within the levee system of the Mississippi River and has typical ridge/swale topography with riverfront hardwood species associations (Hodges and Switzer 1979). Soils are mostly silt loam and clay. Past silvicultural activities included a partial harvest in 1979 and infrequent light harvests before 1969.

Two reproduction cutting methods were used. The clearcut involved removing all merchantable stems during the winter of 1995-1996. In April, 1996, all remaining stems > 5 cm diameter at breast height (d.b.h.) were felled. The selection cut, as practiced by Anderson-Tully Company, involved the removal of approximately one-third to one-half of the total

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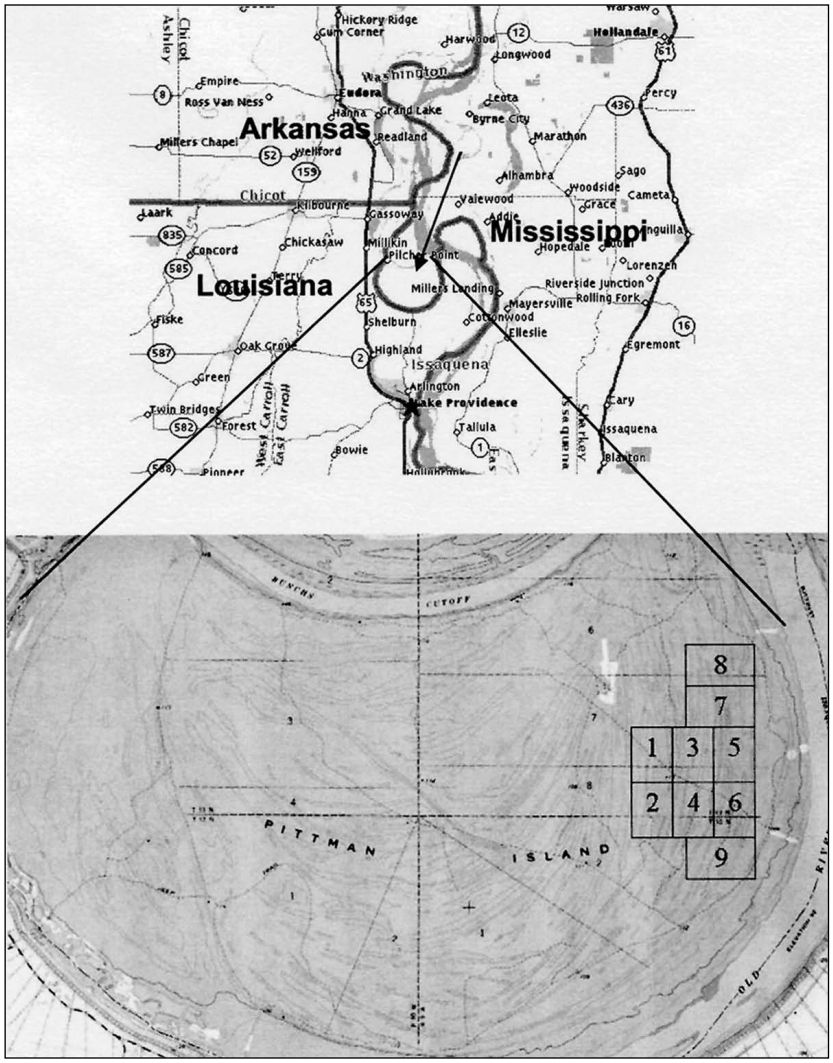

Figure 1—Location of Pittman Island, MS, near the northeastern corner of Louisiana, and showing treatment layout with stands 1, 6, and 7 clearcuts, 4, 5, and 8 selection cuts, and 2, 3, and 9 controls.

stand basal area and favored, to retain for future development, desirable species such as green ash (*Fraxinus pennsylvanica* Marsh.), sweet pecan [*Carya illinoinensis* (Wangenh.) K. Koch], and Nuttall oak (*Quercus texana* Buckl.). The harvesting treatments and control were about 20 ha in size and were replicated 3 times in a randomized design (fig. 1).

Stand Variables

Pre-treatment sampling occurred on 16 0.1-ha circular plots systematically located along 4 transects in each of the 9 stands. All trees > 9.6 cm d.b.h. were measured by species, d.b.h., crown classification, and topographic position (ridge or swale). Soil pH and texture measures were taken from the plots in each stand and averaged after determination. Canopy coverage was measured after harvest using a standard spherical crown densiometer.

Beetle Collecting

Beetles 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. Each trap consisted of a cylinder made from a 15-cm long section of 10-cm diameter white PVC pipe. The cylinder was buried vertically (with open end up) and level with the ground surface. A 700-ml plastic drinking cup was placed in the cylinder and filled about one-third full with preserving fluid, a 1:1 mixture of ethylene glycol and water. To simplify content removal, an easily removable strainer (made from another plastic cup and aluminum window screen) was placed into the bottom of each drinking cup. A 0.09-m^2 plywood rain lid, held about 5 cm over the cup using three large nails as legs, reduced the amount of water entering each trap. Beetles were separated from the trap contents in the laboratory, soaked in warm soapy water to clean the body of dirt and fats, rinsed, placed in 80 percent ethyl alcohol for 1 month, and then pinned for identification. Traps were serviced weekly from July 18 to November 19 in 1996, July 08 to November 17 in 1997, and June 14 to November 11 in 2000. Flooding occasionally influenced the site and beetle sampling. In 1996, the entire site was flooded from mid May to mid June, in 1997 from early March to mid April, in 1998 from late April to late May, and in 1999 from early to mid February. No flooding occurred in the extremely dry summer of 2000.

Beetles were identified to genus using Ball and Bousquet (2001). Representative specimens of difficult-to-identify beetles were sent to George Ball (E.H. Strickland Entomological Museum, University of Alberta) for identification. The four *Brachinus* species identified by Ball included *B. adustipennis* Erwin, *B. alternans* Dejean., *B. ovipennis* LeConte, and *B. quadripennis* Dejean. Identifications to species were made using characters provided by George Ball.

Analysis

Stand parameters were analyzed using the mean of 16 subsamples taken from each stand and the PROC GLM in SAS (SAS Institute Inc. 1999). Significance was accepted at $\alpha \leq 0.05$. Correlation analysis with PROC CORR in SAS was used to relate canopy coverage for the years 1996 and 1997 to *B. alternans* numbers, the only species with ample numbers across these 2 years and treatments. Because canopy coverage varied little between the 2 years, years were pooled to increase statistical sensitivity. The influence of treatments on beetles was analyzed using Chi-Square analysis in SPSS (SPSS Inc. 2004) on beetle counts by year and treatment. The analysis revealed departures from equal representation among the treatments. To assess species preferences for specific treatments, the presence-absence data by treatment, year, and replicate for the four *Brachinus* species was analyzed using the Cluster Analysis procedure in PC-ORD (McCune and Mefford 1999). We used the Flexible Beta linking method ($\beta = -0.25$) and the Sorensen (Bray-Curtis) distance measure of the cluster routine.

RESULTS AND DISCUSSION

Stand Variables

The 1995 pre-harvest parameters (table 1) clearly show no differences in common tree and soil measurements. This shows that subsequent treatment effects are likely the result of post-harvest influences. As expected, the post-harvest sampling showed harvesting significantly altered canopy coverage (table 1). However, correlation analysis of *B. alternans* numbers with canopy coverage showed weak relationships ($r = 0.443$, $P = 0.0749$), so canopy coverage provides little predictive value in assessing why this species may have "preferred" specific treatments.

Beetles

A total of 10,235 ground beetles representing 40 species were collected over the 3 years. Of these, 6,733 or 66 percent, were *Brachinus* individuals, comprising four species. The *Brachinus* are studied because they dominated the ground beetle fauna. Table 2 shows the *Brachinus* count by species, year, and treatment. Of the *Brachinus* taxa, *B. alternans* dominated the site with 97 percent of the specimens. Evidently, this forested island provides suitable habitat for this species.

The contingency table analysis of counts by year and treatment revealed significant differences among treatments, with fewer beetles collected in the clearcuts over all 3 years than would be expected by chance (Pearson Chi-Square = 550.9, 4 df; P = 0.000) (table 3). Thus, these beetles do not prefer cleared areas. Instead, they preferred the control and selection cuts, although this tendency was less obvious in 1996,

Table 1—Stand parameters measured pre-treatment in 1995 and post-treatment in 1996, 1997, and 1998

		Treatments							
		Control		Selection cut		Clearcut			
Parameter	Year	Mean	SE	Mean	SE	Mean	SE	F value	P > F
Pre-treatment									
Trees per ha	1995	467	22	438	28	478	28	1.31	0.4000
Basal area per ha	1995	27	2.35	27	0.24	27	1.52	0.34	0.8400
Soil pH (0--7.5 cm)	1995	6.3	0.05	6.4	0.06	6.3	0.07	3.94	0.1064
Soil texture (0--7.5 cm)	1995	Clay	Clay	Clay	Clay	Clay	Clay		
Soil texture (22.9--30.5 cm)	1995	Silty clay	Silty clay	Silty clay	Silty clay	Clay	Clay		
Post-treatment									
Canopy coverage	1996	95	0.11	62	1.97	0	0.00	909.11	0.0001
	1997	92	2.12	65	1.57	0	0.00	405.54	0.0001
	1998	69	2.19	44	0.96	0	0.00	238.66	0.0001

Table 2—Number of each *Brachinus* species collected from pitfall traps by treatment and year at Pittman Island, MS

	Treatments									
	Check			Selection cut			Clearcut			
Species	1996	1997	2000	1996	1997	2000	1996	1997	2000	Totals
B. adustipennis	6	0	0	10	0	0	53	6	0	75
B. alternans	681	1,137	191	2,282	1,031	202	627	342	47	6,540
B. ovipennis	2	22	7	12	5	6	4	22	3	83
B. quadripennis	0	2	5	17	3	2	2	2	2	35
Totals	689	1,161	203	2,321	1,039	210	686	372	52	6,733

Table 3—Percentage of all *Brachinus* collected from pitfall traps by year and treatment at Pittman Island, MS

Year	Check	Treatments: Selection cut	Treatments: Clearcut	Total
	- - - - - - - - - - *percent* - - - - - - - - - -			
1996	18.6	62.8	18.6	3,696
1997	45.1	40.4	14.5	2,572
2000	43.6	45.2	11.2	465
Total				6,733

just after the harvest. Also, the numbers of beetles declined precipitously during the collecting season in 2000, apparently due to an extended drought.

Cluster analysis (fig. 2) showed there was no pattern of preference for silvicultural treatments by beetle species, with all three treatments typically associated with the principal clusters. *B. alternans* was present in all years and treatments, so this species has little predictive value in assessing treatment preferences. *B. ovipennis* and *B. adustipennis* provide the major separation, but no clear treatments preferences are present.

Warriner and others (2002) found more *B. alternans* in bottomland stands thinned 2 years earlier, than in un-thinned stands. Similarly, Thompson and Allen (1993) noted that *B. alternans* was most common in an experimental bottomland clearcut (with treatments that included both with and without deadening of unmerchantable residual trees) than in the undisturbed controls. They also reported *B. alternans* numbers were much lower in the clearcut that was sheared and chopped.

Thus, our results further indicate that *B. alternans* is widespread and abundant, and tolerant of moderate disturbance. Furthermore, this study reinforces that selection cuts provide adequate habitat for these beetles, and the clearcuts provide less suitable habitat.

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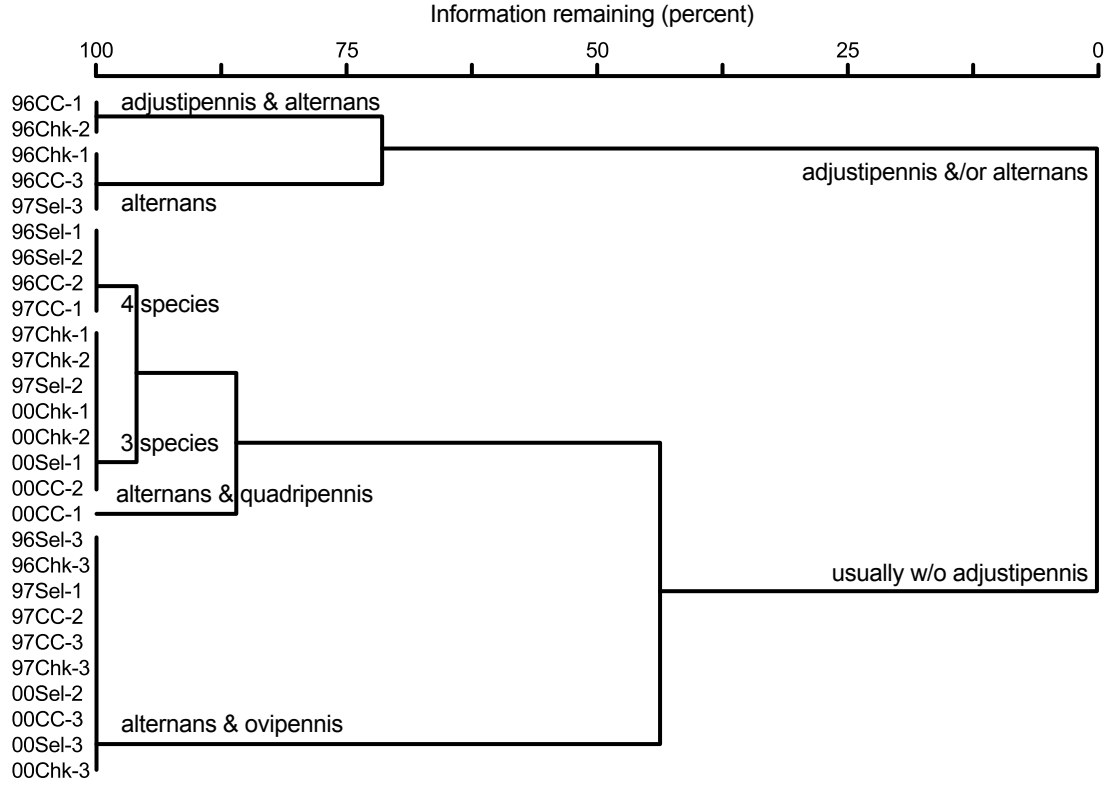

Figure 2—Dendrogram showing relationships among silvicultural treatments, years, and replicates for *Brachinus* species based on presence/absence data. [key: last 2 numbers of year, abbreviated treatment (control = Chk, selection cut = Sel, clearcut = CC) and replicate number (1, 2, or 3)].

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