Deer in Pocosin Habitat after Catastrophic Wildfire

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Abstract: Pocosins are peat bogs that support dense, evergreen shrub cover providing abundant, low-quality browse for white-tailed deer (*Odocoileus virginianus*). This habitat type is subject to infrequent, intense wildfires, and in May 1986 a wildfire burned across 18,200 ha (>90%) of the Holly Shelter Game Land in eastern North Carolina. We studied the response of the deer population to the fire by comparing pre- and postfire data on density, harvest, physical condition, and nutrition. We also analyzed nutritional quality of browse samples from burned and unburned areas for 2 years after the fire. Browse quality was higher in burned areas in the year of the fire, but differences were short-lived and were not reflected in protein levels of rumen contents. Deer density and harvest declined by about 60% the first fall after the fire probably because deer were temporarily displaced from the area. Only 36 deer were found dead during thorough postfire searches. There were apparent improvements in deer body mass and condition, but these effects were subtle or temporary. Density, condition, and harvest returned to prefire levels within 3 years.

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Deer populations in infertile forest habitats in the Southeast often respond poorly to management practices directed toward reducing deer numbers and increasing browse availability. Browse quality and fluctuating food supplies, such as acorns, override density-dependent habitat relationships (Osborne 1976, Johnson et al. 1986, Wentworth et al. 1990, 1992; Shea et al. 1992, Osborne et al. 1992). In such habitats, leaves of deciduous woody plants are the primary foods during the growing season (Harlow and Hooper 1971, Wentworth et al. 1990, Osborne et al. 1992) and provide the most nutritious forage. Leaves of broadleaf, evergreen woody plants dominate the winter diet when mast is not available (Wentworth et al. 1990, Osborne et al. 1992), and generally are of low nutritional quality (Garner 1987, Wentworth et al. 1990). However, acorns, in varying quantities, are nearly always available to deer in fall and can influence deer condition, reproduction, and population dynamics (Harlow and Jones 1965, Wentworth et al. 1990, 1992; Osborne et al. 1992). In pocosins, levels of foliar nutrients are extremely low (Wells 1946, Smith et al. 1956), acorns are not available in significant quantity, deciduous woody plants are not abundant, but evergreen browse is. This situation provides an opportunity to study deer performance on a diet of low quality broadleaf evergreen leaves in the absence of acorns.

Pocosins also experience intense wildfires at infrequent intervals, resulting in a sudden release of nutrients tied up in the vegetation. Pocosins, therefore, provide an extreme situation in which to study the effects of fire on browse quality and deer populations.

An intense fire burned over a large pocosin in North Carolina in spring 1986, killing much of the vegetation. We selected this area (1) to examine nutritional-habitat relationships in an environment with abundant low-quality forage and relatively few acorns or other high energy foods and, (2) to monitor the response of browse quality and the number and quality of deer to a catastrophic wildfire.

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Background and Study Area Description

Pocosin habitats in general are described by Christensen et al. (1981), Sharitz and Gibbons (1982), and Ash et al. (1983). Pocosins are saturated peat bogs, often elevated above the surrounding land and, therefore, have low nutrient input. Soils are infertile and very acid (pH <4.0). Many woody plant species associated with these habitats have thick, leathery leaves and are evergreen. The foliage is typically low in nutrients and digestibility and may be high in tannins and other defensive compounds. Vast, dense thickets of shrubs and vines provide a year-round abundance of low-quality browse for deer. Production of acorns (*Quercus* spp.) is restricted to marginal sand ridges or alluvial swamps. Therefore, mast available in pocosins is mainly soft fruits of the genera *Ilex, Nyssa,* and *Smilax.*

The study area, Holly Shelter Game Land, is a 19,747-ha area in Pender County, North Carolina. Holly Shelter is 80%–90% pocosin habitat with adjacent sandy pine savannahs. Several Carolina bays, with vegetation similar to pocosins, are superimposed on these habitats. At the time of the study, vegetation was mainly extensive, almost impenetrable shrub thickets with scattered pond pine (*Pinus serotina*) and bay trees (*Gordonia lasianthus, Magnolia virginiana,* and *Persea borbonia*). Predominant evergreen shrubs and vines were large gallberry (*Ilex coriacea*), small gallberry (*I. glabra*), laurel greenbrier (*Smilax laurifolia*), and fetterbush (*Lyonia lucida*). Swamp cyrilla (*Cyrilla racemiflora*), which dominated large portions of the area, is tardily deciduous and is often available to deer until late in the winter. The most common deciduous shrubs were honeycup (*Zenobia pulverulenta*) and sweet pepperbush (*Clethra alnifolia*).

The Holly Shelter area was acquired by the North Carolina Wildlife Resources Commission (NCWRC) in 1939. Wells (1946) mapped and described its vegetation in 1945, at which time most of the area was dominated by swamp cyrilla (32% coverage) and honeycup (28%). The NCWRC conducted a study of deer diet and nutrition on the area from 1944–1947. The study showed swamp cyrilla dominated the diet in all seasons (55%–82%) and browse was deficient in protein, phosphorus, and cobalt (NCWRC unpubl. data and Smith et al. 1956).

Over the next 40 years occasional light fires burned relatively small portions of the area. Although honeycup has a shallow root system and is favored by light fires (Wells 1946), it declined to uncommon status. A decade of drought resulted in several large pocosin fires in eastern North Carolina in the 1980s including 1 of 38,305 ha centered on the Pungo National Wildlife Refuge in April 1985 (Osborne et al. 1986). In May 1986 about 18,200 ha (>90%) of the Holly Shelter Game Land was burned during the most intense fire to occur there in >70 years. It burned almost all above-ground vegetation in the pocosin habitat, and burned as deep as 1 m into the peat, killing root systems of most plants in some areas.

Methods

Systematic helicopter surveys were conducted by NCWRC personnel in late May and early June 1986 to assess mortality of deer and other wildlife. Aerial surveys were supplemented by spot checks on the ground. The effectiveness of helicopter surveys in detecting deer mortality after intense fire in pocosin habitat had been demonstrated on Pungo National Wildlife Refuge the previous year (Osborne et al. 1986).

We collected leaves from important woody species each September and February for 2 years following the fire (September 1986–February 1988). Samples were collected in 3 disjunct sites in burned and unburned portions of the pocosin. Composite samples of about 300 g of current year leaves were obtained at each site and analyzed for crude protein, calcium, and phosphorus by standard methods (Williams

1984). Dry matter digestibility of swamp cyrilla was estimated by the cellulase digestion technique (Clarke et al. 1982).

Samples of rumen contents were taken from deer killed by hunters, 1986–1990, and age, weight, antler measurements, and condition were recorded. Condition was rated subjectively on a scale of *1* (no kidney fat) to *4* (kidneys encased in fat). Rumen contents were washed through sieves, sorted, identified, and measured by taxa, as described by Wentworth et al. (1990). Data were summarized by aggregate percent volume. The washed rumen contents were analyzed for crude protein, calcium, and phosphorus as described above.

We analyzed data obtained by the NCWRC before and after the 1986 fire for trends. Abomasal parasite counts (Eve and Kellogg 1977) taken in 7 herd health checks (1976–1990); numbers, weights, and antler measurements of hunter-killed deer during 1983–1990; and data from track counts conducted before and after the 1986 fire were compared. Track counts were conducted in each fall, beginning in 1982, and replicated 3–4 times (except 2 replicates in 1985). Routes totalled 18.3 km (16.4 km in 1989 and 1990) on roads traversing the area.

Because this was a case study of an unpredictable event it could not be experimentally designed. For the most part, data were obtained from hunter-killed deer available in the years before and after the fire. Generally, we judged sample sizes to be too snall and variable for valid statistical tests of differences, thus we only calculated means and standard errors for these data. Comparisons of forage quality between burned and unburned areas, which were sampled by design, were done with 2-sample *t*-tests on square-root transformed data ($P \leq 0.10$).

Results and Discussion

Mortality and population trends.—Aerial and ground surveys revealed 36 deer killed by the 1986 fire, mostly where the headfire met a backfire set by suppression crews. Mortality was estimated at <10% of the population. In contrast, mortality from the Pungo fire was thought to be higher (10%–20%) because the peat substrate continued to burn for more than 3 weeks causing injuries and infections resulting in much secondary mortality. The Holly Shelter fire was extinguished by heavy rains within a few days.

Despite apparent low mortality, few deer were seen in subsequent aerial surveys or by hunters in fall 1986 (Table 1). Public pressure resulted in cancellation of a scheduled antlerless deer hunt. Before the fire, the track-count index had declined steadily for 4 years, dropping from an average of 12.1 tracks per km in 1982 to 8.6 in 1985 (Table 1). The index in the fall of 1986, after the fire, was 59% lower than in 1985 and 71% lower than in 1982. By 1988, track-counts had returned to the 1985 level. This evidence indicates that, although mortality was low, there was a substantial reduction in the number of deer on the area after the fire. Apparently, this resulted from dispersal to escape the fire and only gradual reoccupation of the area over the next 6–15 months. Reported harvest in 1987 was comparable to or exceeded prefire levels and remained high through 1990 (Table 1).

Table 1. Numbers of deer harvested and results of early fall track counts, Holly Shelter Game Land, North Carolina, 1979–1990.

Year	Deer harvested			Track count index[a]	
	Bucks	Does	Total	$\bar{x}$	SE
Prefire					
1979	38	5	43		
1980	55	19	74		
1981	60	5	65		
1982	51	7	58	12.1	
1983	48	12	60	10.7	0.08
1984	54	13	67	9.8	1.50
1985	37	17	54	8.6	0.19
Postfire					
1986	20	1[b]	21	3.5	0.98
1987	60	13	73	4.5	0.29
1988	62	13	75	8.9	2.38
1989	64	25	89	12.4	3.18
1990	55	30	85	12.0	3.78

[a]Number of deer crossings/km during a 24-hour period along 18.3 km (16.4 km in 1989 and 1990) of roads traversing the area. Counts were replicated 2–4 times each year.
[b]Antlerless deer hunt was cancelled.

Condition indexes.—Changes in physical quality of deer were not clearly demonstrated because sample sizes were small, especially before the fire. However, there were increases in body mass and antler measurements of harvested deer after the fire, especially in the younger classes (Table 2). Mean condition indices increased from 1.0 in 1983 and 1985 to 2.8 in 1987, declining to 1.7 in 1989 and 1990. Abomasal parasite counts (APC) did not differ greatly among years before and after the fire. The 3 APC's before the fire (1976, 1981, 1983) ranged from 1,390 to 1,010. No APC was made in 1986. Abomasal parasite counts for 1987 and 1988 were 1,472 and 1,363, respectively. They were lowest (896) in 1989, when the harvest and track

Table 2. Mass and antler beam diameters of 1.5-year-old and 2.5-year-old bucks killed by hunters, Holly Shelter Game Land, North Carolina, 1983–1990.

Year	Live mass (kg)						Antler beam diameter (mm)					
	1.5 year olds			2.5 year olds			1.5 year olds			2.5 year olds		
	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE	N	$\bar{x}$	SE
Prefire												
1983	2	29.2	1.13	3	43.9	2.54	0			0		
1985	4	36.4	2.39	4	47.2	1.46	3	12	1.0	4	17	3.3
Postfire												
1987	4	51.8	2.38	7	59.7	2.66	4	15	1.4	7	23	2.5
1988	10	41.7	1.17	10	56.7	1.94	10	12	0.9	10	22	1.2
1989	14	39.5	1.44	3	47.7	2.74	11	12	1.0	3	18	4.4
1990	4	45.9	2.93	6	49.3	3.99	4	16	5.1	8	23	2.7

count indexes indicated that population density was highest, and highest (1,544) in 1990. These values are within a range reported by Eve and Kellogg (1977) for deer populations at or slightly below carrying capacity.

Diet.—The bulk of the fall diet was comprised of very few plant species (Table 3). Diets were similar each year after the fire, except fruits were absent the first fall and peaked at 40% of the aggregate volume in 1988, the third fall after the fire. Laurel greenbrier was the predominant fruit consumed. This trend in soft fruit production following top-kill by fire is typical for the species of shrubs and vines involved (Johnson and Landers 1978). Agricultural crops (mainly corn and soybeans) and acorns together accounted for 16%–32% of the diet in each year. Both of these food types were essentially unavailable in the pocosin proper. They were obtained from around the margins of the pocosin. Neither food type occurred in deer examined in the 1940s (NCWRC unpubl. data), but apparently they now provide a consistent energy supplement in fall to an otherwise low-energy diet. Green leaves and incidentally taken stems comprised a major portion of the diet every year. Swamp cyrilla was the most important single food item in every year except 1988. It averaged 32% of the volume and occurred in 98% of the rumens. Laurel greenbrier was second in importance in its contribution to the leafy portion of the diet and provided the bulk of the fruit in the diet. Together, swamp cyrilla and laurel greenbrier contributed 43%–51% of the diet by volume in each of the 5 years.

The 1944–1947 study and ours showed that deer in this pocosin habitat depend heavily upon swamp cyrilla and laurel greenbrier. Gallberries were the only other species browsed consistently in either study.

Browse quality.—Trends in nutrient levels of important browse species were similar (Table 4). Crude protein content was higher in samples from burned areas than unburned areas the first summer (*Ilex* spp.) and winter (all species) after the fire, but only for swamp cyrilla were differences still evident in the second summer and winter (Table 4). Phosphorus levels were higher in the burned area through the second growing season. A similar trend was apparent for calcium. Both protein and phosphorus were well below the levels reported desirable for weaned fawns (14%–22% and 0.26%, respectively, [Verme and Ullrey 1984]) in all sampling periods. Digestible dry matter of swamp cyrilla, the only species tested, was higher in burned areas of the pocosin in September 1986 ($\bar{x}$ = 45% compared to 38% in unburned areas) but did not differ between burned and unburned areas in February 1987 ($\bar{x}$ = 45% for both areas). Rumen protein and phosphorus content of hunter-killed deer varied among years after the fire (Table 5), and there was no apparent explanation, except that protein was depressed in 1988 because of the large amount of fruit (especially greenbrier, which had a crude protein content of only 5.4%) in the diet (Table 3).

Smith et al. (1956) concluded that protein and phosphorus deficiencies probably limit deer production and quality on the Holly Shelter area. Their values for protein and phosphorus are similar to those reported here for the same species and seasons. However, their values for samples collected in May were much higher, especially for swamp cyrilla and laurel greenbrier.

Modest improvements in the quality of woody plant regrowth after burning are

Table 3. Aggregate percent volume of important food items[a] in the fall diet of white-tailed deer on Holly Shelter Game Land, North Carolina, 1986–1990.

Food item	1986 (N = 4)	1987 (N = 16)	1988 (N = 20)	1989 (N = 35)	1990 (N = 44)	Mean (N = 5 yr)
Leaves and stems						
Cyrilla racemiflora	33.5	35.5	13.0	39.2	41.2	32.5
Smilax spp.	9.3	1.0	2.1	3.6	1.4	3.5
Ilex spp.	2.1	0.1	6.6	2.9	4.2	3.2
Trilisa odoratissima		0.3		5.5	5.2	2.2
Gelsemium sempervirens	7.0	1.3	0.4		0.7	1.9
Sorbus arbutifolia	3.3	3.0	1.7	0.1		1.6
Magnolia virginiana	2.1	0.1	0.6	0.4	1.0	0.8
Polygonum hydropiperoides			4.1			0.8
Rhus spp.	0.8	1.0				0.4
unidentified	4.2	3.7	1.0	4.0	2.5	3.1
Fruit						
Smilax spp.		14.9	33.2	0.2		9.7
Quercus spp.	15.3	0.1	0.1	17.5	11.3	8.9
Ilex spp.		4.7	2.1	3.7	16.4	5.4
Persea borbonia		7.2	8.1	1.9	0.2	3.5
Nyssa sylvatica		9.2		0.6	1.1	2.2
Magnolia virginiana			5.8		0.7	1.3
Cuscuta sp.	4.9		0.1			1.0
Rhus spp.			2.4	0.1	0.1	0.5
Agricultural crops	16.6	15.4	15.4	12.2	8.5	13.6
Fungi	0.5	1.2	2.0	7.6	3.2	2.9
Total	99.6	98.6	98.6	99.5	97.7	98.8

[a] ≥ 1% in any year.

Table 4. Comparisons of mean percent (% dry mass) crude protein, calcium, and phosphorus for leaves of selected browse species from burned and unburned areas of Holly Shelter Game Land, North Carolina, 1986–1988.

Species and	Area burned in May 1986			Unburned area		
sampling date	Protein	Ca	P	Protein	Ca	P
Ilex glabra/coriacea						
Sep 1986	7.5[a]	0.30	0.08[a]	5.6	0.26	0.05
Feb 1987	8.4[a]	0.40[a]	0.10[a]	6.8	0.33	0.07
Sep 1987						
Feb 1988	6.0	0.41[a]	0.07[a]	5.5	0.34	0.06
Cyrilla racemiflora						
Sep 1986	8.5	0.27	0.07[a]	7.0	0.30	0.06
Feb 1987	10.9[a]	0.42	0.09[a]	7.8	0.39	0.07
Sep 1987	8.0[a]	0.41	0.09[a]	6.8	0.30	0.05
Feb 1988	7.7[a]	0.37[a]	0.06	6.3	0.29	0.06
Smilax laurifolia						
Sep 1986	8.1	0.37[a]	0.08[a]	8.0	0.23	0.06
Feb 1987	10.5[a]	0.57[a]	0.10[a]	8.5	0.39	0.09
Sep 1987	7.9	0.45[a]	0.08[a]	8.6	0.35	0.06
Feb 1988	8.0	0.57[a]	0.08	8.9	0.33	0.08

[a] Significantly different ($P \leq 0.10$) from the corresponding value for the unburned area.

Table 5. Protein, calcium, and phosphorus content (% dry mass) of rumen contents from deer killed by hunters, Holly Shelter Game Land, North Carolina.

		Protein		Ca		P	
Year	N	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1986	4	6.8	0.88	0.35	0.068	0.13	0.012
1987	10	7.7	0.44	0.20	0.050	0.21	0.017
1988	5	5.5	0.29	0.16	0.043	0.17	0.008
1989	10	7.1	0.46	0.47	0.023	0.22	0.011
1990	12	9.6	0.46				

well-documented (Stransky and Harlow 1981). In deciduous species these improvements usually persist no longer than the end of the first growing season after burning (Stransky and Harlow 1981). However, elevated protein and phosphorus levels may be detected in leaves of some evergreen species in the second winter after burning (Thackston et al. 1982, Wentworth 1986, Garner 1987).

Conclusions and Management Implications

This study demonstrates the difficulty in detecting responses of deer populations to habitat changes, even those of catastrophic proportions over a large area. Although the survey after the fire indicated low acute mortality, there may have been a substantial, but temporary, reduction in the deer population caused by dispersal after the fire.

There were apparent improvements in mass, antler size, and condition after the fire. This improvement was not attributed to increased browse availability resulting from reduction in deer numbers or change in vegetation structure because there was more than adequate browse before the fire. Increased fruit production following burning was not a factor because mass and condition of deer peaked in the second year, whereas fruit production did not peak until the third. The improvement in forage quality after the fire was brief and could not be detected by chemical analysis of rumen contents. If the response in deer condition resulted from improved forage quality, then where forage quality is very poor, even slight improvements must have a significant effect. Another possible explanation is that deer were forced onto uplands around the pocosin and encountered agricultural crops and feed that landowners supplied especially for deer after the fire. When deer moved back into the pocosin, they modified their home ranges and continued to take advantage of this supplemental food source.

Despite the drastic impact of the fire on habitat density and structure and a temporary but substantial reduction in deer density, probably resulting from dispersal, immediate effects on the deer population were short-lived. Similarly, biologists were unable to detect any significant change in numbers or quality of deer harvested after the 1985 fire on Pungo National Wildlife Refuge, despite the fact that substantial mortality was known to have occurred (Osborne et al. 1986). Infrequent, very intense fires, such as the Holly Shelter and Pungo fires, result in sudden and substantial nutrient release and plant rejuvenation. If improvements in browse quality resulting from intense fires produce insignificant effects on deer quality, then there is cause for serious doubt about benefits to deer from relatively minor habitat manipulations such as prescribed burning in shrub-dominated pocosin. Prescribed burning of this habitat type requires considerable effort and cost and may not be justifiable for the purpose of improving deer habitat.

Long-term effects of this intense peat-consuming fire may be more significant than the short-term effects. Five years after the fire, significant reduction in shrub cover and dense regeneration of pond pine were evident in some areas. Destruction of root systems of shrubs, reduction of the peat layer and consequent changes in hydrology and future fire-susceptibility, and shading of shrubs by dense pond pine may have significant, but as yet unpredictable, effects on deer populations in the future.

Literature Cited

Ash, A. N., C. B. McDonald, E. S. Kane, and C. A. Pories. 1983. Natural and modified pocosins: literature synthesis and management options. U.S. Fish and Wildl. Serv. FWS/OBS-83/04. 156pp.

Christensen, N. L., R. B. Burchell, A. Liggett, and E. L. Simms. 1981. The structure and development of pocosin vegetation. Pages 43–61 *in* C. J. Richardson, ed. Pocosin wetlands. Hutchinson Ross Publ. Co., Stroudsburg, Pa.

Clarke, T., P. C. Flinn, and A. A. McGowan. 1982. Low-cost pepsin-cellulase assays for prediction of digestibility of herbage. Grass and Forage Sci. 37:147–150.

Eve, J. H. and F. E. Kellogg. 1977. Management implications of abomasal parasites in southeastern white-tailed deer. J. Wildl. Manage. 41:169–177.

Garner, J. A. 1987. Chemical composition of broadleaved evergreens in the Georgia flatwoods during winter. M.S. Thesis, Univ. Georgia, Athens. 67pp.

Harlow, R. F. and F. K. Jones, Jr. 1965. The white-tailed deer in Florida. Fla. Game and Fresh Water Fish Comm. Tech. Bul. 9. 240pp.

——— and R. G. Hooper. 1971. Forages eaten by deer in the Southeast. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 25:18–46.

Johnson, A. S. and J. L. Landers. 1978. Fruit production in slash pine plantations in Georgia. J. Wildl. Manage. 42:606–613.

———, P. E. Hale, J. M. Wentworth, and J. S. Osborne. 1986. Are we really managing deer populations? Abstr. Southeast Deer Study Group Meet. 9:9–10.

Osborne, J. S. 1976. Population dynamics of the Blackbeard Island white-tailed deer. M.S. Thesis, Univ. Georgia, Athens. 117pp.

———, R. D. McClanahan, E. B. Gillis, V. F. Nettles, and O. Florschutz. 1986. Effects of wildfires in a North Carolina pocosin on deer populations, harvest, and habitat. Abstr. Southeast Deer Study Group Meet. 9:5–6.

———, A. S. Johnson, P. E. Hale, R. L. Marchinton, C. V. VanSant, and J. M. Wentworth. 1992. Population ecology of the Blackbeard Island white-tailed deer. Tall Timbers Research, Inc. Bul. 26. 124pp.

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

Shea, S. M., T. A. Breault, and M. L. Richardson. 1992. Herd density and physical condition of white-tailed deer in Florida flatwoods. J. Wildl. Manage. 56:262–267.

Smith, F. H., K. C. Beeson, and W. E. Price. 1956. Chemical composition of herbage browsed by deer in two wildlife management areas. J. Wildl. Manage. 20:359–367.

Stransky, J. J. and R. F. Harlow. 1981. Effects of fire on deer habitat in the Southeast. Pages 135–142 *in* G. W. Wood, ed. Prescribed fire and wildlife in southern forests. Belle W. Baruch For. Sci. Inst., Clemson Univ., Georgetown, S.C.

Thackston, R. E., P. E. Hale, A. S. Johnson, and M. J. Harris. 1982. Chemical composition of mountain-laurel kalmia leaves from burned and unburned sites. J. Wildl. Manage. 46:492–496.

Verme, L. J. and D. E. Ullrey. 1984. Physiology and nutrition. Pages 91–118 *in* L. K. Halls, ed. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pa.

Wells, B. W. 1946. Vegetation of the Holly Shelter Wildlife Management Area. North Carolina Dep. Conserv. Devel., Div. Game and Inland Fish Bul. 2. 40pp.

Wentworth, J. M. 1986. Winter burning and wildlife habitat in southern Appalachian hardwoods. M.S. Thesis, Univ. Georgia, Athens. 102pp.

———, A. S. Johnson, and P. E. Hale. 1990. Influence of acorn use on nutritional status and reproduction of deer in the southern Applachians. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 44:142–154.

———, ———, ———, and K. E. Kammermeyer. 1992. Relationships of acorn abundance and deer herd characteristics in the southern Appalachians. South. J. Appl. For. 16:5–8.

Williams, S., ed. 1984. Official methods of analysis of the Association of Official Analytic Chemists. Assoc. Off. Anal. Chem., Arlington, Va. 1,141pp.