SMALL MAMMAL COMMUNITIES ASSOCIATED WITH PINE PLANTATION MANAGEMENT OF POCOSINS

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Abstract: To assess how habitat alterations can affect community structure, we compared small mammal populations in undisturbed pocosins with those in pocosins managed as pine (*Pinus* spp.) plantations. We used snap traps and pitfalls to sample small mammals in 3 pine plantations and 2 undisturbed pocosin habitat types in eastern North Carolina from May 1991 to May 1992. Small mammal community composition differed ($P < 0.001$) among the 5 habitats, largely due to the presence in young and thinned pine stands of pioneering species (least shrew [*Cryptotis parva*], house mouse [*Mus musculus*], rice rat [*Oryzomys palustris*], cotton rat [*Sigmodon hispidus*]) that are uncharacteristic of pocosins. We could not detect ($P > 0.05$) an effect of plantation management on species associated with pocosins (short-tailed shrew [*Blarina brevicauda*], southeastern shrew [*Sorex longirostris*], cotton mouse [*Peromyscus gossypinus*], golden mouse [*Ochrotomys nuttalli*], white-footed mouse [*P. leucopus*]), possibly because pocosin-like habitat persisted in managed stands. Alternatively, the study design may have lacked statistical power to detect negative responses to disturbance evident in capture trends for these species. We hypothesize that management-related disturbance causes short-term declines or local extinctions of some small mammals, associated with pocosins, which later recover or recolonize. To minimize small mammal community changes associated with disturbance, we recommend managing habitat structure in pine plantations to emulate habitat of undisturbed pocosins.

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Pocosins are freshwater wetlands found on the Coastal Plain of the southeastern United States and are characterized by overstories of pond pine (*Pinus serotina*) and loblolly bay (*Gordonia lasianthus*) and dense understories of shrubs and vines growing on raised bogs of acidic, nutrient-poor, peat soils. Biomass of aboveground vegetation varies between oligotrophic and eutrophic extremes referred to as short and tall pocosins, respectively (Sharitz and Gibbons 1982, Christensen et al. 1988). Pocosin fauna has received little study (Wilbur 1981), but Clark et al. (1985) described high species diversity and low population densities across a spectrum of pocosin-like wetlands, although most species occurred irregularly or in association with edges.

As of 1979, 44% of all habitat classified as pocosin, ranging from undisturbed pocosins to pine plantations modified for pulp and timber production, was owned by timber companies (Richardson 1981). Modifications for pine plantation management include draining, bedding (using heavy machinery to create parallel ridges and furrows for planting and water management), fertilizing, managing fire, and high density planting and short rotation management of loblolly pine (*P. taeda*; Campbell and Hughes 1981). Net effects of these practices on small mammal communities are unknown. In other systems, seral changes in mammal communities in pine plantations were similar to those in natural stands, although occurring at an accelerated pace (Atkeson 1974, Langley and Shure 1980, Mengak et al. 1989).

We evaluated changes in small mammal communities associated with disturbed (i.e., managed pine plantations) and undisturbed pocosins. We hypothesized that changes in habitat structure imposed by management would change small mammal communities, and we expected that changes during the course of a timber rotation would be analogous to those that occur during old field succession (Atkeson 1974, Langley and Shure 1980, Mengak et al. 1989). Because successional development of pine plantations does not parallel pocosin seral stages (Christensen et al. 1988), we were uncertain

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how pocosin small mammals would respond to disturbance caused by timber management.

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STUDY AREA

We sampled managed stands on Weyerhaeuser Company property and undisturbed pocosins in the Croatan National Forest in eastern North Carolina. We selected managed stands to represent progression of a pine plantation through a rotation, highlighting points thought to be critical to wildlife community composition: (1) 2–5-year-old stands with open canopies, (2) unthinned 9–11-year-old stands with closed canopies, and (3) commercially thinned 18–21-year-old stands. Undisturbed stands were selected short and tall pocosins. All stands were geographically isolated by ≥500 m and were ≥34 ha.

METHODS

We replicated each treatment (open canopy, closed canopy, thinned pine plantations, short and tall pocosins) 3 times for 15 stands. Homogeneity of habitat structure within selected stands permitted a systematic sampling scheme for trapping and macrohabitat sampling. We placed a 1,000-m transect in the interior of each stand, and established 10 reference points at 100-m intervals along each transect. We maintained a 100-m buffer between all reference points and habitat edge (subjectively determined).

Habitat

To distinguish treatments, develop small mammal-habitat associations, and determine how differences in habitat among treatments might be responsible for observed differences in small mammal communities, we sampled several habitat variables. We performed sampling in 5 circular plots perpendicularly offset 10 m from even-numbered reference points along each transect. We assessed the following overstory variables from stems >5 cm diameter at breast height (dbh) in 0.03-ha plots: (1) species, (2) density (stems/ha), and (3) percent canopy closure (measured with a spherical densiometer). To characterize the understory, we recorded species and visually estimated percent cover of shrubs (woody stems <5 cm dbh) and herbaceous cover in 28- and 7-m^2 plots, respectively, centered in overstory plots. Additionally, we measured density of large, downed woody material (logs >7.5-cm diam) in 28-m^2 circular plots, density of small downed woody material (sticks 2.5–7.5-cm diam) in 7-m^2 circular plots, and litter depth at each reference point (Brown 1974).

We averaged observations within a stand to provide variable estimates for each stand, with $n = 15$ for each variable. We evaluated differences in habitat structure among treatments with 1-way analysis of variance (ANOVA) tests (stand [treatment]) to compare vegetation data at $P = 0.05$ (SAS Inst. Inc. 1990). We identified treatments with different ($P < 0.05$) habitat variables by least significant difference means separation.

Small Mammals

We sampled small mammals during 18 May–29 June 1991, 1–20 February 1992, and 4–29 May 1992. During each period, we set 100 snap traps in each stand. We laid 5 100-m trap lines parallel to the transect beginning with each odd-numbered reference point. Each trap line had 20 paired snap traps (1 museum special and 1 rat trap) set at 10-m intervals and baited with peanut butter, rolled oats, and raisins. We trapped over 5 consecutive nights in each stand.

We buried a pitfall trap, consisting of a 3.8-L can with a punctured bottom, flush with the ground at both ends of each 100-m snap trap line. Because of low pitfall capture rates during the first 2 trapping periods, we added a new array consisting of 2 buried 20-L buckets spaced 10 m apart connected by a drift fence of aluminum flashing for the third period. We tended pitfalls for 7 consecutive nights in each stand (70 pitfall nights, periods 1 and 2; 84 pitfall nights, period 3).

During the third trapping period, 400 snap trap nights and 48 pitfall nights were lost to a wild fire that burned 1 short pocosin stand while traps were in place. Capture numbers for this stand were proportionally adjusted to keep capture effort comparable across all stands.

Table 1. Mean values for herbaceous plant cover, shrub cover, canopy closure, tree stem density (stems/ha), downed woody material (no./plot), and litter depth for pine plantations (3 stands each) and pocosin (3 each) habitats in eastern North Carolina, 1992.

	Pine plantation[a]						Pocosin[b]					
	Open canopy		Closed canopy		Thinned		Short		Tall			
Variable	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	F[c]	P
Herbaceous cover (%)	48.0A[d]	25.3	14.7B	16.6	22.5B	22.1	15.8B	7.8	2.9C	4.3	5.9	0.01
Shrub cover (%)	56.0	26.3	58.5	22.1	58.9	25.9	97.7	3.2	67.0	28.2	2.6	0.10
Canopy closure (%)	11.0B	19.7	97.9A	1.2	90.8A	9.0	3.7B	7.2	97.4A	5.4	208.8	0.00
Stems/ha	0.2D	0.4	45.5B	9.0	18.6C	8.6	7.9CD	5.0	62.1A	34.5	56.4	0.00
No. sticks 2.5–7.5 cm	3.9A	2.6	0.2B	0.4	2.7A	3.5	0.0B	0.0	1.6A	3.7	5.5	0.01
No. logs >7.5 cm	5.3A	6.1	0.2B	0.6	1.1B	2.0	0.2B	0.5	1.7B	2.1	4.8	0.02
Litter depth (cm)	1.3A	1.4	4.6B	2.1	4.5B	2.1	4.5B	1.4	6.6C	3.3	16.8	0.00

[a] Pine plantation treatments: open canopy = stands 2–5 yr old, closed canopy = stands 9–11 yr old, thinned = commercially thinned stands 18–21 yr old.
[b] Pocosin treatments: short and tall denote oligotrophic and eutrophic structural extremes, respectively.
[c] ANOVA F-values (4, 10 df) for comparisons across 5 treatments.
[d] Means followed by the same letter within a row are not different (LSD separation, $P > 0.05$).

We averaged total captures (pitfall and snap trap combined) by treatment over the 3 field seasons. Because capture rates were too low to estimate capture probabilities (and therefore abundance) by species for each treatment, we used mean total captures of each species within a stand (resulting from equal sampling effort) as an index of abundance (Lancia et al. 1994: 219). Therefore, we assumed that capture probabilities were equal within each species across all stands. Because of the depauperate small mammal populations associated with pocosins (Clark et al. 1985), no technique is likely to produce sufficient captures to enable estimates of capture probabilities (Lancia et al. 1994). To describe the structure of small mammal communities in each treatment, we used total species captured (S) and the Shannon-Wiener diversity index (H'; Hair 1980). We rank-transformed (Lehmann 1975) total captures, S, and H' for analysis to avoid making normal theory assumptions.

To test for differences in small mammal community composition across treatments, we used multivariate analysis of variance (MANOVA; SAS Inst. Inc. 1990) of total captures to evaluate relative distribution of all species among treatments (open canopy, closed canopy, thinned pine plantations, short and tall pocosins). To clarify community differences suggested by MANOVA and to identify species whose relative abundance among treatments could underlie these differences, we evaluated S, H', and total captures for each species with a Kruskal-Wallis test ($P = 0.05$; SAS Inst. Inc. 1990). We identified different treatments by least significant difference means separation. To determine how habitat structure might account for differences in small mammal communities among treatments, we evaluated relationships between diversity indices and habitat structure with the Kendall Tau-b test for correlation (SAS Inst. Inc. 1990). We also used Kendall's Tau-b correlations between total captures and habitat structure to evaluate habitat associations of species showing a preference for a treatment.

RESULTS

Habitat

Herb cover varied within and among treatments. Herbaceous vegetation was predominant only in the open-canopy pine plantations, which differed from other habitats in herbaceous plant cover (Table 1). Thinned plantations tended to have relatively high herbaceous plant cover, but did not differ from closed-canopy plantations. Herbaceous vegetation was sparse in undisturbed pocosins (Table 1).

Shrub layers were also variable among and within treatments. Differences among shrub cover estimates appeared great, but differed only at $P = 0.10$ (Table 1). In open-canopy plantations, rapid shrub growth was changing midstory structure. Shrub cover for all closed-canopy plantations was patchy, whereas shrub

Table 2. Mean total captures of small mammal species and observed species richness (*S*) and diversity (*H'*) in pine plantation (3 stands each) and pocosin (3 each) habitats over 3 field seasons, eastern North Carolina, 1991–92.

	Pine plantation[a]						Pocosin[b]				
	Open canopy		Closed canopy		Thinned		Short		Tall		
Species or index	$\bar{x}$[c]	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	P[d]
Least shrew	2.22A[e]	2.99	0.00B	0.00	0.00B	0.00	0.00	0.00	0.00B	0.00	0.00
Southeastern shrew	0.89	0.69	2.11	1.07	1.78	1.71	5.11	1.26	2.11	3.10	0.18
Short-tailed shrew	1.55	1.07	2.00	3.46	1.67	2.33	2.11	1.35	0.55	0.38	0.70
House mouse	1.56A	1.35	0.00B	0.00	0.00B	0.00	0.00B	0.00	0.00B	0.00	0.00
Eastern harvest mouse	7.67A	1.67	0.22B	0.38	3.22AB	3.75	2.33AB	3.48	0.00B	0.00	0.03
White-footed mouse	0.44	0.77	0.00	0.00	1.33	2.31	2.22	3.27	0.11	0.19	0.24
Cotton mouse	0.00	0.00	1.67	2.89	1.89	1.84	0.00	0.00	5.33	6.11	0.27
Golden mouse	2.22	3.02	3.78	2.14	3.00	3.00	4.44	3.02	8.78	4.34	0.42
Pine vole	0.00	0.00	0.00	0.00	0.00	0.00	1.33	2.31	0.00	0.00	nt[f]
Rice rat	1.11A	0.77	0.22B	0.38	0.11B	0.19	0.00B	0.00	0.00B	0.00	0.01
Cotton rat	20.67A	16.52	0.22B	0.38	6.11A	7.07	0.00B	0.00	0.00B	0.00	0.00
Southern bog lemming	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.58	0.33	0.58	nt
S	5.20A	0.88	2.20B	1.35	4.00AB	1.5	4.10AB	1.39	2.70B	0.35	0.06
H'	1.07	0.08	0.47	0.35	0.91	0.53	1.1	0.37	0.65	0.09	0.12

[a] Pine plantation treatments: open canopy = stands 2–5 yr old, closed canopy = stands 9–11 yr old, thinned = commercially thinned stands 18–21 yr old.
[b] Pocosin treatments: short and tall denote oligotrophic and eutrophic structural extremes, respectively.
[c] Treatment means presented, comparisons performed on ranked means.
[d] *P*-values for Kruskal-Wallis tests across 5 treatments.
[e] Means followed by the same letters within a row are not different (LSD separation, $P > 0.05$).
[f] nt = not tested because of insufficient captures.

growth in thinned stands was concentrated along clear-cut rows. Shrub cover was uniformly high and impenetrable in short pocosins but variable in tall pocosins.

Overstories of pine plantations were dominated by loblolly pines, although bottomland hardwoods persisted along windrows and ditches. All overstory trees in short pocosin stands were pond pines, whereas the overstory of tall pocosins was dominated by pond pine and loblolly bay. Canopy closure and stem density were high in tall pocosin, closed-canopy, and thinned pine plantation treatments. Midrotation thinning altered the overstory of thinned pine plantations, resulting in fewer, although larger, stems per ha than in younger closed-canopy plantations. Because short pocosin stands had little overstory, stem density and canopy closure were lowest for this treatment (Table 1).

Downed woody material was most prominent in pine plantations with a recent history of thinning or harvest and in tall pocosins (Table 1). The number of large logs was highest in open-canopy pine plantations, whereas tall pocosins and open-canopy and thinned plantations had more small sticks than did closed-canopy plantations and short pocosins. Litter depth was lowest in open-canopy stands and highest in tall pocosins, but nearly equal among the 3 other treatments.

Small Mammal Trapping

We captured 803 small mammals representing 12 species in snap traps and 126 small mammals of 7 species in pitfalls (Table 2). Overall capture success was 2.5, 2.1, and 6.5%, respectively, in the 3 trapping periods.

The relative distribution of small mammal species, and hence community composition, varied among treatments (MANOVA Wilk's λ, $F = 19.87$, 40 df, $P < 0.001$). Species diversity (H') did not differ among treatments, although richness (S) approached significance ($P = 0.05$) with undisturbed pocosins and open-canopy pine plantations having the greatest richness (Table 2). Both indices were negatively correlated with stem density and canopy closure (Table 3).

Eleven species were captured in sufficient numbers to warrant analyses (Table 2). Captures of only least shrews, house mice, eastern harvest mice (*Reithrodontomys humulis*), rice rats, and cotton rats differed among treatments. These species were all found either primarily or exclusively in pine plantation stands with dense

Table 3. Kendall's Tau-b (τ_b) correlations of selected[a] small mammal captures and species diversity indices with habitat structure from pine plantation and undisturbed pocosin habitats, eastern North Carolina, 1991–92.

Species or Index	Macrohabitat variables[b]											
	Stems/ha		Herbaceous cover (%)		Canopy closure (%)		No. logs >7.5 cm		No. sticks 2.5–7.5 cm		Litter depth (cm)	
	τ_b	P	τ_b	P	τ_b	P	τ_b	P	τ_b	P	τ_b	P
Least shrew	−0.52	0.02	0.58	0.01			0.53	0.02			−0.55	0.02
House mouse	−0.52	0.02	0.58	0.01			0.53	0.02			−0.55	0.01
Eastern harvest mouse	−0.63	0.00									−0.50	0.01
Rice rat	−0.45	0.36									−0.66	0.00
Cotton rat	−0.41	0.46	0.48	0.02					0.46	0.03	−0.50	0.15
S[c]	−0.54	0.01			−0.41	0.04						
H'[d]	−0.46	0.02			−0.40	0.04						

[a] Analysis performed only on species with treatment preferences ($P < 0.05$).
[b] Shrub cover did not differ ($P > 0.05$) among treatments and was not included in analyses.
[c] Species richness.
[d] Shannon-Wiener species diversity index.

understory vegetation. One exception was the eastern harvest mouse, which was commonly caught (19 captures) in 1 short pocosin stand. This stand differed from other short pocosins because it contained harvest mice and pine voles (*Microtus pinetorum*; 12 captures), species more commonly associated with old field or agricultural habitats (Smolen 1981, Cawthorn and Rose 1989).

Capture numbers for all early successional species were associated with values for habitat variables that distinguished the open-canopy pine plantations from other treatments. Each was negatively correlated with stem density and litter depth (Table 3). Capture numbers for cotton rats, least shrews, and house mice were positively correlated with herbaceous cover; all species except rice rats and eastern harvest mice were positively correlated with downed woody material >7.5 cm in diameter (Table 3).

DISCUSSION

Pine plantation management results in small mammal communities distinct from those in undisturbed pocosins. This effect can be attributed to dense ground vegetation in recently disturbed pine stands. All small mammal species showing a treatment preference were pioneering species captured in open-canopy or thinned plantations, but were not found in undisturbed pocosins. The relative abundance of each of these species was associated with habitat characteristics prevalent in young, open-canopy pine plantations (e.g., low stem density, high herbaceous cover, minimal litter depth).

The succession of small mammal species through a pine stand's development was analogous to old field succession, supporting conclusions of previous studies (Atkeson 1974, Langley and Shure 1980, Mengak et al. 1989). Pioneering species invaded newly established pine stands and persisted as long as the overstory was open and the understory was dominated by dense herbaceous cover. In pine plantations with complete canopy closure, the characteristic tall pocosin species were most prevalent, found in apparently the same abundance and density as in undisturbed stands.

There was a departure from the old field succession pattern in thinned pine plantations. Thinned stands were the most structurally complex among the treatments, exhibiting substantial growth of shrubby and herbaceous vegetation under the long, regularly distributed canopy openings created by thinning. The habitat sampling protocol we employed, although appropriate for homogenous stands in the other treatments, was probably insufficient to characterize habitat in thinned plantations. However, the apparent interspersion of early-, mid-, and late-successional vegetation provided habitat for some pioneering species that disappeared with canopy closure. The presence of cotton rats and eastern harvest mice in thinned stands, co-existing with cotton mice and golden mice normally found under closed canopies, resulted in diverse small mammal communities.

Because captures for none of the species characteristic of undisturbed pocosins differed among treatments, management apparently has little adverse effect. This may be because all mice common to pocosins are ecological generalists

(Linzey and Packard 1977, Wolfe and Linzey 1977, Lackey et al. 1985). The rapid recovery of shrubs in plantations following disturbance and their persistence under a closed canopy probably provided habitat for semiarboreal species throughout stand rotation. However, declining trends in relative abundance of cotton mice, golden mice, white-footed mice, and southeastern shrews in response to pine plantation management are suggested. These trends may represent biological significance (sensu Tacha et al. 1982) that we could not detect, and could prove statistically significant with more intensive sampling.

Our study design possibly lacked statistical power to detect some differences between undisturbed pocosins and pine plantations. Although there is no practical way to estimate power of a Kruskal-Wallis test (Lehmann 1975), the possibility of insufficient power is reasonable because adding invading species to a community without displacing the original inhabitants should result in higher species richness and diversity. Conclusions about effects of pine plantation management on pocosin small mammals should therefore be conservative. However, we hypothesize that management-related disturbance probably results in the decline or local disappearance of pocosin small mammal populations, which later recover or recolonize.

Because of insufficient captures we could not evaluate effects of management on the southern bog lemming (*Synaptomys cooperi*) caught only in undisturbed pocosins. However, this is the first evidence that southern bog lemmings inhabit pocosins and can be found as far south as central North Carolina (Clark et al. 1993). We speculate that bog lemmings, a species that is associated with the sphagnum bog habitat (Linzey 1983) that is most prevalent in short pocosins, could be adversely affected by disturbance of pocosins.

MANAGEMENT IMPLICATIONS

Timber management alters pocosin small mammal communities, for at least as long as dense ground vegetation is present in managed pine stands. The influx of uncharacteristic, pioneering small mammals in recently disturbed pocosins represents the most prominent management effect we observed. To mitigate this, we recommend managing pine plantations to emulate undisturbed pocosins as much as possible by suppressing herbaceous vegetation and releasing native shrub species following disturbance. These practices will maintain the structural analogies of open-canopy pine stands to short pocosin and closed-canopy pine stands to tall pocosin, and will likely provide sufficient habitat for most pocosin small mammals. This management approach is supported by our observations in 2 pine plantations (1 open canopy, 1 thinned) where habitat structure and small mammal communities resembled those in undisturbed pocosins more than those in treatment replicates (Mitchell 1992).

Managing pine plantations to emulate pocosins will result in relatively depauperate small mammal communities, which may seem counter to notions of biodiversity management. We suggest that the integrity of an ecological community is a more appropriate measure of biodiversity than simple species richness. The merit of adding disturbance-associated species to increase diversity in a normally depauperate community is questionable.

If, as we hypothesize, pocosin small mammals decline or disappear following disturbance and then rapidly recolonize, the re-establishment of these species in recently disturbed plantations is dependent upon the proximity and dispersion of source populations (Pulliam 1988). We recommend landscape-scale research to investigate how interspersion of pine plantations and undisturbed pocosins affects the demography of local small mammal populations.

LITERATURE CITED

ATKESON, T. D. 1974. Succession of small mammals on pine plantations in the Georgia Piedmont. M.S. Thesis, Univ. Georgia, Athens. 66pp.

BROWN, J. K. 1974. Handbook for inventorying downed woody material. U.S. For. Serv. Intermt. For. and Range Exp. Stn., Ogden, Ut. 24pp.

CAMPBELL, R. G., AND J. H. HUGHES. 1981. Forest management systems in North Carolina pocosins: Weyerhaeuser. Pages 199–213 *in* C. J. Richardson, ed. Pocosin wetlands: an integrated analysis of Coastal Plain freshwater bogs in North Carolina. Hutchinson Ross Publ. Co., Stroudsburg, Pa.

CAWTHORN, J. M., AND R. K. ROSE. 1989. The population ecology of the eastern harvest mouse (*Reithrodontomys humulis*) in southeastern Virginia. Am. Mid. Nat. 122:1–10.

CHRISTENSEN, N. L., R. B. WILBUR, AND J. S. MCLEAN. 1988. Soil-vegetation correlations in the pocosins of Croatan National Forest, North Carolina. U.S. Fish and Wildl. Serv. Biol. Rep. 88(28). 97pp.

CLARK, M. K., D. S. LEE, AND J. B. FUNDERBURG, JR. 1985. The mammal fauna of Carolina bays, pocosins, and associated communities in North Carolina: an overview. Brimleyana 11:1–38.

———, M. S. MITCHELL, AND K. S. KARRIKER. 1993. Notes on the geographical and ecological distribution of relict populations of *Synaptomys cooperi* (Rodentia: Arvicolidae), from eastern North Carolina. Brimleyana 19:155–167.

HAIR, J. D. 1980. Measurement of ecological diversity. Pages 269–276 *in* S. D. Schemnitz, ed. Wildlife management techniques manual. The Wildl. Soc., Washington, D.C. 686pp.

LACKEY, J. A., D. G. HUCKABY, AND B. G. ORMISTON. 1985. *Peromyscus leucopus*. Mamm. Species 247: 1–10.

LANCIA, R. A., J. D. NICHOLS, AND K. H. POLLOCK. 1994. Estimating the number of animals in wildlife populations. Pages 215–253 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitat. Fifth ed. The Wildl. Soc., Bethesda, Md. 740pp.

LANGLEY, A. K., JR., AND D. J. SHURE. 1980. The effects of loblolly pine plantations on small mammal populations. Am. Midl. Nat. 103:59–65.

LEHMANN, E. L. 1975. Nonparametrics: statistical methods based on ranks. Holden-Day, San Francisco, Calif. 457pp.

LINZEY, A. V. 1983. *Synaptomys cooperi*. Mamm. Species 210:1–5.

LINZEY, D. W., AND R. L. PACKARD. 1977. *Ochrotomys nuttalli*. Mamm. Species 75:1–6.

MENGAK, M. T., D. C. GUYNN, JR., AND J. GIBSON. 1989. Ecological implications of loblolly pine regeneration for small mammal communities. For. Sci. 35:503–514.

MITCHELL, M. S. 1992. Effects of intensive forest management on the mammal communities of selected North Carolina pocosin habitats. M.S. Thesis, North Carolina State Univ., Raleigh. 147pp.

PULLIAM, H. R. 1988. Sources and sinks, and population regulation. Am. Nat. 132:652–661.

RICHARDSON, C. J. 1981. Pocosins: an ecosystem in transition. Pages 3–19 *in* C. J. Richardson, ed. Pocosin wetlands: an integrated analysis of Coastal Plain freshwater bogs in North Carolina. Hutchinson Ross Publ. Co., Stroudsburg, Pa.

SAS INSTITUTE INC. 1990. SAS procedures guide. Version 6. SAS Inst. Inc., Cary, N.C. 705pp.

SHARITZ, R. R., AND J. W. GIBBONS. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. U.S. Fish and Wildl. Serv., FWS/OBS-82/04, 93pp.

SMOLEN, M. J. 1981. *Microtus pinetorum*. Mamm. Species 147:1–7.

TACHA, T. C., W. C. WARDE, AND K. P. BURNHAM. 1982. Use and interpretation of statistics in wildlife journals. Wildl. Soc. Bull. 10:355–362.

WILBUR, H. 1981. Pocosin fauna. Pages 62–68 *in* C. J. Richardson, ed. Pocosin wetlands: an integrated analysis of Coastal Plain freshwater bogs in North Carolina. Hutchinson Ross Publ. Co., Stroudsburg, Pa.

WOLFE, J. L., AND A. V. LINZEY. 1977. *Peromyscus gossypinus*. Mamm. Species 70:1–5.

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