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EFFECTS OF FOREST MANAGEMENT PRACTICES ON TERRESTRIAL COLEOPTERAN ASSEMBLAGES IN SAND PINE SCRUB

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ABSTRACT

Coleopteran assemblages were sampled monthly for one year using pitfall traps in replicated sites of three 5- to 7-year-old disturbance treatments and mature forested sand pine scrub in the Ocala National Forest, Marion County, Florida. Disturbance treatments were (1) burning at high-intensity and salvage-logging; (2) clearcutting, roller-chopping and broadcast seeding, and; (3) clearcutting and bracke-seeding. Community similarity of coleopterans was high. No differences in species richness, diversity, density, or evenness were detected. Of 40 species captured, only seven were common (n > 50). Predaceous beetles were numerically dominant followed by scavengers. Few xylophagous or herbivorous coleopterans were captured, probably due to trap bias. Peaks of annual above-ground terrestrial activity varied among species. An absence of differences among treatments may reflect similar plant communities or structural habitat features. Additionally, a dearth of mature forest specialists might be predicted in systems where mature forest was historically rare due to large-scale, high-intensity, and low-frequency wildfire.

Key Words: Beetle assemblage, clearcutting, wildfire.

RESUMEN

Durante un año fueron muestreadas mensualmente comunidades de coleópteros usando trampas de suelo en sitios replicados que poseen tres tipos de tratamientos con 5 a 7 años de edad, y el matorral que crece bajo un bosque maduro de pino de arena (sand pine) en el Bosque Nacional de Ocala, en el condado de Marion, en la Florida. Los tratamientos fueron (1) quema de gran intensidad y preservación de los troncos; (2) tala, corte de los troncos en pedazos y siembra de semillas al voleo, y (3) tala y siembra de semillas en los claros talados. La similaridad de comunidades de coleópteros fué elevada. No se encontraron diferencias en riqueza de especies, diversidad, o densidad. De 40 especies capturadas solamente siete fueron comunes (n > 50). Los escarabajos depredadores fueron numéricamente dominantes, seguidos por los comedores de carroña. Fueron capturados pocos coleópteros xilófagos o herbívoros, probabemente debido a los tipos de trampas. Los picos de actvidad terrestre por encima del suelo variaron entre las especies. La falta de diferencia entre los tratamientos puede reflejar comunidades de plantas o formas de habitats estructurales similares. Adicionalmente, la falta de especialistas de bosque maduro podría ser pre-

dicha en sistemas donde el bosque maduro es históricamente raro debido al fuego a gran escala, alta intensidad y baja frecuencia.

Coleopteran assemblages often are useful indicators for monitoring effects of land management practices on biodiversity (Eyre et al. 1989; Kremen et al. 1993). Many species have specific habitat requirements and are capable of dispersing as habitat suitability declines (Refseth 1980). Also, the microcosm of food web dynamics, niches, and habitat requirements represented within the order Coleoptera permits insight into ecological shifts as land use changes.

Historical changes in climate and sea level, and subsequent isolation have led to a high endemism of plants (Christman & Judd 1990), vertebrates (Auffenberg 1982), and invertebrates (Deyrup 1989) in scrub. Knowledge of scrub arthropod distribution sheds light on the biogeography of Florida scrub but is poorly documented (Deyrup 1989).

The scrub ecosystem occurs in xeric, infertile sandy soils (Kalisz & Stone 1984) along coastal areas and inland ridges of Florida and extreme southern Alabama. The thick, sclerophyllous shrub layer is dominated by myrtle oak (*Quercus myrtifolia* Willd.), sand live oak (*Q. geminata* Small), Chapman's oak (*Q. chapmanii* Sarg.), rusty lyonia (*Lyonia ferruginea* Nutt.), and two species of palmetto (*Serenoa repens* Small and *Sabal etonia* Swingle ex Nash.). Herbaceous groundcover is scant. Sand pine (*Pinus clausa* Vasey ex Sarg.) scrub is a habitat variant containing sand pine as a dominant component.

The peninsular Florida variety of sand pine, *Pinus c. clausa*, has serotinous cones. Here, the naturally even-aged, monospecific sand pine canopy is maintained by the release of copious quantities of seed (recorded as > 2.47 million per ha, Cooper et al. 1959) following stand-replacing wildfire. Historically, low-frequency, high-intensity, and large-scale wildfire created a forest mosaic of temporally shifting age-classes (Rawlings 1933, Webber 1935, Bartram 1955, Myers 1990). An open, shrub-dominated habitat was maintained between wildfires, while mature forest probably existed intermittently in time and space, especially in sites protected from fire. The largest remaining area of scrub occurs in the Ocala National Forest in central Florida. Current forest management of sand pine scrub there entails clearcutting patches of approximately 8-24 ha. Heavy machinery used during the clearcutting operation crushes and kills nearly all above-ground vegetation. Clearcutting is commonly followed either by roller-chopping and broadcast seeding or "bracke-seeding." Roller chopper blades penetrate the soil to a maximum depth of 15 cm. Soil surface disturbance with this method is nearly complete. Bracke-seeding entails direct seeding along small, machine-created ridges (about 8 cm high). This method patch-scarifies approximately 30% of the soil surface (Outcalt 1990). Because of the wood fiber value and the possibility of large-scale, uncontrolled burns, fires in sand pine stands are usually extinguished as rapidly as possible. Normally, burned sites are salvage-logged.

Plant community recovery and habitat structure of clearcuts are similar in many respects to community recovery and structure following high-intensity wildfire (Campbell & Christman 1982, Abrahamson 1984a, 1984b, Schmalzer & Hinkle 1992, Greenberg et al. 1995). Major differences include (1) the absence of fire-associated cues for attracting pyrophyllic coleopterans to clearcuts; (2) the presence of few standing trees or snags in clearcuts versus an abundance of snags for several years following a wildfire (unless salvage-logged, as in this study); (3) more slash piles and less bole-sized woody debris in clearcuts (personal observation), and; (4) landscape patterns such as patch size and connectivity.

Because it occurs on ideal sites for citrus and urban development, sand pine scrub is fast becoming and endangered ecosystem (Myers 1990). It is critical that the scrub ecosystem on public lands be managed to maintain the characteristic species diversity associated with the ecosystem and its driving processes.

This study is one portion of a larger study comparing plant, bird, and herpetofaunal communities among four stand treatments: intense burning and salvage-logging; clearcutting followed by either roller-chopping or bracke-seeding; and naturally regenerated, mature sand pine scrub. Here we describe and quantitatively compare coleopteran assemblages among these treatments. The study also provides information on annual cycles of commonly captured coleopterans.

MATERIALS AND METHODS

Coleopterans were sampled using drift fences and pitfall traps in three replicated 5- to 7-year-old disturbance treatments and mature forested sand pine scrub (n = three sites each) in the Ocala National Forest, Marion County, Florida (Table 1). Disturbance treatments were (1) high-intensity burning, salvage-logging, and natural regeneration (HIBS); (2) clearcutting, roller-chopping, and broadcast seeding (RC), and; (3) clearcutting and bracke-seeding (BK). Mature (≥ 55 yr) sand pine stands that had naturally regenerated following a stand-replacing fire in 1935 were used as a control (MF). All sites had similar elevation, topographic, and soil characteristics; same pretreatment age, and (known) disturbance history (identical to MF); same post-treatment age for HIBS, RC, and BK sites (within 1.5 yr) (Table 1); were greater than 8.5 ha; and were more than 0.9 km from known water sources.

Sand pine density and height were measured in five 100-m^2 plots per site (or in a 20 m^2 subplot if density was high). Three 10-m line transects were randomly established within quadrats to quantify percent cover of the vegetation and microsite characteristics by category, including herb, shrub, pine, woody debris, leaf litter, and bare ground, using the line intercept technique (Mueller-Dombois & Ellenberg 1974). In MF, sand pine canopy cover was estimated using a spherical densiometer at the midpoint of each line transect.

Trapping arrays were designed and concurrently used for herpetofaunal sampling (Greenberg et al. 1994) but proved effective in sampling surface-active terrestrial arthropods as well. Arrays (modified from Campbell & Christman 1982) consisted of eight 7.6-m lengths of erect 0.5-m-high galvanized metal flashing arranged in an "L" shaped pattern with a 7.6-m space between each length. Two black 18.9-liter plastic paint buckets (pitfall traps) with 28.5-cm diam were sunk flush with the ground at both ends of each fence (n = 16 pitfall traps per site). To improve drainage, 1.25-cm holes were drilled into the bottoms of the pitfall traps. Drill holes were blocked with sticks to prevent escape. No killing agents were used in pitfalls. Arrays were located a minimum of 25 m from roads or stand edges (except for two drift fences of one array). We assumed that consumption of arthropods by vertebrates was minimal due to low capture rates of vertebrates during arthropod sampling periods. Any effects were consistent among treatments.

Arthropods were trapped for one 48-hour period each month from October 1991 through September 1992. Coleopterans were preserved in ethyl alcohol.

One-way analysis of variance (ANOVA) (SAS 1989) was used to determine differences among treatments in total numbers of individuals trapped, total numbers by

TABLE 1. DATES OF TREATMENT ADMINISTRATION AND VEGETATION SAMPLING IN THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB.

Treatment	Burn	Clearcut or Salvage	Site Preparation	Sand Pine Seed	Sample
Burn-salvage (HIBS)	May 1985	June-Oct 1985	N/A	N/A	Summer 1991
Chop (RC)	N/A	Apr '83-Feb '85	June '86	Winter '86-'87	Summer 1991
Bracke (BK)	N/A	Fall '86	Winter '86-'87	Winter '86-'87	Summer 1991
Mature (MF)	Spring 1935	N/A	N/A	N/A	Summer 1991

species, Shannon's diversity indices, species richness, and evenness (Brower & Zar 1977). Horn's Index of Community Similarity (Horn 1966) was used to compare community overlap among treatments.

Each species was assigned to one of four feeding guilds: predator, scavenger (carrion and dung beetles), herbivore (root-, stem-, foliage-, or flower-feeding beetles), and xylophage based on adult food habits. ANOVA was used to detect differences in coleopteran density for each feeding guild.

Annual above-ground terrestrial activity cycles were estimated from captures of each commonly trapped species (n ≥ 50 individuals caught over the 1-year period) for each trapping period.

Results

Mature forest differed structurally from disturbance treatments in having lower stem density and greater foliar cover and height of sand pine. Mature stands also had less bare ground and higher leaf litter, nonwoody plants (primarily lichens), and shrub cover than disturbance treatments (Table 2) (see also Greenberg et al. 1995).

A total of 1,849 beetles representing 40 species in 14 families was captured (Table 3). Only seven species were commonly captured (≥ 50 individuals). Two carabid species of *Pasimachus* (*P. strenuus* LeConte and *P. subsulcatus* Say) were dominant followed by the tenebrionid *Polopinus youngi* Kritsky and an undescribed tenebrionid species of *Helops*.

Three females of *Romulus globosus* Knull (Cerambycidae), a rare scrub endemic, were captured in the July trapping period. Based on collection dates of other specimens, this species is most active in June and July (Thomas 1991). *Peltotrupes youngi* Howden, a species endemic to the Ocala National Forest scrub in Marion and Putnam counties (Woodruff 1973), was relatively abundant. There were no differences in density of individual species among treatments (Table 3).

There were no differences among treatments in density, diversity, or evenness of captured coleopterans (Table 4). Species richness was lower in MF than in any of the disturbance treatments, but differences were not statistically significant (Table 4). Horn's Index of Community Similarity indicated a high degree of community overlap among all treatments (Table 5).

Feeding guild structure did not differ among treatments (Table 3; Fig. 1). Predaceous beetles were dominant, composing 63-73% of total beetle numbers, followed by scavengers (21-30%), herbivores (5-9%) and xylophages (≤ 1%).

Two general patterns of annual above-ground terrestrial activity cycles were apparent. Among completely trapped species, *Peltotrupes youngi* Howden and *Helops* sp. appeared to be most active above-ground from December-March and inactive mostly from June-October. Several other species were active above-ground from at least May-October (*Polypleurus* sp. from April-August) but inactive during the cooler winter months (Fig. 2).

Discussion

Several studies report decreases in forest specialists but increases in overall coleopteran diversity following forest disturbance, fragmentation, or deforestation as species of open habitat invade and mature forest generalists persist (Lenski 1982, Baguette & Gerard 1993, Buse & Good 1993, Halme & Niemela 1993, Niemela et al. 1993). Conversely, Niemela et al. (1988) found few differences in carabid assemblages

TABLE 2. STRUCTURAL CHARACTERISTICS (MEAN ± SE) OF SAND PINE SCRUB HABITAT IN THREE 5-7 YEAR POST-DISTURBANCE TREATMENTS AND 55-YEAR-OLD MATURE FOREST (N = FIVE SITES PER TREATMENT), OCALA NATIONAL FOREST, FLORIDA. DIFFERENT LETTERS DENOTE SIGNIFICANT DIFFERENCES AMONG TREATMENTS ($P < 0.05$).

	Pine			Shrub	Non-woody Plants	Leaf Litter	Bare Ground	Woody Debris
Treatment	Stems/ha	Height (m)	Foliar (% Cover)	% Cover				
Burn-salvage (HIBS)	4076.0[a]	2.7[a]	41.8[a,b]	51.2[a,b]	6.8[a,b]	66.6[a,b]	16.8[a]	20.3[a]
	653.0	0.1	11.7	7.9	3.4	7.3	4.9	8.1
Chop (RC)	3496.0[a]	2.8[a]	45.8[a]	42.9[a]	13.7[a]	70.2[a]	22.9[a]	2.1[b]
	270.1	0.1	9.0	7.3	6.4	7.1	5.9	2.2
Bracke (BK)	3080.0[a]	1.9[b]	21.2[b]	59.0[b]	4.9[b]	57.1[b]	21.5[a]	20.8[a]
	388.4	0.1	7.5	8.1	2.1	8.6	6.5	6.7
Mature (MF)	641.7[b]	16.7[c]	83.9[c]	73.4[c]	35.9[c]	99.6[c]	0.3[b]	5.3[c]
	64.8	0.6	4.5	7.8	10.3	0.6	0.5	1.8

TABLE 3. TOTAL NUMBER OF COLEOPTERANS CAPTURED IN EACH OF THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB FROM OCTOBER 1991 THROUGH SEPTEMBER 1992 IN THE OCALA NATIONAL FOREST, MARION COUNTY, FLORIDA.

		Treatment			
Guild[1]	Species	Burn-salvage (HIBS) (n = 3)	Chop (RC) (n = 3)	Bracke (BK) (n = 3)	Mature (MF) (n = 3)
	ALLECULIDAE	—	—	1	—
H	*Hymenorus* sp.	—	—	1	—
	BURPRESTIDAE	3	2	2	
X	*Chalcophora virginiensis* Drury	3	2	2	—
	CARABIDAE	299	251	365	292
P	*Apenes opaca* LeConte	—	—	1	—
P	*Apenes sinuata* (Say)	1	—	—	—
P	*Carabid* sp. 1	—	1	—	—
P	*Carabid* sp. 2	—	1	—	—
P	*Cyclotrachelus faber* (Germar)	4	—	1	3
P	*C. hernandensis* Van Dyke	—	—	1	—
P	*C. morio* (Dejean)	—	—	1	—
P	*C. ovalum* Chaudoir	3	12	1	1
P	*Harpalus caliginosus* Fabricius	—	—	1	—
P	*Helluomorphoides clarvilleii* (Dejean)	3	14	16	8
P	*Pasimachus strenuus* LeConte	199	163	207	166
P	*P. subsulcatus* Say	89	60	136	114

[1]H = Herbivore; X = Xylophage; P = Predator; S = Scavenger.

TABLE 3. (CONTINUED) TOTAL NUMBER OF COLEOPTERANS CAPTURED IN EACH OF THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB FROM OCTOBER 1991 THROUGH SEPTEMBER 1992 IN THE OCALA NATIONAL FOREST, MARION COUNTY, FLORIDA.

		Treatment			
Guild[1]	Species	Burn-salvage (HIBS) (n = 3)	Chop (RC) (n = 3)	Bracke (BK) (n = 3)	Mature (MF) (n = 3)
	CERAMBYCIDAE	2	—	2	2
X	*Archodontes m. melanopus* (L.)	1	—	—	1
X	*Prionus pocularis* Dalman	—	—	—	1
X	*Romulus globosus* Knull	1	—	2	—
	COCCINELLIDAE	—	3	—	—
P	*Cycloneda s. sanguinea* (L.)	—	3	—	—
	CURCULIONIDAE	7	5	2	13
H	*Agraphus bellicus* (Say)	7	3	1	12
H	*Gerstaekeria hubbardi* LeConte	—	2	—	—
H	*Hylobius pales* Boheman	—	—	—	1
H	*Sphenophorus* sp.	—	—	1	—
	ELATERIDAE	1	—	1	—
P	*Agrypnus rectangularis* (Say)	—	—	1	—
H	*Elaterid* sp.	1	—	—	—
	HISTERIDAE	1	—	—	—
P	*Histeridae*	1	—	—	—
	PHENGODIDAE	2	—	—	—
P	*Phengodes* sp.	2	—	—	—

[1]H = Herbivore; X = Xylophage; P = Predator; S = Scavenger.

TABLE 3. (CONTINUED) TOTAL NUMBER OF COLEOPTERANS CAPTURED IN EACH OF THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB FROM OCTOBER 1991 THROUGH SEPTEMBER 1992 IN THE OCALA NATIONAL FOREST, MARION COUNTY, FLORIDA.

		Treatment			
Guild[1]	Species	Burn-salvage (HIBS) (n = 3)	Chop (RC) (n = 3)	Bracke (BK) (n = 3)	Mature (MF) (n = 3)
	SCARABAEIDAE	62	33	30	40
S	*Ateuchus lecontei* (Harold)	1	—	—	—
H	*Diplotaxis* sp.	12	7	5	1
S	*Peltotrupes youngi* Howden	23	2	6	28
S	*Phanaeus igneus floridanus* d'Olsoufieff	2	9	1	—
H	*Strategus antaeus* (Drury)	24	15	18	11
	SILPHIDAE	3	3	—	—
S	*Nicrophorus carolinus* (L.)	3	3	—	—
	STAPHYLINIDAE	—	1	—	1
P	Staphylinid sp. 1	—	—	—	1
P	Staphylinid sp. 2	—	1	—	—
	TENEBRIONIDAE	103	105	157	55
S	*Glyptotis cribatus* LeConte	2	—	5	3
S	*Gonwanocrypticus obsoletus* (Say)	—	1	—	—
S	*Helops* sp.	32	40	56	—
S	*Polopinus disjunctus* Kritsky	—	1	—	—

[1]H = Herbivore; X = Xylophage; P = Predator; S = Scavenger.

TABLE 3. (CONTINUED) TOTAL NUMBER OF COLEOPTERANS CAPTURED IN EACH OF THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB FROM OCTOBER 1991 THROUGH SEPTEMBER 1992 IN THE OCALA NATIONAL FOREST, MARION COUNTY, FLORIDA.

		Treatment			
Guild[1]	Species	Burn-salvage (HIBS) (n = 3)	Chop (RC) (n = 3)	Bracke (BK) (n = 3)	Mature (MF) (n = 3)
S	*P. youngi* Kritsky	47	52	80	18
S	*Polypleurus* sp.	22	11	16	34
	TOTAL INDIVIDUALS	483	403	560	403

[1]H = Herbivore; X = Xylophage; P = Predator; S = Scavenger.

TABLE 4. MEAN (± SE) SPECIES RICHNESS, DIVERSITY, AND EVENNESS OF COLEOPTERA TRAPPED FROM OCTOBER 1991 TO SEPTEMBER 1992 IN THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB, OCALA NATIONAL FOREST, FLORIDA.

	Richness	Diversity	Evenness
Burn-salvage (HIBS)	15.3	0.800	0.676
	(1.9)	(0.057)	(0.019)
Chop (RC)	13.7	0.783	0.691
	(1.5)	(0.061)	(0.026)
Bracke (BK)	14.7	0.763	0.655
	(0.7)	(0.018)	(0.025)
Mature (MF)	10.7	0.681	0.667
	(0.9)	(0.048)	(0.055)
P-value	0.098	0.385	0.899
F-value	3.00	1.15	0.19
df	2	2	2

between mature and successional coniferous taiga. This appears to be the case for sand pine scrub as well.

Several possibilities exist for the similarity in species composition and community structure among disturbance treatments and mature sand pine scrub. The pitfall trapping technique may have missed important species (Adis 1989), including non-terrestrial species such as many monophagous herbivores, xylophages, and mature forest-specialists. However, similar studies using pitfall traps detected differences in species composition among treatments (e.g. Lenski 1982, Baguette & Gerard 1993, Buse & Good 1993, Halme & Niemela 1993, Niemela et al. 1993). Because trap bias is consistent across treatments, comparisons using standardized trapping techniques are valid.

Differences among treatments may have been present for the first few years following disturbance but were not detected because stands were not sampled until 5-7

TABLE 5. HORN'S INDEX OF COMMUNITY SIMILARITY (R_O)[2] FOR COLEOPTERA IN THREE TREATMENTS AND MATURE FORESTED SAND PINE SCRUB, OCALA NATIONAL FOREST, FLORIDA.

	Burn-salvage (HIBS)	Chop (RC)	Bracke (BK)
Burn-salvage (HIBS)			
Chop (RC)	0.931		
Bracke (BK)	0.945	0.939	
Mature (MF)	0.913	0.821	0.874

[2]As R_0 approaches one, community overlap increases.

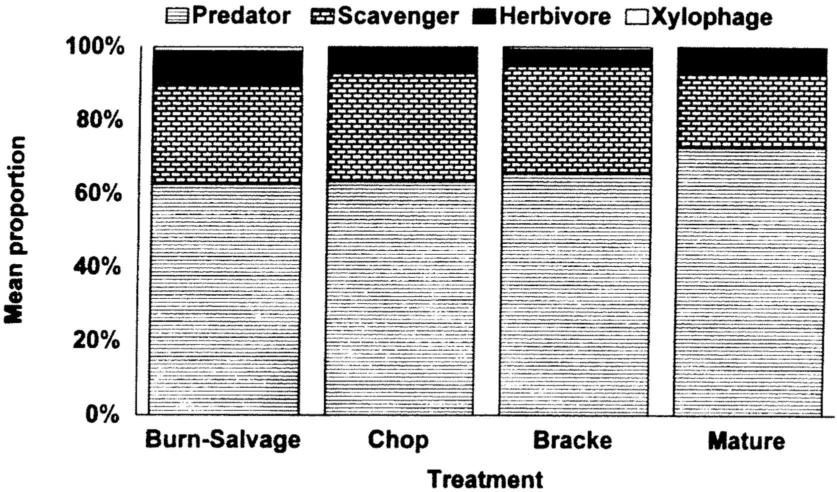

Fig. 1. Mean proportion of Coleoptera in four feeding guilds in three disturbance treatments and mature forest in sand pine scrub, Ocala National Forest, Florida.

years post-disturbance. Small stand size and time since disturbance permitted ample opportunity for recolonization of disturbance treatments by coleopterans. Nonetheless, similarity in coleopteran community composition indicates that suitable habitat exists 5-7 years post-disturbance, whether by silvicultural means or by wildfire.

Similarity of many habitat features between 5-7-year-old disturbed and mature sand pine scrub may also contribute to like coleopteran community composition among treatments. Differences in pine age, height, and density, as well as percent bare ground were the most prominent differences between MF and disturbance treatments. However, minimal differences in composition of dominant (woody) plant species exist between early and late-successional sand pine scrub or among disturbance treatments (Greenberg et al. 1995). Infertile, acid sands and low water availability render productivity and palatability of the sclerophyllous vegetation low in sand pine scrub. Although several species of herbs occur within the study area (Greenberg et al. 1995), total cover is low. These factors may partially explain the low representation of herbivorous coleopterans. Nonetheless, endemic, host-specific herbivores might be expected where plant species distribution is restricted as is sand pine or endemic herbaceous species of scrub (Deyrup 1989).

Herbaceous plant species diversity is higher in disturbed scrub than in mature forest. Among disturbance treatments, herbaceous plant community similarity, species richness, and species diversity did not differ significantly (Greenberg et al. 1995). However, disturbance treatments could differentially affect occurrences of some plant species. Trap bias against plant specialists and xylophages could lead to potential differences among treatments going undetected.

The apparent absence of forest specialists within sand pine scrub could be due to the historical prevalence of young forests due to low-frequency, high intensity wildfire (Rawlings 1933, Webber 1935, Bartram 1955, Bonan & Shugart 1989). Even in the absence of fire, sand pine stands begin to break up after about 50-70 years (Myers 1990) due to disease or structural weakness. Historically, sand pine density in the study area probably varied spatially and temporally as well; many scrubs have few to no

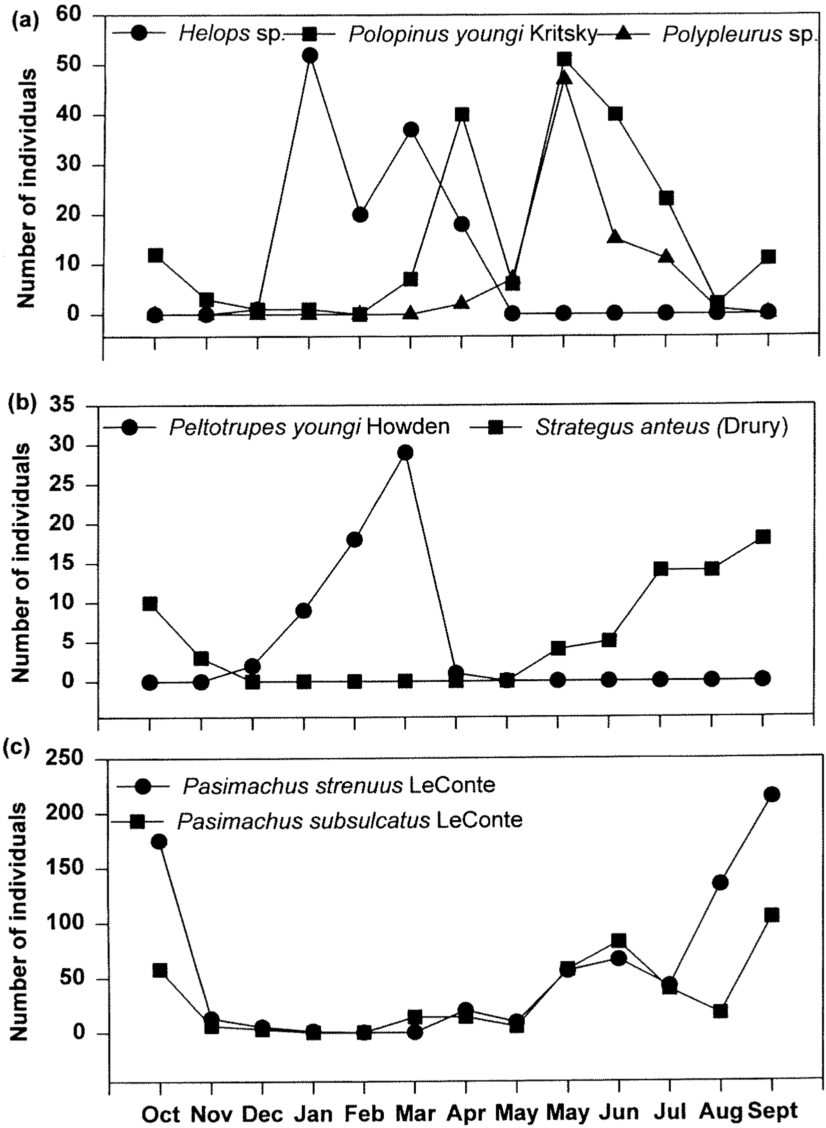

Fig. 2. Annual above-ground terrestrial activity cycles of (a) tenebrionids; (b) scarabs; and (c) carabids in the Ocala National Forest, Florida.

sand pine. Coleopterans are unlikely to have evolved into a specialized mature forest niche where habitat availability was rare or unreliable.

The predominance of carabids, tenebrionids, and staphylinids reflects both the trap bias toward ground-dwelling coleopterans and their relative abundance. The overwhelming prevalence of predaceous Coleoptera (primarily carabids) may be due to an abundance of arthropod prey within sampled sites (C. H. G. unpublished data). Predaceous beetles may have consumed non-predaceous beetles in traps, but the additional presence of other arthropod prey reduces the likelihood that this was a significant problem.

Xylophagous species were under-represented in this study due to trap bias. Additionally, this guild may have been more abundant had HIBS not been salvage-logged. However, small-diam woody debris was available in the form of slash piles (from onsite delimbing) in HIBS and BK treatments. Woodpiles were less common in RC sites because the roller-chopping fragmented and buried woody debris (Table 2). Few snags were present in MF or in disturbance treatments.

Stand age may also account for low representation by xylophages which may have been more abundant during the first 1-2 years post-logging. The absence of pyrophyllous species in the HIBS treatment was probably due to elapsed time since fire and post-fire salvage-logging.

Monthly variation in above-ground terrestrial activity cycles suggests that trapping in all months is necessary for a complete census of coleopterans as well as for gaining an understanding of their ecology.

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REFERENCES CITED

ABRAHAMSON, W. G. 1984a. Species responses to fire on Florida Lake Wales Ridge. American J. Botany 71: 35-43.

ABRAHAMSON, W. G. 1984b. Post-fire recovery of Florida Lake Wales Ridge vegetation. American J. Botany 71: 9-21.

ADIS, J. 1989. Problems of interpreting arthropod sampling with pitfall traps. Zoologischer Anzeiger 202: 177-184.

AUFFENBERG, W. 1982. Florida environments and their herpetofaunas, part 3. Herpetogeography. Florida Herpetol. 4: 1-35.

BAGUETTE, M., AND S. GERARD. 1993. Effects of spruce plantations on carabid beetles in southern Belgium. Pedobiologia 37: 129-140.

BARTRAM, W. 1955. The Travels of William Bartram. 1791. M. Van Doren [ed.], Dover, New York.

BONAN, G. B., AND H. H. SHUGART. 1989. Environmental factors and ecological processes in boreal forests. Annu. Rev. Ecol. Syst. 20: 1-28.

BROWER, J. E., AND J. H. ZAR. 1977. Field and Laboratory Methods for General Ecology. W. C. Brown Company, Dubuque, Iowa.

BUSE, A., AND J. E. G. GOOD. 1993. The effects of conifer forest design and management on abundance and diversity of rove beetles (Coleoptera: Staphylinidae): implications for conservation. Biol. Conserv. 64: 67-76.

CAMPBELL, H. W., AND S. P. CHRISTMAN. 1982. Field techniques for herpetofaunal community analysis, p. 193-200 *in* N. J. Scott [ed.]. Herpetological communities. U.S. Department of Interior, Fish and Wildlife Service Wildlife Research Report 13.

CHRISTMAN, S. P., AND W. S. JUDD. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53: 52-73.

COOPER, R. W., C. S. SCHOPMEYER, AND W. H. DAVIS MCGREGOR. 1959. Sand pine regeneration on the Ocala National Forest. U.S. Department of Agriculture Forest Service Productivity Research Report 30.

DEYRUP, M. 1989. Arthropods endemic to Florida scrub. Florida Scientist 52: 254-270.

EYRE, M. D., M. L. LUFF, S. P. RUSHTON, AND C. J. TOPPING. 1989. Ground beetles and weevils (Carabidae and Curculionoidea) as indicators of grassland management practices. J. Applied Entomol. 107: 508-517.

GREENBERG, C. H., D. G. NEARY, L. D. HARRIS, AND S. P. LINDA. 1995. Vegetation recovery following high-intensity wildfire and silvicultural treatments in sand pine scrub. American Midl. Nat. 133: 372-412.

GREENBERG, C. H., D. G. NEARY, AND L. D. HARRIS. 1994. Effect of high-intensity wildfire and silvicultural treatments on herpetofaunal communities in sand pine scrub. Conserv. Biol. 8: 1047-1057.

HALME, E., AND J. NIEMELA. 1993. Carabid beetles in fragments of coniferous forest. Annles Zoologici Fennici 30: 17-29.

HORN, H. S. 1966. Measurements of overlap in comparative ecological studies. American Nat. 100: 419-424.

KALISZ, P. J., AND E. L. STONE. 1984. The longleaf pine islands of the Ocala National Forest, Florida: a soil study. Ecology 65: 1743-1754.

KREMEN, C., R. K. COLWELL, T. L. ERWIN, D. D. MURPHY, R. F. NOSS, AND M. A. SANJAYAN. 1993. Terrestrial arthropod assemblages: their use in conservation planning. Conserv. Biol. 7: 796-808.

LENSKI, R. E. 1982. The impact of forest cutting on the diversity of ground beetles (Coleoptera: Carabidae) in the southern Appalachians. Ecol. Entomol. 7: 385-390.

MUELLER-DOMBOIS, D., AND H. ELLENBERG. 1974. Aims and Methods of Vegetation Ecology. Wiley, New York.

MYERS, R. L. 1990. Scrub and high pine, pp. 150-193 *in* R. L. Myers, and J. J. Ewel [eds.]. Ecosystems of Florida. University of Central Florida Press, Orlando.

NIEMELA, J., Y. HAILA, E. HALME, T. LAJTI, T. PAJUNEN, AND P. PUNTTILA. 1988. The distribution of carabid beetles in fragments of old coniferous taiga and adjacent managed forests. Annales Zoologici Fennici 25: 107-119.

NIEMELA, J., D. LANGOR, AND J. R. SPENCE. 1993. Effects of clearcut harvesting on boreal ground-beetle assemblages (Coleoptera: Carabidae) in western Canada. Conserv. Biol. 7: 551-561.

OUTCALT, K. W. 1990. Operational trials of a scarifier-seeder for regenerating Ocala sand pine. South J. Appl. For. 14: 85-88.

RAWLINGS, M. K. 1933. South Moon Under. Scribners, New York.

REFSETH, D. 1980. Ecological analyses of carabid communities—potential use in biological classification for nature conservation. Biol. Conserv. 17: 131-141.

SAS INSTITUTE. 1989. SAS User's Guide: Statistics, Version 6, Fourth edition SAS Institute, Cary, North Carolina.

SCHMALZER, P. A., AND C. R. HINKLE. 1992. Recovery of oak-saw palmetto scrub after fire. Castanea 57: 158-173.

THOMAS, M. C. 1991. Rediscovery of *Romulus globosus* Knull (Coleoptera: Cerambycidae). Insecta Mundi 5: 127-128.

WEBBER, H. J. 1935. The Florida scrub, a fire fighting association. American J. Botany 22: 344-361.

WOODRUFF, R. E. 1973. The scarab beetles of Florida (Coleoptera: Scarabaeidae), part 1. The Laparosticti (Subfamilies: Scarabaenae, Aphodiinae, Hybosorinae, Ochodaeinae, Geotrupinae, Acanthocerinae). Florida Department of Agriculture, Division of Plant Industry. Arthropods of Florida and Neighboring Land Areas vol. 8.