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The Effects of Extreme Drought on Native Forage Nutritional Quality and White-tailed Deer Diet Selection

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Abstract - Forage availability is often used as a measure of habitat quality for *Odocoileus virginianus* (White-tailed Deer; hereafter "Deer"). Many studies have evaluated treatment effects on forage availability, but the effects of other abiotic factors, such as drought, on native forages and Deer diet selection are poorly understood. We measured diet selection and nutritional quality of commonly occurring forages following extreme drought (2007) and normal rainfall years (2008) in 4 closed-canopied hardwood stands in the Central Hardwoods region. Deer selected 6 forage species in both years of the study. Within these 6 species, crude protein (CP) and acid detergent fiber (ADF) were not different, and neutral detergent fiber (NDF) increased during the year of normal rainfall. Thirteen other commonly occurring forages showed a different trend, with CP negatively affected by drought and ADF and NDF unaffected. Less-selected species in the drought year and a greater selection-index cut-off value suggest Deer were more selective of species consumed during extreme drought because fewer plants met their nutritional requirements. Our data support the selective quality hypothesis, predicting Deer become more selective of plant species to meet nutritional requirements when resources are limited. Our data suggest more frequent and intense droughts predicted as a result of global climate change may influence diet selection of deer and decrease forage quality enough to limit lactation during the late-summer stress period in the Southeast.

Introduction

Odocoileus virginianus Zimmerman (White-tailed Deer; hereafter "Deer") are among the most important wildlife species, economically and ecologically, in the southern United States (Miller 2001). Deer are the most sought-after game species by hunters (US Fish and Wildlife Service and US Department of Commerce, Bureau of the Census 1993) and they directly impact forest regeneration, understory species composition and structure, and consequently habitat quality for other wildlife species (Anderson and Katz 1993; Casey and Hein 1983; de Calesta 1994; Rossell et al 2005, 2007; Tilghman 1989; Webster et al. 2005). Previous literature has evaluated effects of various forest treatments on forage quality, availability, and nutritional carrying capacity (NCC) (Beck and Harlow 1981, Blake et al. 1987, Brose and Van Lear 1999, Chamberlain and Miller 2006, Edwards et al. 2004, Jones et al. 2009, Lashley et al. 2011, Masters et al. 1993, Miller and Miller 2004, Mixon et al. 2009, Peitz et al. 2001, Shaw et al. 2010, Wood 1988). Data related to diet selection in unmanaged and managed forests have been reported for much of the Southeast (Harlow and Hooper 1972, Johnson et al. 1995, McCullough 1985, Shaw et al. 2010, Warren and Hurst 1981). However, data evaluating the effects of other factors, such as drought, on forage

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quality, availability, and diet selection are limited, and as a result, the inter-relationships among forage quality, availability, selection, and NCC and their impact on Deer are largely unknown. For example, Lashley et al. (2011) reported NCC decreased among treatments of similar forage availability, which they attributed to lower crude protein values in some plants in response to drought during 1 year of the study. To the best of our knowledge, no other study has presented related data in the southeastern US.

The effects of water deficits on annual and perennial forage legumes have been documented (Carter and Sheafer 1983, Peterson et al. 1992); however, the effects of drought on native forages or food habits of Deer have not been evaluated in the Southeast. Studies on *Odocoileus hemionus* Rafinesque (Desert Mule Deer) in the western US have reported that during extreme drought, deer diets change to favor evergreen shrubs and drought-resistant plants, and that mortality is increased (Anthony 1976, Lawrence et al. 2004). Given the economic importance of Deer, and the potential for droughts to become more frequent and intense as a result of global climate change (Easterling et al. 2000), further investigation of drought effects on ungulate ecology and native plant species is warranted. We evaluated the effects of extreme drought on native forage quality and diet selection by Deer in 4 closed-canopy hardwood stands in the Central Hardwoods region within the Southern Appalachian Ridge and Valley physiographic province. Our objectives were to 1) measure drought effects on nutritional quality among common plant species in the Central Hardwoods and 2) evaluate the effects of drought conditions on diet selection by Deer.

Study Area

We conducted our study across 4 upland hardwood stands located in four separate watersheds on the Chuck Swan State Forest and Wildlife Management Area (CSF) in Union, Campbell, and Anderson counties, TN (Fig. 1). CSF is jointly managed by the Tennessee Division of Forestry (TDF) and the Tennessee Wildlife Resources Agency (TWRA). CSF encompasses 9892 ha and is 92% forested, with the remaining acreage in mowed fields, wildlife food plots, logging decks, and maintained roads. Hardwood stands range from 1–200 years in age and are generally managed on an 80–100-year rotation following natural regeneration. Upland hardwood, bottomland hardwood, and mixed pine-hardwood are the primary vegetation types on CSF. For a more detailed description, refer to Lashley et al. (2011).The majority of openings are dominated by nonnative perennial cool-season grasses and maintained by mowing; others are planted in warm-season food plots, including *Zea mays* L. (Corn) and *Sorghum bicolor* (L.) Moench (Grain Sorghum).

Sandstone ridges with 15–30% northwest-facing slopes 365–490 m in elevation characterize the topography of CSF. The majority of the soils on the study area are classified in the Clarksville-Fullerton-Claiborne association. Temperatures range from a yearly average high of 20.4 °C to a yearly average low of 7.9 °C. The area receives approximately 120-cm of rain per year (National Oceanic and Atmospheric Administration 2008). However, 2007 was the driest year on record with a departure of -38 cm for the year and a departure of -22 cm for April–September (National Oceanic and Atmospheric Administration 2008).

Surveys conducted by the TWRA estimated 10–12 Deer per km^2, and herd management includes a draw-hunt system following state regulations. The average annual Deer harvest at CSF has been 3–4 Deer per km^2 since 2005 (TWRA 2009).

Methods

Species selection

We used 50-m line transects to determine plant selection by Deer at CSF during mid-August of 2007 and 2008. Two transects were randomly placed in all 4 stands. Each transect was sampled at 3 systematically located plots. Plot centers were located at 10, 25, and 40 m along the transect, and we recorded all stems of each species and number of stems browsed in a 1.5-m x 1.2-m x 1.2-m plot (Shaw et al. 2010). We used the structure of damage in remaining forage tissues and the foraging ecology of Deer and other wildlife to distinguish herbivory between wildlife species (Rezendez 1992). We distinguished Deer herbivory from that of Lagomorphs, other small mammals, and insects

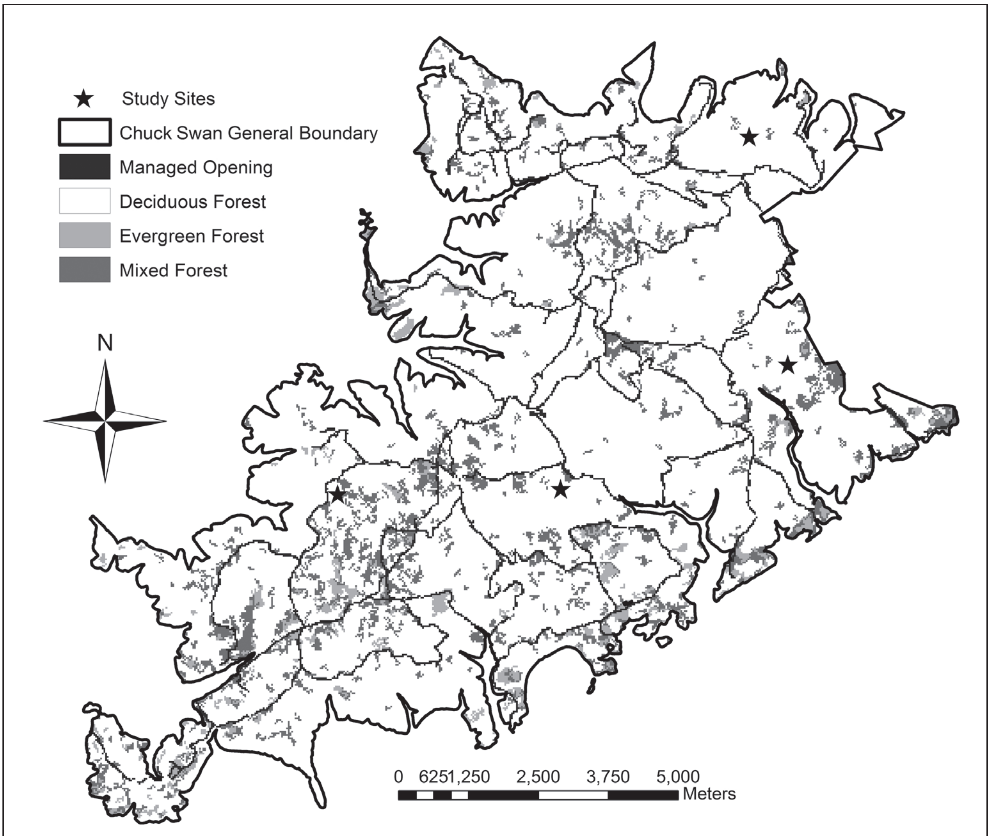

Figure 1. Chuck Swan State Forest and Wildlife Management Area located in Anderson, Campbell, and Union counties, TN.

by the nature of the bite, considering blunt-tipped bites to be Deer herbivory with angular or wavy bites attributed to other mammals and insects, which were excluded from the survey. Although Shaw et al. (2010) reported herbaceous species were not a significant portion of Deer diet following burning, we included all forages detected in the selection transects regardless of their classification (e.g., grass, forb, semi-woody vines, and woody), and all plants with <5 stems in a year were lumped into a common category within the respective year. Shaw et al. (2010) reported a lack of herbaceous species in closed-canopy stands following burning, herbaceous species were prevalent in our study site, and we included all forages detected in the selection transects regardless of their classification. We calculated a selection index (Chesson index; Chesson 1978, 1983; Lashley et al. 2011; Shaw et al. 2010) by dividing the ratio of use and availability for a given species by the sum of ratios for all species, including all woody, semi-woody, and herbaceous plants. This index generates a value for each species and a cut-off value for comparison. We compared index values for each species to the index cut-off (0.035 in 2007, 0.028 in 2008) to determine selection. Greater cut-off values indicate more stringent guidelines for a resource to be considered selected. Species with a selection rating ≥ the cut-off value were considered selected more than available, while species with 50–99.9% of the cut-off value were considered moderately selected. Moderately selected plants were not considered to be species that were sought-after for consumption, but also were not avoided by Deer. In other words, Deer do not seek out moderately selected plants but may consume them if available. Any plant species below 50% of the cut-off value were considered avoided by Deer and generally not browsed by them.

Forage analysis

We collected representative samples, including leaves and tender shoots from the current growing season of 19 forages, within each stand on 15 August 2007 and 2008. We chose mid-August to accurately reflect nutritional quality of plants during the late-summer stress period, which is the most stressful period for lactating females because of decreased available nutrition and more stringent nutritional requirements (Verme and Ullrey 1984). We dried all samples to constant mass in an air-flow dryer at 50 °C and ground them using a 1-mm-mesh Wiley mill. We recorded moisture content as a precautionary measure to ensure we did not catalyze the malliard reaction (non-enzymatic browning) when drying the forages. Similar to caramelization, this process could artificially inflate lignin content in the subsequent assay. Forages ranged from 50 to 91% water, and there were no apparent inflations in resulting fiber measurements. Nutrient analyses included crude protein (CP), using the combustion analyzer method (AOCS 1999), and acid detergent fiber (ADF) and neutral detergent fiber (NDF), using ankom fiber determination (AOCS 2005, AOAC 2005), in 2007 and 2008, and were conducted by SURE-TECH™ Laboratories (2435 Kentucky Avenue Indianapolis, IN 46221; SURE-TECH™ Laboratories is certified by the National Forage Testing Association). We considered CP an important metric during the growing season, as there is a large protein burden on females during lactation that must be met through their diet rather than body reserves (Sadleir 1987). CP is a measure of proteins in the cell cytoplasm and chloroplasts of plants, but some of the proteins may be unavailable for animal utilization (Ball et al. 2002). Thus, we also measured NDF and ADF, which chemically distinguish the readily available, soluble cell contents from the less digestible cell walls. NDF represents all cell-wall material, while ADF is a measure of only the lignified or otherwise undigestible portions (Ball et al. 2002). We did not consider the role of condensed tannins in compromising the digestibility of CP because recent literature concluded tannins were not a great threat to summer diet quality of Deer in the Southeast (Jones et al. 2010).

Data analysis

We conducted a two-sampled *t*-test using SYSTAT to compare nutrient levels within selected forages between years. A separate analysis was conducted on the other species sampled but not selected by Deer. CP, ADF, and NDF values were each averaged by year to assess differences between the drought year and normal year, not to evaluate differences between species within a year or an individual species across years.

Results

Five woody/shrubs and 1 herbaceous species were selected more than available in the drought year (2007), whereas 6 woody and 2 herbaceous species were selected in the normal rainfall year (2008). Five of the 6 species selected in the drought year were also selected in the normal year, with *Cornus florida* L. (Flowering Dogwood) being the exception (Table 1). During the drought year, only 1 species was moderately selected compared to 7 species during the normal year (Table 2).

In all species collected, CP was negatively affected (P = 0.001), NDF decreased (P = 0.017), and ADF was unaffected by drought (P = 0.204). Both CP (P = 0.285) and ADF (P = 0.922) were unaffected during the drought year within the 6 species selected in both years. NDF was greater during the normal year among these 6 species (P = 0.01). The 13 common species which were not selected in both years showed a different trend than the 6 selected species. CP was negatively affected by drought (P = 0.002), while ADF (P = 0.165) and NDF (P = 0.133) were not affected (Tables 3, 4).

Discussion

Drought affected nutritional quality among native forages and forage selection by Deer. CP decreased in all plant species evaluated during the drought year with the exception of *Nyssa sylvatica* Marsh (Blackgum). NDF also decreased in all plant species during the drought year with the exception of *Coreopsis* spp. (tickseed). Only *Desmodium* spp. (desmodium) met the nutritional requirements for a lactating doe with one fawn during the drought year, while 7 species met the requirements during the normal year (14% CP for lactating doe with one fawn; Verme and Ullrey 1984; Table 3). Fewer species were selected and fewer species received moderate use during the drought year, suggesting Deer were less selective of plant parts consumed during the drought year and less selective of plant species during the normal year. Intake may be affected most by physical factors, such as bulkiness (large volume per unit of mass), suggesting our results might have been influenced by intake differences during times of nutritional stress (Verme and Ullrey 1984). In general, voluntary intake of forage in ruminants will increase as NDF of that forage decreases (Mertens 1987). We observed a decrease in NDF in the drought year of the study, indicating forage intake could increase during drought years.

Nutritional quality possibly decreased within species because of accelerated plant maturation resulting from drought, and the negative effects of plant maturity on CP content and digestibility are well documented (Ball et al. 2002). However, our data showed ADF was unaffected in any of the species groups

Table 1. Forages selected and/or important deer foods at Chuck Swan State Forest and Wildlife Management Area, August 2007–2008. T = total, B = bites, D.i. = drought index, N.i. = normal index.

	Drought year		Normal year				Change from normal to drought years		
	T	B	T	B	D.i.	N.i.	CP	ADF	NDF
Selected species									
Nyssa sylvatica Marsh[A] (Blackgum)	10	3	23	14	0.12	0.10	1.37	0.04	-41.9
Desmodium spp.[A] (desmodium)	9	3	11	8	0.14	0.12	-9.20	5.11	-17.3
Smilax spp.[A] (greenbrier)	113	64	84	49	0.23	0.10	-1.80	4.03	-20.9
Euonymous americana L.[A] (Strawberrybush)	9	7	5	4	0.32	0.13	-1.35	-11.00	-14.9
Vitis spp.[A] (grape)	197	33	139	63	0.07	0.08	-3.95	-3.02	-4.13
Rubus spp.[B] (blackberry)	-	-	22	12	-	0.09	-3.04	-0.95	-1.32
Cornus florida L.[B] (Flowering Dogwood)	19	2	23	3	0.04	0.02	-9.53	-9.17	-12.2
Parthenocissus quinquefolia Planch[B] (Virginia Creeper)	213	6	151	35	0.01	0.04	-3.19	4.44	-7.75
Dioscorea villosa L.[B] (Wild Yam)	-	-	25	14	-	0.09	-3.74	-14.40	-30.8
Non-selected species[C]									
Prunus serotina Ehrhart (Black Cherry)	9	0	32	1	0	0.01	-3.31	-10.40	-18.6
Vaccinium spp. Aiton (Blueberry)	98	8	-	-	0.03	-	-1.45	2.40	-1.05
Acer spp. (maple)	210	6	194	19	0.01	0.02	-3.06	1.30	-5.48
Quercus spp. (oak)	54	1	65	3	0.01	0.01	-9.36	-3.25	-10.1
Sassafras albidum Nuttall (Sassafras)	31	0	31	4	0	0.02	-2.44	-9.81	-23.5
Liriodendron tulipifera L. (Yellow Poplar)	21	0	15	2	0	0.02	-1.86	-5.80	-16.2
Phytolacca americana L. (American Pokeweed)	-	-	-	-	-	-	-18.80	-0.60	-1.46
Dicanthelium spp.(low panicgrass)	-	-	-	-	-	-	-3.94	-3.97	-1.22
Oxydendron arboreum de Condolle (Sourwood)	-	-	-	-	-	-	-2.06	-6.42	-9.22
Coreopsis spp. (tickseed)	-	-	-	-	-	-	-3.26	-1.21	13.33

[A]Forages selected in both years of the study.
[B]Forages selected in one year of the study.
[C]Forages not selected, but reported as important Deer forages in the literature.

analyzed. Lashley et al. (2011) reported significant decreases in available CP and increased lignin content in Maturity Group 4 soybeans, and a shorter duration to hard seed during the drought year. That finding was consistent with other literature evaluating the effects of drought-induced stress on annual and perennial forage legumes (Carter and Sheafer 1983, Peterson et al. 1992), but it is unclear why ADF in our study did not conform to the same trends within the literature.

Our data support the selective-quality hypothesis (Weckerly and Kennedy 1992) derived from the feeding strategies of *Damaliscus korrigum* Burchell (Topi; Jarman and Sinclair 1979). Deer were less selective when resources were abundant, which supports the findings of Weckerly and Kennedy (1992). Some species (e.g., *Smilax* sp. [greenbrier], *Cornus florida*, etc.) showed a shift in the magnitude of selection, whereas other forages, such as *Parthenocissus quinquefolia* (L.) Planch (Virginia Creeper), were avoided in the drought year even though they were more abundant. Some herbaceous species, such as desmodium, were browsed less in the drought year despite an increase in abundance. The selection cut-off in the drought year was much greater than in the normal year. According to the Chesson index, heavier selection on fewer species will increase the index value, so species must meet more stringent guidelines to qualify as selected (Chesson 1978, 1983). Also, the number of selected species and the number of plants receiving moderate use was greater in the normal year, indicating Deer were less selective of species because more plants met the nutritional

Table 2. Magnitude of selection of forages at Chuck Swan State Forest and Wildlife Management Area 2007–2008. T = total, B = bitten, % = % cut off.

	Drought year				Normal year			
	T	B	Index	% [A]	T	B	Index	% [A]
Selected species								
Euonymous americana (Strawberrybush)	9	7	0.32	914.91	5	4	0.13	473.25
Vitis spp. (grape)	9	3	0.14	392.11	11	8	0.12	430.23
Nyssa sylvatica (Blackgum)	10	3	0.12	352.89	23	14	0.10	360.08
Smilax spp. (greenbrier)	113	64	0.23	666.23	84	49	0.10	345.08
Dioscorea villosa (Wild Yam)	-	-	-	-	25	14	0.09	331.28
Rubus spp. (blackberry)	-	-	-	-	22	12	0.09	322.67
Desmodium spp. (desmodium)	197	33	0.07	197.05	139	63	0.08	268.12
Cornus florida[B] (Flowering Dogwood)	19	2	0.04	123.82	23	3	0.02	77.16
Parthenocissus quinquefolia (Virgininia Creeper)	213	6	0.01	33.14	151	35	0.04	137.12
Moderately selected								
Fagus americanus (American Beech)	9	0	0	0	7	1	0.02	84.51
Liliaceae spp. (lilly)	23	0	0	0	37	5	0.02	79.94
Lireodendron tulipifera (Yellow Poplar)	21	0	0	0	15	2	0.02	78.88
Sassafras albidum (Sassafras)	31	0	0	0	31	4	0.02	76.33
Toxicodendron radicans Kuntze (Poison Ivy)	40	0	0	0	40	4	0.02	59.16
Acer spp. (maple)	210	6	0.01	33.61	194	19	0.02	57.94

[A]Indicates magnitude of selection. Greater values indicate greater selection.
[B]Species only selected more than available in one year of the study.

Table 3. Discrete nutritional values for selected and important Deer foods in drought and normal rainfall years at Chuck Swan State Forest and Wildlife Management Area, August 2007–2008.

	Drought year			Normal year		
	CP	ADF	NDF	CP	ADF	NDF
Selected species						
Nyssa sylvatica[A] (Blackgum)	12.61	17.84	23.82	11.24	17.80	65.69
Desmodium spp.[A] (desmodium)	16.95	32.53	40.90	20.90	35.55	45.03
Smilax spp.[A] (greenbrier)	10.85	28.23	39.76	12.65	24.20	60.64
Euonymous americana[A] (Strawberrybush)	9.71	26.29	27.57	11.06	37.27	42.51
Vitis spp.[A] (Wild Grape)	10.96	30.05	30.45	20.16	24.94	47.79
Rubus spp.[B] (blackberry)	10.08	23.87	28.81	13.12	24.82	30.13
Cornus florida[B] (Flowering Dogwood)	8.52	14.98	17.20	18.05	24.15	29.44
Parthenocissus quinquefolia[B] (Virgininia Creeper)	11.23	29.97	28.36	14.42	25.53	36.11
Dioscorea villosa[B] (Wild Yam)	10.02	31.25	37.96	13.76	45.61	68.74
Non-selected species[C]						
Prunus serotina (Black Cherry)	9.93	24.38	26.14	13.24	34.75	44.75
Vaccinium spp. (blueberry)	7.76	35.55	37.75	9.21	33.15	38.80
Acer spp.(maple)	7.81	28.00	30.82	10.87	26.70	36.30
Quercus spp. (oak)	10.20	30.97	37.74	19.56	34.22	47.84
Sassafras albidum (Sassafras)	11.34	33.79	61.79	13.78	43.60	85.24
Lireodendron tulipifera (Yellow Poplar)	10.60	32.42	33.44	12.46	38.22	49.61
Phytolacca americana (American Pokeweed)	11.06	11.24	20.59	29.81	11.84	22.05
Dicanthelium spp. (low panicgrass)	10.73	32.67	56.18	14.67	36.64	57.40
Oxydendron arboreum (Sourwood)	9.48	19.48	26.03	11.54	25.90	35.25
Coreopsis spp. (tickseed)	7.58	30.55	40.41	10.84	31.76	27.08

[A]Forages selected in both years of the study.
[B]Forages selected in one year of the study.
[C]Forages not selected but reported as important Deer forages in the literature.

Table 4. Nutritional quality of Deer foods in drought and normal rainfall years at Chuck Swan State Forest and Wildlife Management Area, August 2007–2008.

	Drought year		Normal year	
	Mean	SE	Mean	SE
All species[A]				
Crude protein	10.5	0.47	14.8	1.08
Acid detergent fiber	27.4	1.53	30.5	1.88
Neutral detergent fiber	35.2	2.73	46.4	3.56
Selected[B]				
Crude protein	11.47	1.28	14.2	2.05
Acid detergent fiber	28.41	2.50	28.82	3.13
Neutral detergent fiber	31.38	2.89	50.08	4.36
Non-selected[C]				
Crude protein	9.89	0.34	15.09	1.41
Acid detergent fiber	26.43	2.00	31.06	2.54
Neutral detergent fiber	34.27	3.57	43.84	5.01

[A]Includes all 19 species collected in the study.
[B]Includes only the 5 species selected in both years of the study.
[C]Includes the 14 species that were not selected in both years of the study.

requirements of Deer. Nine percent of stems detected during the drought year showed evidence of herbivory, while 18% did during the normal year, and the average % cut-off for selected species in the drought year (441.17) was greater than during the normal year (333.48), further suggesting Deer focused diet selection on fewer plants during drought (Tables 1, 2). Deer likely were more selective of plant species rather than plant parts, selecting fewer species more aggressively during the drought. This finding was illustrated in our data by heavier selection on greenbrier during the drought year when other plants were nutritionally insufficient even though the relative abundance was greater. With less abundant tender shoots and leaves, as in extreme drought, Deer must become more selective of plant species consumed and thus dependent on fewer plant species to meet their late growing-season nutritional requirements. Harlow and Hooper (1972) found Deer actively seek out particular plants and plant parts within each season. Their findings were consistent within hundreds of rumens from many physiographic regions across the southeastern US (Johnson et al. 1995).

Global climate change has become a topic of interest and could have implications in diet selection and forage quality across the range of Deer. If climatic conditions, such as drought, become more frequent and intense (Easterling et al. 2000), our data suggest recruitment within local Deer populations and persistence of commonly eaten Deer forages could be impacted. Without foods to support lactation, recruitment could decrease during drought years as a result of neonate starvation, which is already a common source of mortality in ungulate neonates in the Southwest in drought years (Carrol and Brown 1977, Pojar and Bowden 2004). Furthermore, commonly eaten plant species could be reduced by intense herbivory because of changes in diet selection during drought years (Rossel et al. 2005). The effects of Deer on the understory strata have been reported in the literature in areas where Deer exceed NCC (Casey and Hein 1983, de Calesta 1994), but our data suggest intense browsing could be exacerbated by drought in areas where Deer densities otherwise would not exceed NCC.

Management implications

Drought played a key role in the nutritional quality and selection of plants by Deer during the late-summer stress period. Managers should be aware of the potential effects of drier conditions on NCC for Deer and should consider how Deer density might need to be adjusted to offset reductions in forage quality. Further investigation is warranted on how climate change may affect the ecology of Deer and associated plant and animal communities in the Southeast.

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